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Sex Prediction Using Hand and Foot Anthropometric Variables of the Hausa Ethnic Group of Kano State, Nigeria

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ABSTRACT

The study was designed to predict sex using hand and foot anthropometric variables among the Hausa ethnic group in Kano State, Nigeria. The study was a cross-sectional survey conducted on 444 participants (199 females and 245 males, age range: 11-26 years) across selected LGAs (Gwarzo, Gwale, and Kibiya) in Kano. Their height was measured using a stadiometer, and hand and foot dimensions were measured using a digital vernier calliper. Ink-soaked hand and footprints were printed on a plain sheet placed on a wooden platform, while hand and footprint dimensions were measured from the sheet. Descriptive statistics were computed to determine the mean ± SD. Sexual dimorphism was assessed using the independent t-test, and stepwise logistic regression analysis was performed to predict sex. Most of the hand and foot variables are sexually dimorphic; males have significantly higher values in hand length, hand breadth, foot breadth, hand index, handprint length, handprint breadth, palmprint length, footprint length, footprint breadth, footprint heel breadth, mid footprint width, handprint index, and footprint index. In comparison, females have higher values of 2nd digit length, 3rd digit length, 4th digit length, 5th digit length, 2nd digit print length, and 2DP:4DP. Sex prediction using stepwise binary logistic regression indicated that palm length, 2nd digit length, hand breadth, and foot breadth were the best single predictors of sex, with an overall percentage accuracy of 75.6% and 76.3% in direct and print measurements, respectively. Therefore, hand and foot dimensions from either direct or indirect measurements can be used in sex prediction among the Hausa ethnic group in Kano.

Keywords: sex, prediction, hand, foot, Hausa, Kano

INTRODUCTION

Sex prediction is a process that alleviates the complexities of human identification and offers significant insights into individual identity[1, 4, 5]. It is fundamental in establishing personal identification, which can be advantageous in mass tragedies and criminal prosecutions [2]. Nonetheless, the sex of an unidentified individual can be determined using several methods, including anthropometric measurements of the skull and mandible, investigation of soft tissues, examination of teeth, and DNA analysis of dental samples [3]. The human hand and foot exhibit sexual dimorphism, enabling the prediction of sex when isolated specimens are acquired [6, 7]. Previous reports indicate that the majority of body dimensions are greater in males than in their female counterparts [8, 9]. However, individual variances may exist among different populations and ethnic regions, potentially attributable to other factors [10]. The primary challenge for forensic anthropologists in identification is the specificity of population-based identification techniques, particularly in sex determination by cranial measurements [11]. Similarly, population affinity is a critical variable in assessing sex, as the expression of sexually dimorphic characteristics, physical size, and social and behavioural patterns varies among communities [12].

Sex prediction is a primary criterion for determining an individual's identity [13]. It is frequently regarded as one of the most straightforward tasks in forensic inquiry. Various anthropometric methods are utilised to ascertain the gender of an individual from retrieved body parts. These anthropometric approaches seek to identify cut-off points in the measurement of certain body parts or bones that differentiate between sexes. As a result of the influence of sex hormones, males exhibit greater height, size, and muscularity compared

to females; thus, measurements over a certain threshold indicate a male, while those below suggests a female. [6].

Furthermore, the challenge of sex prediction becomes exceedingly complex in instances involving remains that are in an advanced state of decomposition, disfigured, fragmented, or skeletal, where it is typical to retrieve dismembered and peripheral body parts. Consequently, proficiency in forensic anthropology frequently necessitates the examination of skeletonised and severely decomposed remains; thus, ascertaining stature using various metrics, such as hand outlines 14, and predicting sex are often the most straightforward aspects of constructing the biological profile [15]. Additionally, sex prediction emerges as the primary and most significant aspect [16]. Certain bones have been extensively researched for sex prediction, with established dependability. The cranium, pelvis, and long bones are the most scrutinised among these bones. The pelvis is the most dependable area for sex discrimination, exhibiting accuracy rates of 95–98% [17].

While DNA technologies are regarded as the most reliable approach for sex prediction, they possess drawbacks, including limited accessibility, time consumption, the necessity for skilled personnel, and high costs. Consequently, approaches like osteometry, which are more accessible, cost-effective, extremely precise, readily available, rapid, and do not necessitate specialised expertise, have become favored for sex prediction [18]. Furthermore, anthropometric measures of the metatarsal indicate that sex estimation research on foot bones predominantly emphasises the morphology of the first metatarsal and the transverse arch of the foot in both sexes [19]. Predicting the sex of individuals from the Hausa ethnic group residing in Kano using hand- and foot-based anthropometric data is essential.

MATERIALS AND METHODS

Measuring tape (to the nearest 0.1 cm), stadiometer (Holtain Ltd., Crymych, Dyfed, UK) to the nearest 0.1 cm, digital standing scales (Model DS-410, Seiko, Tokyo, Japan), to the nearest 0.1 kg, digital vernier calliper (Starrett, 123 Series, U.S.A.) were used.

Anthropometry

Direct measurements of the hand

I. Hand length (HL) in cm: Measured from the midpoint of the distal wrist crease to the tip of the middle finger using a plastic measuring tape (palmar surface of the hand in supine position).
II. Handbreadth (HB) in cm: Measured from the head of the 5th to the 2nd metacarpal using a sliding vernier calliper (palmar surface of the hand in supine position).
III. Wrist breadth (WB) will be measured across the styloid processes (oblique to the long axis of the arm) with pressure to compress the tissue using a sliding calliper.
IV. Palm length was measured as the distance between the midline of the distal wrist crease and the base of the middle finger.
V. Wrist circumference in cm was measured using a measuring tape as the circumference of the wrist at the wrist crease.
VI. Length of the fingers in cm is the distance between the proximal metacarpophalangeal flexion crease and the fingertip.
VII. Foot length (FL) in cm: The length between the extreme point of the heel and the extreme point of the longest toe (either first or second toe) was measured as foot length.
VIII. Foot breadth (FB) in cm: Measured at the widest point of the sole, which is from the metatarsophalangeal joint of the 1st metatarsal and that of the 5th metatarsal of the foot using a sliding vernier calliper.
IX. Foot height (FH) was measured as the distance between the distal part of the lateral malleolus and the floor.
X. Footprint Length (FPL) in cm: The maximum distance between the heel (pternion) and the longest toe (akropodian)
XI. Footprint Breadth (FPB) in cm: The distance between the most prominent point on the medial side of the foot to the most prominent point on the lateral side (which corresponds to the heads of the first to fifth metatarsals).
XII. Footprint Heel Breadth (FHB in cm: The maximum distance from the most protruding point on the medial surface of the heel to the corresponding protrusion on the lateral surface of the heel.
XIII. Mid Footprint Width (MFW) in cm: It is the narrowest distance of the middle of the plantar prints.

Study location

The major inhabitants of Kano are Hausa and Fulani, with minorities representing virtually all tribes in Nigeria and a minute fraction of foreigners [20]. Kano State is located between latitude 12.2º North and longitude 9.4º East, with Kano City as the capital of the State. Kano State is composed of three senatorial districts: Kano Central, Kano South, and Kano North senatorial districts. Two local government areas were randomly selected from each district to ensure an even distribution of data. The selected local governments are Gwale and Municipal LGA, representing Kano Central; Rano and Kibiya, representing Kano South; and Gwarzo and Shanono, representing Kano North district.

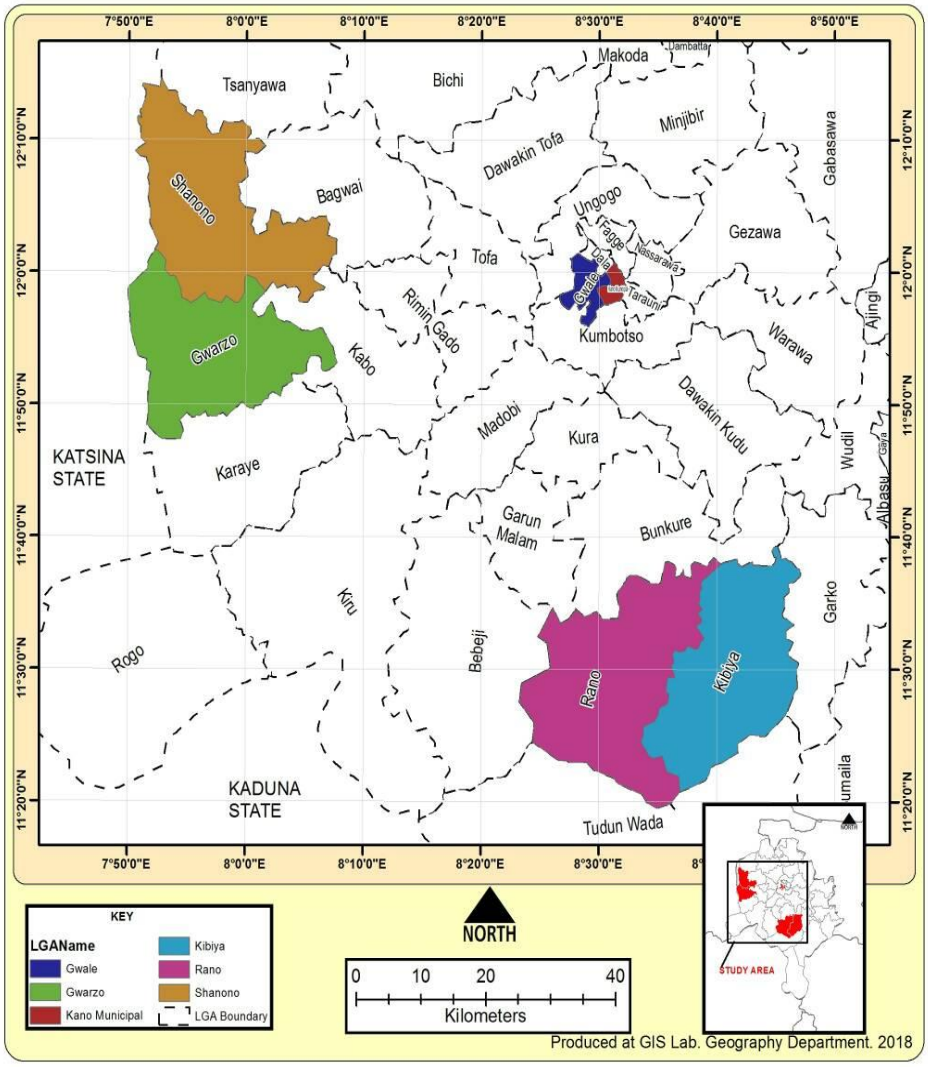

Figure 1: Administrative Map of Kano with the selected area of study

Inclusion criteria

Apparently, healthy subjects with no hand or foot deformities, free of inflammation or pathological changes, and Hausa participants from Kano, including grandparents, were included in the study.

Exclusion criteria

Non-Hausa ethnic groups were excluded from the study**, those with metabolic and/or developmental disorders, having poorly defined wrist creases, with diseases and/or injuries that may affect stature, and hand and foot morphology and pathologies that affected stature (kyphosis of the spine, extensive degeneration of the vertebral bodies, etc.).**

Sampling technique

A random sampling method was adopted. The subjects were used to obtain hand and foot dimensions, handprints, footprints, and other body variables.

The sample size required for this study is calculated using the formula by [21] below;

$$n = \frac{Z^2 \quad pq}{d^2} = 384$$

Where n = desired sample size, Z= standard normal deviation 1.96 at 95% confidence level, q= 1 – p, d= degree of precision, p= proportion =0.7 (70%). The minimum sample size from the equation above is 384; however, the study used a population of 444 to increase statistical power.

Ethical approval and informed consent

Before the commencement of the research, approval was obtained from the Ethical Committee of the College of Health Sciences, Ahmadu Bello University, Zaria. Informed consent was sought from the participants.

RESULTS

Table 1 shows descriptive statistics of hand and foot anthropometric parameters from direct measurements of the Hausa ethnic group in the general population of Kano. It was observed that the anthropometric variables of the general population were reported as mean ± SD, with minimum and maximum values.

Table 2 presents descriptive statistics for hand and foot anthropometric parameters derived from print measurements of the Hausa ethnic group in Kano (n=444). It was observed that the general population had mean ± SD, minimum, and maximum values for all variables.

Table 3 presents sexual dimorphism in body and hand-and-foot anthropometric parameters, based on direct measurements of the Hausa ethnic group in Kano. It was observed that male subjects have higher values in height, hand length, hand breadth, palm length, foot length, and foot breadth, while female subjects have higher values in 2nd digit length, 3rd digit length, 5th digit length, and 2D:4D with p value < 0.005.

Table 4 presents sex prediction using hand and foot dimensions from direct measurements of the Hausa ethnic group of Kano. It was observed that palm length is the strongest predictor of sex, with an overall percentage of 75.6%, whereas foot length is the weakest predictor of sex.

Table 5 presents a sex prediction using hand and foot dimensions from indirect (prints) measurements of the Hausa ethnic group of Kano. It was observed that footprint breadth is the best predictor of sex, with an overall percentage of 76.3%, while footprint heel breadth is the weakest predictor of sex.

DISCUSSION

In the present study, sexual dimorphism in hand and foot anthropometric parameters was assessed through both direct and print measurements among the Hausa ethnic group in Kano. Males exhibited significantly higher values in height, weight, hand length, hand breadth, foot breadth, and hand index, whereas females demonstrated higher values for the lengths of the second, third, fourth, and fifth digits. These findings are consistent with earlier studies conducted in various populations [22, 23, 24, 26]. Previous research has established that males typically have larger hands than females. Our results align with reports from Bangladesh [27, 28,] and South India [29], which also demonstrated significant sexual dimorphism in hand measurements. Gender-related differences were also evident in handprint dimensions, with males showing significantly greater values in handprint length, handprint breadth, palmprint length, and second digit-print length. In comparison, females displayed greater values in the first, third, fourth, and fifth digit-print lengths. These observations are supported by findings from other populations [30, 31].

With respect to foot anthropometric variables, males demonstrated significantly higher values in foot length, foot breadth, footprint length, and footprint breadth. These results are consistent with findings from other populations in India [32]. The observed differences in both hand and foot dimensions between males and females may be attributed to genetic factors, as males generally tend to exhibit larger anthropometric dimensions. Additionally, variation in body dimensions across and within populations may be influenced by nutrition, traditional habits, physical activity, age, geographical location, ethnicity, sex, and race [33, 34].

In this study, stepwise binary logistic regression for sex determination identified palm length, second digit length, hand breadth, and foot breadth as the strongest single predictors of sex, with an overall classification accuracy of 75.6%. This outcome is consistent with other studies [7, 35]. The relatively lower accuracy observed among the Hausa ethnic group may be due to variability in anthropometric measurements across populations, as differences have been reported in datasets from Africa, Europe, Asia, and the Americas [36].

Our findings are in agreement with previous studies in which hand breadth, hand length, and foot length emerged as robust sex predictors, achieving up to 88.7% accuracy in discriminant analyses [26, 37, 38]. The minor differences in predictive power are likely attributable to genetic variation, geographical location, nutrition, and levels of physical activity, which differ across populations and ethnic groups [10, 39]. Several other studies further support our observations [40, 41, 42]. For example, [43] reported foot breadth as the most accurate single predictor of sex, while [42] found that left foot breadth yielded an accuracy of 88.5%. In contrast, our study identified right-foot breadth and right-footprint breadth as the most accurate single predictors, with accuracies of 75.6% and 76.4%, respectively. Based on these findings, palm length, second digit length, hand breadth, second digit-print length, and palmprint length, derived from both direct and print methods, are reliable predictors of sex. This observation is consistent with prior research [7, 44], which identified hand breadth as the most reliable sex predictor across populations. Thus, hand dimensions, particularly hand breadth, can serve as reliable indicators of sex in the Hausa population studied.

CONCLUSION

Hand and foot anthropometrics can correctly be used in the prediction of sex among the Hausa ethnic group in Kano. The variables used have overall percentage

accuracies of 75.6% and 76.3% in direct and print measurements, respectively.

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Conflict of interest: None declared

Author's contributions:

- ✓ **DS.:** Initial conceptualization of the work**,** Introduction and Discussion, **DB.:** Results and Discussion, **TJA.:** Data analysis and Discussion, **TY.:** Methodology and Discussion, **ALH.:** Data analysis and Results, **YHM.:** Discussion and Conclusion, **UKB.:** Introduction, **SMO:** Data analysis, **MMM**: Discussion, **GA**: Results and conclusion, **II**: Results, **GI**: Methodology, **GID**: Methodology and Data analysis, **IAT**: Summary and conclusion, **GAA**: Results and data analysis. **NHM**: Introduction and referencing, **AS:** Methodology.

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181

Table 1: Descriptive statistics of hand and foot anthropometric parameters

Variables	Mean± SD	Minimum	Maximum
Age (yrs)	14.77±1.89	11.00	26.00
Height (cm)	148.78±11.33	121.00	177.00
Weight (kg)	37.64±7.55	20.00	64.00
Body mass index (kg/m^2)	16.91±2.25	12.02	26.11
Hand length (cm)	16.51±1.49	12.10	20.40
Hand breadth (cm)	6.96±0.78	4.50	10.10
Palm length (cm)	8.90±0.94	5.40	11.20
1st digit length (cm)	5.43±0.74	3.10	8.00
2nd digit length (cm)	6.71±0.97	3.00	9.30
3rd digit length (cm)	7.71±1.08	3.90	10.40
4th digit length (cm)	6.70±1.00	3.20	9.10
5th digit length (cm)	5.63±0.89	2.30	8.00
Foot length (cm)	22.89±1.78	14.70	28.00
Foot breadth (cm)	8.43±0.92	4.70	11.00
Foot height (cm)	8.32±1.20	3.90	11.00
2D:4D	0.967±0.07	0.70	1.50
Hand index (%)	42.20±3.36	30.86	53.66
Foot index (%)	36.77±3.04	20.26	62.59

Table 2: Descriptive statistics for hand and foot anthropometric parameters derived from print measurements of the Hausa ethnic group in Kano (n=444).

Variables	Mean± SD	Minimum	Maximum
Handprint length (cm)	15.77±1.43	11.80	20.00
Handprint breadth (cm)	6.35±0.66	4.30	9.00
Palmprint length (cm)	8.30±0.93	5.30	11.00
1st digitprint length (cm)	4.92±0.65	3.00	7.00
2nd digitprint length (cm)	6.40±0.76	3.20	8.80
3rd digitprint length (cm)	7.36±0.80	3.70	9.60
4th digitprint length (cm)	6.73±0.76	3.30	9.00
5th digitprint length (cm)	5.29±0.65	3.20	7.10
Footprint length (cm)	22.06±1.71	16.10	27.00
Footprint breadth (cm)	7.89±0.91	4.10	11.00
Footprint heel breadth (cm)	4.50±0.72	2.80	9.30
Mid footprint width (cm)	2.31±1.04	0.30	7.00
2DP:4DP	0.96±0.05	0.72	1.10
Handprint index (%)	40.36±3.18	32.53	52.00
Footprint index (%)	35.74±2.79	18.22	44.34
Chippaux-Simark index (%)	29.31±11.35	5.00	74.00
Staheli plantar arch index (%)	51.32±19.36	8.00	124.00

DP: Digitprint

Table 3: Sexual dimorphism in body and hand-and-foot anthropometric parameters

	Female	Male		
Variables	**Mean± SD**	**Mean± SD**	**T**	**P**
Age (yrs)	14.46±1.80	15.01±1.80	-3.079	0.002
Height (cm)	148.07±10.84	149.38±11.70	-1.207	0.002
Weight (kg)	36.71±6.47	38.41±8.28	-2.374	0.018
Body mass index (kg/m^2)	16.69±2.19	17.09±2.28	-1.838	0.067
Hand length (cm)	16.31±1.16	16.68±1.69	-2.676	0.008
Hand breadth (cm)	6.77±0.55	7.12±0.88	-4.875	0.001
Palm length (cm)	8.64±0.78	9.14±1.00	-5.689	0.001
1st digit length (cm)	5.35±0.60	5.47±0.81	-1.841	0.066
2nd digit length (cm)	6.90±0.71	6.57±1.09	3.777	0.001
3rd digit length (cm)	7.87±0.74	7.56±1.23	3.097	0.002
4th digit length (cm)	7.132±0.73	6.91±1.15	2.240	0.026
5th digit length (cm)	5.75±0.64	5.55±1.06	2.295	0.022
Foot length (cm)	22.43±1.49	23.29±1.89	-5.218	0.001
Foot breadth (cm)	8.18±0.72	8.61±0.99	-5.234	0.001
Foot height (cm)	8.42±0.91	8.27±1.39	1.319	0.188
2D:4D	0.97±0.055	0.95±0.08	2.677	0.008

Table 4: Sex prediction using hand and foot dimensions from direct measurements of the Hausa ethnic group of Kano.

Variables	Step	B	P-Value	Constant	Cox & Snell R^2	Nagel kerke R^2	$\chi 2$	P value	Percentage Accuracy		
									Male	Female	Overall Accuracy
Palm length (cm)	1	0.611	0.001	-5.214	0.069	0.093	31.90	0.001	67.6	40.7	55.5
Palm length (cm)	2	1.000	0.001	-3.25	0.157	0.210	75.78	0.001	76.6	56.3	67.5
2nd digit length (cm)		-0.804	0.001								
Palm length (cm)	3	0.758	0.001	-6.613	0.230	0.308	115.914	0.001	78.3	67.8	73.6
2nd digit length (cm)		-1.301	0.001								
Foot breadth (cm)		1.056	0.001								
Hand breadth	4	0.929	0.001	-7.903	0.261	0.350	134.264	0.001	78.3	72.4	75.6
Palm length (cm)		0.602	0.001								
2nd digit length (cm)		-1.541	0.001								
Foot breadth (cm)		0.803	0.001								
Hand breadth (cm)	5	0.879	0.001	-9.929	0.271	0.362	139.878	0.001	78.7	70.9	75.2
Palm length (cm)		0.529	0.001								
2nd digit length (cm)		-1.613	0.001								
Foot length (cm)		0.235	0.022								
Foot breadth (cm)		0.590	0.005								

Table 5: Sex prediction using Hand and foot dimensions from indirect (prints) measurements of the Hausa ethnic group of Kano

Variables	Step	B	P-Value	Constant	Cox & Snell R^2	Nagel kerke R^2	$\chi 2$	P value	Percentage Accuracy		
									Male	Female	Overall Accuracy
Footprint breadth (cm)	1	0.749	0.001	-5.684	0.091	0.122	42.33	0.001	73.50	45.20	60.8
2nd digitprint length (cm)	2	-1.470	0.001	-3.343	0.214	0.286	106.875	0.001	76.30	70.90	73.9
Footprint breadth (cm)		1.648	0.001								
Handprint breadth (cm)	3	1.293	0.001	-5.968	0.261	0.350	134.423	0.001	77.60	68.30	73.4
2nd digitprint length (cm)		-1.769	0.001								
Footprint breadth (cm)		1.186	0.001								
Handprint breadth (cm)	4	1.207	0.001	-7.252	0.279	0.373	145.15	0.001	80.00	71.90	76.4
Palmprint length (cm)		0.554	0.001								
2nd digitprint length (cm)		-1.937	0.001								
Footprint breadth (cm)		0.974	0.001								
Handprint breadth (cm)	5	1.291	0.001	-7.126	0.285	0.381	148.973	0.001	80.80	69.80	75.9
Palmprint length (cm)		0.569	0.001								
2nd digitprint length (cm)		-1.946	0.001								
Footprint breadth (cm)		1.100	0.001								
Footprint heel breadth (cm)		-0.384	0.062								