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Sex Prediction Using Finger, Hand and Foot Measurements for Forensic Identification in a Nigerian Population

O. Ogbonnaya IROANYA[*1], T. Frank EGWUATU[1], O. Temitope TALABI[1], I. Stella OGUNLEYE[1]

Abstract

In forensics, the identification of recovered human remains is important and of great significance. Sex determination is the most important primary parameter in human identification. We investigated the predictive role of the anthropometric measurements of hand, finger and foot dimensions in sex determination. The main objective was to correlate sexual dimorphism with hand, finger and foot dimensions and determine their sectioning point(s) and also ascertain the variables which can better predict sex. A cross sectional study was carried out using 200 students from Faculty of Science, University of Lagos, Nigeria aged 16-30years. The collected data was analyzed using IBM SPSS version 23. The average hand length, breadth and index were found to be 17.44mm, 8.09mm and 0.3781mm greater in male compared to the female subjects respectively, with no significant ($p<0.05$) difference between the right and left hand in the same sex. The resultant hand index suggests the females have higher dolichocheir morphology compared to males and no hyperbrachycheir morphology. The cutoff point index for the right (≤43.41mm) and left (≤42.90mm) hand is suggestive of female, but is suggestive of male if the right hand is >43.41mm and left hand is >42.90mm. A foot index section points for the right (347.9mm) and left (349.4mm) foot was taken for male and female foot identification. A cut of point of 348.7mm was obtained to define sexual dimorphism of the foot index. There was strong correlation between foot dimensions of both feet for the same sex ($p<0.01$) while the foot dimensions of the male and the female were significantly ($p<0.05$) different. The hand (length and breadth), index/ring fingers ratio, foot (length and breadth) and ankle breadth are therefore important indices and forensic identification tool for predicting sexual dimorphism and identifying human remains for medicolegal examinations.

Keywords: sexual dimorphism, index/ring fingers ratio, hand and foot dimensions, dolichocheir, medicolegal examinations

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1. INTRODUCTION

Precise identification is the most important step in forensic and medicolegal practices [1]. The establishment of the identity of the deceased in cases of disaster is of the greatest importance to the forensic scientists [2]. Identification of victims using dismembered human remains has constantly been a challenge in medico-legal investigations [3]. Anthropometry involves the technique of measuring the shape of the human body quantitatively. In Forensics, anthropometry can assist in the identification of mutilated, decomposed and or skeletal unidentified remains so as to determine the sex, age, stature and or race. It can also help to estimate how long a corpse has been decomposing, determine possible cause of death e.g. fractured skull and some inimitable feature(s) of an individual like some medical procedures.

Sex determination using anthropometric parameters is currently covered in many studies [1,4 - 6]. When they are available, the pelvic and cranial features were the most accurate and commonly used features to determine sex. Some researchers have used the measurements of other parts of the body to estimate sex [1, 4 - 11].

In this study we were able to, predict the sex of individuals using morphometric measurements of finger, hand and foot, decipher the variables that are independents sex predictors and also estimate the sectioning point for determining sex using foot, hand and finger dimensions of some students in the Faculty of Science, University of Lagos, Nigeria via the use of statistical analysis. Based on the results of this research, the anthropometric dimensions of the finger, hand and foot can be used to predict gender. The data presented in this study will aid detectives and other researchers especially forensic scientists, determine sex from the foot, finger and hand dimensions. To the best of our knowledge, this is the first study that determined sex of students from the Faculty of Science, University of Lagos, Nigeria using anthropometric dimensions of the finger, hand and foot.

2. MATERIAL AND METHODS

Study Design

This study was conducted using two hundred students (100 male and 100 female) between the age of 16 and 30 years from the Faculty of Science, University of Lagos, Nigeria. During the preliminary study, all measurements for 10 participants were taken by one of the researchers so as to assess intra-observer error. The next day, all measurements for the 10 participants were taken independently by two researchers and the measurements were assessed for inter-observer error. For this study, all measurements were taken for all the 200 participants by two researchers in duplicate so as to avoid observer bias and the mean values used. The subjects with any disease, deformity, injury, fracture, amputation or history of any surgical procedures of the feet were excluded from the study.

Methods

The technique used for measuring the parameters was according to the methods described by Phang *et al.* (2017) [12]. The hand measurements were taken in millimetre (mm) using a tape rule and Vernier Calipers of KTC (KYOTO TOOL) while foot measurements, weight and height were taken in millimetre (mm) using a Stadiometer (RGZ-160) and sliding calliper.

Hand Dimension Measurements

The hand measurements taken were hand length and breadth, arm length, forearm length, wrist width, individual phalange length of each finger for the right and left hands. Arm length was measured as a straight distance from the uppermost edge of the posterior border of the acromion process of the scapula, to mark the beginning of the shoulders using a tape rule,

to the tip of the middle finger. Using a tape rule, other arm measurements were taken e.g. the distances between shoulder to elbow, elbow to wrist and the wrist breadth (i.e. the circumference of the wrist). Hand length and breadth were measured as a straight distance from the midpoint of a line joining the styloid process of the radius and ulna bone of the forearm, to the tip of the middle finger, and as a straight distance from the most laterally set point on the head of the second metacarpal bone to the most medially set point on the head of the fifth metacarpal bone using a Vernier caliper respectively [13]. Phalange length of each finger was also measured, this is the straight distance from the metacarpophalangeal crease of each digit to the tip of the finger.
The hand and finger indices were calculated as:
To calculate IFL/RFL ratio, the index finger length was divided by ring finger length of the same hand.
Hand Index was analyzed and classified based on the standard range described by Martin and Saller (1957) [14] in which five range of hand indices were introduced.

$$\text{Hand index} = \frac{\text{Hand breadth}}{\text{Hand length}} \times 100$$

Five standard range of Hand indices described by Martin & Saller

Variations	Range
Hyperdolichocheir	X – 40.9
Dolichocheir	41.0 – 43.9
Mesocheir	44.0 – 46.9
Brachycheir	47.0 – 49.9
Hyperbrachycheir	50.0 – X

Foot Dimension Measurements

The foot measurements taken were the right foot left (RFL), right foot breadth (RFB), right ankle breadth (RAB), left foot length (LFL), left foot breadth (LFB) left ankle breadth (LAB). Foot length (FL) and breadth (FB) were measured as the direct maximum distance from the most posteriorly projecting point on the heel (pternion) to the anterior tip of whichever toe yields the longest measurement, and the distance from the medial margin of the head of the first metatarsal bone (metatarsal tibiale) to the lateral margin of the head of the fifth metatarsal bone (metatarsal fibulare) respectively. Ankle breadth (AB) was measured as the distance between the points that protrude most laterally. RFL/RFB, LFL/LFB ratios and foot index were estimated.

$$\text{Foot index} = \frac{\text{foot breadth}}{\text{foot length}} \times 100$$

Data Analysis

The data obtained was analysed statistically using IBM SPSS (SPSS; Statistical program for Social Sciences, Inc., Chicago, IL, USA) version 23.0 computer software. Mean, standard error of mean (SEM) for the parameters examined were calculated and p-value <0.05 was considered as significant. Average of mean foot index, RFL/RFB and LFL/LFB ratio of both sexes were used for sex determination of the subjects, which is termed as ‘‘sectioning point’’ [2]. A dividing line (cut-off point) for foot index between the two sexes will be based on sectioning point analysis.

$$\text{Sectioning point} = \frac{\text{mean male value} + \text{mean female value}}{2}$$

3. RESULTS

Measurements of the Hand and finger Dimensions

The descriptive statistics of hand and finger measurements in male and females are shown in table 1. The males showed higher

mean values in all the parameters measured compared to the females.

Table 1
Descriptive statistics for the hand and finger dimension measurements (mm) of the male and female subjects

Parameter (mm)	Males			Females		
	Minimum	Maximum	Mean±S.E	Minimum	Maximum	Mean±S.E
Right hand length	159	225	194.2±1.16	158	200	177.1±1.35
Right hand breadth	76	95	84.4±0.52	70	85	76.5±0.56
Left hand length	164	230	196.1±1.79	160	199	177.7±1.36
Left hand breadth	75	92	84.1±0.51	70	85	75.9±0.59
Right thumb	58	77	65±0.59	51	68	59±0.48
Right index finger	60	80	71.5±0.55	53	77	66.2±0.66
Right middle finger	70	92	81±0.64	65	84	74.8±0.65
Right ring finger	63	85	73.7±0.73	59	78	67.7±0.62
Right little finger	49	70	59.1±0.58	42	64	52.1±0.68
Left thumb	59	75	65.8±0.61	54	69	59.7±0.45
Left index finger	63	83	72.8±0.66	56	79	67±0.65
Left middle finger	69	93	81.7±0.67	65	86	75±0.67
Left ring finger	64	86	75.6±0.65	56	80	68.5±0.67
Left little finger	48	68	59.9±0.65	44	63	52.3±0.69
Right shoulder to middle finger	740	950	842.7±5.46	715	920	779.3±5.58
Right shoulder to elbow	380	465	422.1±2.61	340	450	392.6±3.27
Right elbow to wrist	265	355	301.7±2.27	245	320	277.2±27
Right wrist's width	150	185	169.1±1.14	140	185	159.3±1.43
Left shoulder to middle finger	750	940	837.5±5.41	720	912	775±5.38
Left shoulder to elbow	345	455	418.3±3.20	345	455	390.3±3.10
Left elbow to wrist	245	350	296.7±2.46	235	315	271.9±2.17
Left wrist's width	155	185	168.6±1.10	155	185	160.1±1.41

Measurements of the Foot Dimensions of the Male and female

The measurements of the foot dimensions of the male and females are shown in table 2. The stature of the males was high compared to the females, though the mean BMI value of the females was higher than the mean BMI values of the male. The males showed higher values in the foot parameters measured compared to the females

Table 2

Descriptive statistics of the age, height, weight, BMI and foot dimension measurements of the male and females

Parameters	Females			Males		
	Minimum	Maximum	Mean±SE	Minimum	Maximum	Mean±S.E
Age (years)	17	37	21.3±0.35	18	32	21.4±0.39
Height (mm)	1545	1840	1639.6±7.38	1590	1905	1752.9±7.97
Weight (kg)	45	130	66.1±2.10	50	87	68.2±19
BMI (kg/m^2)	17.7	38.4	24.45±0.66	17.7	31.1	22.2±0.36
Right Foot Length (mm)	230	300	268±0.27	250	335	293.7±2.32
Right Foot Breadth (mm)	84	104	93.8±0.79	87	114	101±0.88
Right Ankle Breadth (mm)	220	315	247.1±2.40	215	300	255.2±2.63
Left Foot length (mm)	175	310	265.4±3.10	250	330	292.6±2.25
Left Foot Breadth (mm)	80	105	93.2±0.78	86	119	101.1±0.89
Left Ankle Breadth (mm)	225	315	249.3±2.37	215	300	256.1±2. 46

Prediction of Sex using both of Hand and Foot Indices

Table 3 shows the individual variation and percentage in hand indices of the males and females based on standard range described by Martin and Saller (1957) [14]. The females showed more dolichocheir and mesocheir morphology compared to males though no female showed hyperbrachycheir morphology.

Table 3
The individual variation in hand indices of the males and females based on standard range described by Martin and Saller

Variation	Male		Female	
	Right hand Index	Left hand Index	Right hand Index	Left hand Index
Hyperdolichocheir	10 (10 %)	18 (18 %)	14 (14 %)	12 (12 %)
Dolichocheir	52 (52 %)	52 (52 %)	48(48 %)	62 (62 %)
Mesocheir	30 (30 %)	24 (24 %)	36 (36 %)	24 (24 %)
Brachycheir	4 (4 %)	6 (6 %)	2 (2 %)	2 (2 %)
Hyperbrachycheir	4 (4 %)	0 (0 %)	0 (0 %)	0 (0 %)

Prediction of sex using hand and foot dimensions and index

The sectioning points for RHI, LHI, RFI and LFI in both sexes are 43.33, 42.8, 34.7 and 34.84 respectively as shown in table 4. The cut-off points for hand indices, foot indices and LIFL/LRFL and RIFL/RRFL in both male and female subjects are 43.07, 34.77 and 0.97 respectively and they define sexual dimorphism among the subjects that participated in this study. The RFI, LFI, RIFL/RRFL ratio and LIFL/LRFL ratio values of the females are high compared to the males.

Table 4

Mean values of hand and foot indices for sex prediction in both male and female subjects

	RHI	LHI	RFI	LFI	RIFL/RRFL	LIFL/LRFL
Male	43.46	42.89	34.39	34.55	0.9699	0.9627
Female	43.2	42.71	35.00	35.12	0.9781	0.9769
Sectioning Point	43.33	42.8	34.7	34.84	0.974	0.9698
Cut Off Point	43.07		34.77		0.9719	

Key:
RHI=Right hand index **LHI=Left hand index**
RFI=Right foot index **RRFL=Right ring finger length** **LIFL=Left index finger length**
LFI=Left foot index **RIFL=Right index finger length** **LRFL= Left ring finger length**

Pearson correlation analyses for the male and female subjects using Foot, Hand, Finger and Hand dimension measurements

In both sexes, height and weight significantly correlated with right foot breadth, right ankle breadth, left foot length, left foot breadth and left ankle breadth ($p \leq 0.05$) as shown in table 5. However, there was no correlation between age and all foot parameters studied in both sexes.

Table 5

Correlation between age, height, weight, BMI and foot dimension measurements in both sexes

	Age (yrs)	Height (mm)	Weight (kg)	BMI (kg/m^2)	RFL (mm)	RFB (mm)	RAB (mm)	LFL (mm)	LFB (mm)	LAB (mm)
Age (yrs)	1	0.02	0.02	0.04	-0.01	-0.00	-0.06	0.04	0.04	0.07
Height (mm)	0.02	1	0.34**	-0.19	0.16	0.56**	0.43**	0.65**	0.63**	0.41**
Weight (kg)	0.02	0.34**	1	0.85**	0.15	0.45**	0.59**	0.44**	0.41**	0.65**
BMI (kg/m^2)	0.04	-0.19	0.85**	1	0.07	0.19	0.37**	0.11	0.09	0.45**
RFL (mm)	-0.01	0.16	0.15	0.07	1	0.27**	0.19	0.3**	0.26**	0.17
RFB (mm)	-0.00	0.56**	0.47**	0.19	0.27**	1	0.65**	0.56**	0.89**	0.63**
RAB (mm)	-0.06	0.43**	0.59**	0.37**	0.19	0.65**	1	0.48**	0.57**	0.92**
LFL (mm)	0.04	0.65**	0.44**	0.11	0.3**	0.56**	0.48**	1	0.6**	0.45**
LFB (mm)	0.04	0.63**	0.41**	0.09	0.26**	0.89**	0.57**	0.6**	1	0.57**
LAB (mm)	0.07	0.41**	0.65**	0.45**	0.17	0.63**	0.92**	0.45**	0.57**	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Key:
LFL = Left Foot length
BMI=Body Mass Index
RFL = Right Foot Length
RFB = Right Foot Breadth
RAB = Right Ankle Breadth
LFB = Left Foot Breadth
LAB = Left Ankle Breadth

In both sexes, height and weight significantly correlated with right hand length, right hand breadth, left hand length and left hand breadth ($p \leq 0.05$) as shown in table 6. However, there was no correlation between age and all hand parameters studied in both sexes.

Table 6
Correlation between age, height, weight and hand dimension measurements in both sexes

	Age (yrs)	Height (mm)	Weight (kg)	BMI (kg/m^2)	Right Hand Length(mm)	Right Hand Breadth(mm)	Left Hand Length(mm)	Left Hand Breadth(mm)
Age(yrs)	1	0.02	0.02	0.08	-0.03	0.1	-0.04	0.15
Height (mm)	0.02	1	0.34**	-0.13	0.8**	0.76**	0.81**	0.74**
Weight (kg)	0.02	0.34**	1	0.69**	0.39**	0.42**	0.38**	0.45**
BMI(kg/m^2)	0.08	-0.13	0.69**	1	0.04	0.01	-0.00	0.05
Right Hand Length (mm)	-0.03	0.8**	0.39**	0.03	1	0.77**	0.96**	0.78**

Right Hand Breadth(mm)	0.1	0.76**	0.42**	0.01	0.77**	1	0.77**	0.94**
Left Hand Length (mm)	-0.04	0.81**	0.38**	-0.00	0.96**	0.77**	1	0.78**
Left Hand Breadth(mm)	0.15	0.74**	0.45**	0.05	0.78**	0.94**	0.78**	1

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

In both sexes, height and weight significantly correlated with right index finger, right middle finger, right ring finger, right little finger, left thumb, left index finger, left middle finger, left ring finger and left little finger ($p \leq 0.05$) as shown in table 7. However, there was no correlation between age and all finger parameters studied in both sexes.

Table 7:
Correlation between age, height, weight and finger dimension measurements in both sexes

	Age (yrs)	Height (mm)	Weight (mm)	BMI (kg/m^2)	RT (mm)	RI (mm)	RM (mm)	RR (mm)	RL (mm)	LT (mm)	LI (mm)	LM (mm)	LR (mm)	LL (mm)
Age (yrs)	1	0.02	0.02	0.08	0.03	-0.04	-0.09	-0.11	-0.06	-0.02	-0.01	-0.07	-0.06	0.01
Height (mm)	0.03	1	0.34**	-0.13	0.73**	0.68**	0.75**	0.73**	0.72**	0.67**	0.72**	0.75**	0.77**	0.71**
Weight (kg)	0.02	0.34**	1	0.69**	0.29**	0.49**	0.45**	0.4**	0.38**	0.23*	0.44**	0.38**	0.43**	0.37**
BMI (kg/m^2)	0.08	0.13	0.69**	1	-0.12	0.08	0.02	-0.03	-0.04	-0.13	0.05	-0.02	0.01	-0.02
RT (mm)	0.03	0.73**	0.29**	-0.12	1	0.72**	0.7**	0.72**	0.74**	0.82**	0.75**	0.74**	0.76**	0.75**
RI (mm)	-0.04	0.68**	0.49**	0.08	0.72**	1	0.92**	0.85**	0.79**	0.64**	0.93**	0.89**	0.88**	0.81**
RM (mm)	-0.09	0.75**	0.45**	0.02	0.7**	0.92**	1	0.91**	0.79**	0.64**	0.88**	0.89**	0.88**	0.8**
RR (mm)	-0.11	0.73**	0.4**	-0.03	0.72**	0.85**	0.91**	1	0.81**	0.65**	0.86**	0.91**	0.92**	0.81**
RL (mm)	-0.06	0.72**	0.38**	-0.04	0.74**	0.79**	0.79**	0.81**	1	0.71**	0.79**	0.81**	0.83**	0.91**
LT (mm)	-0.02	0.67**	0.23*	-0.13	0.82**	0.64**	0.64**	0.65**	0.71**	1	0.74**	0.68**	0.68**	0.7**
LI (mm)	-0.01	0.72**	0.44**	0.05	0.76**	0.93**	0.88**	0.86**	0.79**	0.74**	1	0.9**	0.89**	0.81**
LM (mm)	-0.07	0.75**	0.38**	-0.02	0.74**	0.89**	0.89**	0.91**	0.81**	0.68**	0.9**	1	0.93**	0.84**

LR (mm)	-0.06	0.77**	0.43**	0.01	0.76**	0.88**	0.88**	0.92**	0.83**	0.68**	0.89**	0.93**	1	0.87**
LL (mm)	0.01	0.71**	0.37**	-0.02	0.75**	0.81**	0.8**	0.81**	0.91**	0.7**	0.81**	0.84**	0.87**	1

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Key:
Right Thumb = RT
Right Index = RI
Right Middle = RM
Right Ring = RR
Right Little = RL
Left Thumb = LT
Left Index = LI
Left Middle = LM
Left Ring = LR
Left Little = LL

In both sexes, height and weight significantly correlated with right shoulder to finger length, right shoulder to elbow length, right elbow to wrist length, right wrist width, left shoulder to finger length, left shoulder to elbow length, left elbow to wrist length and left wrist width ($p \leq 0.05$) as shown in table 8. There was no correlation between age and all finger parameters studied in both sexes.

Table 8:
Correlation between age, height, weight and hand dimension measurements in both sexes

	Age (yrs)	Height (mm)	Weight (kg)	BMI (kg/m^2)	RSF (mm)	RSE (mm)	REW (mm)	RWW (mm)	LSF (mm)	LSE (mm)	LEW (mm)	LWW (mm)
Age (yrs)	1	0.02	0.02	0.08	0.02	0-.09	0.09	0.1	0.02	0-.02	0.09	0.18
Height (mm)	0.02	1	0.34**	-0.13	0.84**	0.72**	0.79**	0.57**	0.83**	0.72**	0.74**	0.54**
Weight (kg)	0.02	0.34**	1	0.69**	0.44**	0.34**	0.41**	0.69**	0.43**	0.37**	0.39**	0.67**
BMI (kg/m^2)	0.08	-0.13	0.69**	1	-0.00	-0.04	-0.01	0.31**	0.01	.008	-0.03	0.31**
RSF (mm)	0.02	0.84**	0.44**	-0.00	1	0.84**	0.82**	0.64**	0.98**	0.84**	0.79**	0.63**
RSE (mm)	-0.09	0.72**	0.34**	-0.04	0.84**	1	0.67**	0.49**	0.83**	0.86**	0.62**	0.48**
REW (mm)	0.09	0.79**	0.41**	-0.01	0.82**	0.67**	1	0.61**	0.82**	0.65**	0.88**	0.58**
RWW (mm)	0.1	0.57**	0.69**	0.31**	0.64**	0.49**	0.61**	1	0.62**	0.52**	0.58**	0.92**
LSF (mm)	0.02	0.83**	0.43**	0.01	0.97**	0.83**	0.82**	0.62**	1	0.89**	0.8**	0.62**
LSE (mm)	-.015	0.72**	0.37**	0.01	0.84**	0.86**	0.65**	0.52**	0.88**	1	0.64**	0.5**
LEW (mm)	0.09	0.74**	0.39**	-0.03	0.79**	0.62**	0.88**	0.58**	0..8**	0.64**	1	0.56**
LWW (mm)	0.18	0.54**	0.66**	0.31**	0.63**	0.48**	0.58**	0.92**	0.62**	0.5**	0.56**	1

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Key:
RSF = Right Shoulder to Finger
RSE = Right Shoulder to Elbow
REW = Right Elbow to Wrist
RWW = Right Wrist Width
LSF = Left Shoulder to Finger
LSE = Left Shoulder to Elbow
LEW= Left Elbow to Wrist
LWW = Left Wrist Width

4. DISCUSSION

The identification of a human using skeletal remnants and or dismembered body parts is one of the most important tasks to be achieved by the forensic scientists especially when information vis-à-vis the deceased is unavailable. Sex determination becomes the first priority in the process of identification of a person by a forensic investigator in the case of mishaps, chemical and nuclear bomb explosions, natural disasters, crime investigations, and ethnic studies [15]. Consequently, this study was carried out to ascertain if hand, finger, foot dimensions and their indices can be used to determine sexual dimorphism using some undergraduate students from Faculty of Science, University of Lagos Nigeria.

The results of this study show that the mean value of hand and finger measurements in all the parameters investigated was higher in males compared to females. This is in accordance with the findings in earlier studies whereby female hand dimensions were consistently smaller compared to the male in different human populations [4-6, 8, 16]. This suggests that there is morphological gender difference in the length of the hands and fingers. A key point is that these measurements should be done separately in each population, because the racial and ethnic differences are effective on these measures and reduce the possibility of generalizing [17]. The hand length and breadth observed within the sampled population was found to be greater than that reported by Rastogi *et al* (2008) [18] in a population from North and South India, also in a population from Mauritius and in a population from Upper Egypt [19] and these differences can be explained by racial and population variations.

The right and left index and ring finger ratio (RIFL/RRFL and LIFL/LRFL ratio) was found to be higher in females (0.9781 and 0.9769) compared to males (0.9699 and 0.9627). This is in accordance with the studies by different researchers whereby the index and ring finger ratio in females is higher compared to the males [5, 20]. In this study, index and ring finger ratio $\leqslant$0.9699 for the right hand and $\leqslant$0.9627 for the left hand are suggestive of male while index and ring finger ratio <0.9781 for the right hand and <0.9759 for the left hand is suggestive of female. In a study to determine sex from hand and index/ring finger length ratio in North Saudi population, the index and ring finger ratio $\leqslant$0.920 for the right hand and $\leqslant$0.913 for the left hand is suggestive of male while Index and ring finger ratio <0.920 for the right hand and <0.913 for the left hand is suggestive of female [5]. In an Egyptian population, the index and ring finger ratio $\leqslant$0.976 is suggestive of males, and ratio >0.976 is suggestive of females [19].
In this study, a hand index $\leqslant$43.07 is suggestive of females and is suggestive of males when it is >43.07, while in an Egyptian population some researchers reported that hand index $\leqslant$40.55 is suggestive of females and >40.55 is suggestive of males [19]. However, the average hand index in this study is smaller than that recorded in a Mauritius population [21]. The cut-off points estimated for hand index in this study was found to be ≤43.33 for the right hand and ≤42.80 for the left hand as indicative of a female, while a cut-off point greater than (>) 43.33 for the right hand and greater than (>) 42.80 for the left hand was indicative of a male. This hand index cut-off point is greater than that reported by Rastogi *et al* (2008) [18].

From this study, there are comparatively larger variations in the ring finger length between male and female than in the index finger lengths. These results are in agreement with previous studies using Upper Egyptians and North Saudi population [5, 19] In this current study, the female subjects were reported to have a significantly higher IFL/RFL ratio than the male in both hands. These findings are consistent with the work of McFadden *et al* (2002) [22] where higher digit ratios are

usually an indication of 'femininity' and lower digit ratios indicative of 'masculinity', thus making the IFL/RFL ratios a potentially beneficial parameter for the determination of sex. The cut-off point for the IFL/RFL ratio obtained for sex differentiation in this research were 0.9757 and 0.9702 for the right and left hand respectively. This means that for the right and left hand, ≥0.9757 and ≥0.9702 respectively are predictive of the female sex while lower values predict male. This data is similar to that found in the study of the Upper Egyptian population in which the cut-off point derived for sex differentiation was 0.976 [19] and in the South Indian adult and adolescent population the cut-off point was (0.970) [23]. The IFL/RFL ratio is a statistically significant marker for sex determination in this study and this is in accordance with the works of Kanchan *et al* (2008) [23]. However, Voracek *et al* (2009) [24], performed a comparative analysis and concluded that the IFL/RFL ratio is of modest benefit for the determination of sex, restricting its use in forensic lawsuits. This contrariety may be attributed to the remarkable influence of ethnic and population variability on this ratio, due to the dimensional diversity of the human body, anthropometric measurements of an individual are not constantly credible tools for the determination of sex but still remains assertive for the prediction of sexual dimorphism.

Morphology and morphometry of human feet is greatly affected by the combined effects of heredity and living style of man and that determines the size and shape of the feet or footprints and makes them unique parameter to establish human identity [25, 26]. The study also revealed that sexual dimorphism in the foot length and breadth was larger in the male subjects than in the female subjects. This finding agrees with the reports in some earlier studies [6, 21, 27]. Studies showed that there was a consistent difference in the range of foot index between male and female subjects across ages 18 – 22 and above [28, 29]. This study revealed the foot index of 34.77 cm as the cutoff point therefore a foot index ⩽34.77 is suggestive of males and is suggestive of females when it is >34.77. this showed a similar pattern compared to Agnihotri *et al* 2006 [28] that concluded that a foot index >37 is suggestive of female and ≤37 is that of male. The foot indices in this study showed a dissimilar pattern compared to, the study on randomly selected students of the Ahmadu Bello University, Zaria, Nigeria whereby they stated that foot indices >38 will certainly denote a male Nigerian [30], a study at IDST College, Modinagar, Uttar Pradesh, India whereby all the cases with cutoff point index of ≤37.60 were suggestive of females and ≥37.60 were indicative of males for both the feet [20], and on students from Sri Siddhartha university, Tumkur, Karnataka that states that the average foot index in males and females were 44.91 and 42.63 respectively [27]. The relationship between foot dimensions for the same sex is strongly significant. The correlation values of the foot dimensions between same sex and differences in the male and the female subjects showed that foot is a good determining factor for sex determination. This study revealed that there was a clear difference in the measurement of the foot dimensions of both the male and female subjects, and thus suggests that male's foot dimensions are generally larger than that of the female subjects. This finding is in agreement with reports of Montrakis *et al* (2010) [9].

5. CONCLUSION

The determination of sex in a medical and/or legal examination of a severed hand and foot can be accurately and practically achieved by simply obtaining anthropometric measurements of the hand, fingers and foot. This study showed that hand (length, breadth, wrist width, elbow to wrist length, shoulder to finger length and

shoulder to elbow length), finger (index, middle, ring and little) and foot (breath and ankle breadth) measurements yielded important predictive information about human sexual dimorphism. Foot indices, hand indices and index finger length and ring finger length ratios are good predictors of sex.

Further researches using larger sample sizes and various populations across Nigeria are essential to validate the use of hand, finger and foot indices in the identification of sex for forensic investigations.

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