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Quantitative anthropometric and dermatoglyphic variation of the major ethnic populations in Nigeria

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Abstract:

BACKGROUND: Anthropometry is one of the oldest and widely used measures of human variation. Dermatoglyphics is a valuable technique in human population studies by virtue of its uniqueness, genetic determination, and less vulnerability to selection than other genetic markers.

AIMS: The study aims (1) to elucidate the traditional ethnic identities in Nigeria which are increasingly facing disintegration due to improved means of communication and urbanization and reduced inbreeding and (2) to describe ethnic characteristics that may be valuable for forensic application and future studies of effects on human diversity.

SUBJECTS AND METHODS: We obtained quantitative anthropometric and dermatoglyphic data from 560 volunteers of both sexes, of Yoruba, Igbo, and Hausa origin. The sampling fraction used to attain target sample size for random selection of eligible volunteers was based on the national population figure.

STATISTICAL ANALYSIS: Univariate analysis of variance was used to determine patterns variations, while multivariate analysis was used to determine discrimination among ethnic populations.

RESULTS: The anthropometric and dermatoglyphic variables revealed a discrimination that is consistent with ethnohistorical affiliations. Multiple discriminant analysis of the anthropometrics showed higher discrimination power than the dermatoglyphic variables. The derived ethnic classifying equations from anthropometric parameters classified volunteers as Yoruba 78.2%, Hausa 82.4%, Igbo 91.4%; the dermatoglyphic parameters classified volunteers as Yoruba 66.8%, Hausa 57.4%, Igbo 65.3%. The canonical discriminant function of the anthropometric and dermatoglyphic variables showed clustering of the ethnic populations around each ethnic centroid.

CONCLUSIONS: The results provide ethnohistorical insights into the structure of the ethnic populations and demonstrate the relationship of the gene flow in the ethnic groups through their exhibited phenotypic characteristics.

Keywords:

Anthropometry, dermatoglyphics, ethnic population differentiation

Introduction

Nigeria is a multilinguistic, multicultural, and pluralistic nation with each ethnic population making claims of oral, cultural, and historical identity. The physical characteristics of the different ethnic populations may be used for population subdivision and identity and may have forensic, public health, and industrial applications. Although the degree of ethnic isolation is not high and there has been a long period of historical interactions, each ethnic population has acquired well-defined historical, geographic, and cultural identity. Nevertheless, the traditional ethnic identities are at increased risk of disintegration due to improved means of communication and urbanization and reduced inbreeding. It is

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necessary to study their current characteristics to have insights into future trends of the identity of each ethnic population.

Previous anthropometric and dermatoglyphic studies have documented differences in phenotypic features among Nigerian ethnic populations (Hiernaux and Froment, 1976; Taiwo and Akinde, 2012; Danborno *et al*., 2009; Umar *et al*., 2011; Igbigbi *et al*., 1996; Adetona *et al*., 2008). Conventionally, the Maguzawa tribe (Hausa) inhabited Northwest Nigeria (Kallamu, 2013), the Igbo traditional habitation covers most of Southeast Nigeria (Slattery, 2016), while the Yoruba ethnic population is found mainly in Southwest Nigeria (Facts.ng, 2016). These three ethnic population groups had inhabited the Niger area with a long history of migrations and settlements and with such admixture of social and cultural relationships that it often became difficult to separate the people within these settlements into neat sociocultural groups (Otitie, 2016). The quantifiable cephalometric differences of ethnic populations residing in Nigeria are small as observed from studies of several workers in different ethnic populations. It has been established that the differences in traits of the phenotypic characteristics among or between ethnic groups within a geographical area that had interrelated for a long time were usually very small with an enormous degree of overlap (Richardson, 1980). The factors accounting for these phenotypic variations are genetic, environmental, socioeconomic, and nutritional (Campbell and Tishkoff, 2008; Roberts, 1953, 1978; Hiernaux *et al*., 1975). The phenotypic variability in the expression of genes among individuals and ethnic populations influences the anthropometric and dermatoglyphic variables, which reveal differential history of human origin, and the complex interaction of genetic and environmental factors in producing phenotypes (Campbell and Tishkoff, 2008). Anthropometric and dermatoglyphic variables could therefore reveal patterns of the structure of population groups and their ethnohistorical affiliations (Knight *et al*., 2005).

This study was designed to quantify the physical characteristics of the three Nigerian ethnic groups and to determine the comparative power of anthropological tools for identification and other applications.

Subjects and Methods

Sample size determination was based on the development of nonlinear regression model for the estimation of genetic diversity of large natural population from finite sample sizes regardless of the species and marker systems (Bashalkhanov *et al*., 2009).

The Nigerian population (Np) figure was 140,431,790 (National Population Commission. 2010. Federal Republic of Nigeria 2006 Population and Housing Census. Priority Table IV). The Hausa population of northwest zone (Hp) was 35,915,467. The sampling fraction Hp/Np equaled to 0.3, resulting in the selection of three out of 10 eligible Hausa volunteers. The Igbo population of southeast zone (Ip) was 16,395,555. The sampling fraction Igbo population of southeast zone (Ip)/Np equaled to 0.1, resulting in the selection of one out of 10 eligible Igbo volunteers. The Yoruba population of southwest (Yp) was 27,722,452, and the sampling fraction Yp/Np equaled to 0.2, resulting in the selection of two volunteers out of every eligible 10 Yoruba volunteers. The target sample size was to attain a minimum of 90 volunteers for each ethnic population (Bashalkhanov *et al*., 2009). The total sample size of 560 was taken based on volunteers' availability: 175 for Hausa, 163 for Igbo, 222 for Yoruba.

Anthropometric measurements were obtained from voluntary participants using internationally accepted human anthropometric landmarks [Figure 1] and standard anthropometric procedures. Body weight in kilograms was measured by a Gallenkamp self-zeroing digital weight scale (DT 150 Weiss-Gallenkamp, Company, United Kingdom) accurate to 0.1 kg.

The standing height was measured using a stadiometer (Weiss-Gallenkamp, United Kingdom). The following parameters were measured using digital spreading calipers (Gujarat, India): head length (HH), maximum biparietal diameter (BPD), head (skull) height, nasal

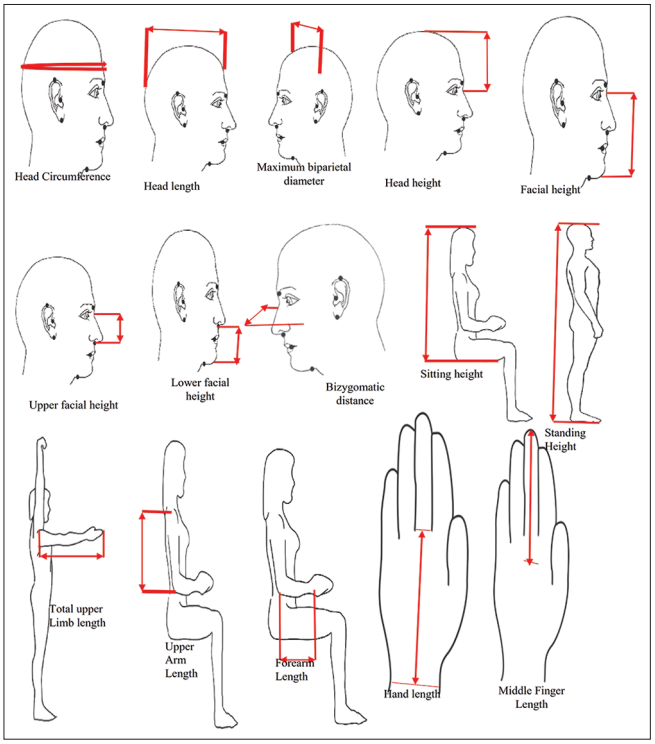

Figure 1: Demonstration of some anthropometric parameters' measurement

height (NH), upper facial height (UFH), lower facial height (LFH), bizygomatic distance (BZD) (facial width).

The cephalometric indices were calculated using standard equations: cephalic index, vertical index, height length index, head modulus index, index of the size of head, morphological facial index, morphological upper facial index, and sagittal nasofacial index [Appendix 1] (Singh *et al*., 2004). The following parameters were measured by a tape measure and a ruler on the right side of the volunteers (Hall *et al*., 2007): sitting height, head circumference (HC), right (R) and left (L) total upper limb length, upper arm length, forearm length, hand length (HAL), middle finger length, palm length (PL), palm width (PW), upper leg (thigh) length, lower leg (calf) length, foot length and foot width. Carrying angle (CA) in degrees was measured by a goniometer (White Plains, USA). All measurements were taken to 0.1 unit. The following parameters were calculated: cormic index (COI), ponderal index (PI), and body mass index (BMI) [Appendix 1].

The volunteer that had anthropometric measurements also had prints of the right and left hands taken with printer's ink on an A4 glossy paper. Each paper has the age, sex, right or left hand, and identification number preceded with Hausa (H), Igbo (I), and Yoruba (Y) on the top of the paper. The volunteer whole hand was placed on the inked slab. The ink was spread to areas of the hand that did not make contact with the slab from distal end of the fingers to the level of proximal wrist crease. The thumb and fingers 2, 3, 4, and 5 were rolled from the radial side to the ulnar to obtain their complete pattern [Figure 2].

Readings of the print were done with × 4 Power Bifocal Margin Lamp Magnifier. The readings were based on the human hand print classification: the five digits (1–5), the thenar area (T), the hypothenar (H), and the central area of the palm (Ashbaugh, 1999). The print variables were classified using the internationally accepted Euro-American classification of palmar and digital prints into arch (A), ulnar loop (UL), radial loop (RL), and whorl (W). The ridges in a pattern were counted on a straight line connecting the core of the pattern and the triradius. The triradius point and the point of core were not included in the count. The following finger and palmar variables were obtained: total finger ridge count (TFRC), a–b RC, percentage frequencies of each arch (A), UL, RL, whorl (W) of both hands, and atd angle of both hands (atd [R], atd [L]). The palm print of right (R) and left (L) of the predefined areas: palm ridge density (PRD)-1 is defined as midpoint of line on thenar eminence connecting mid first metacarpophalangeal crease and mid-distal wrist crease; PRD-2 is a point on hypothenar eminence midpoint of straight line connecting mid of fifth metacarpophalangeal crease and mid distal wrist crease; PRD-3 is a points half centimeter proximal to triradius "a;" PRD-4 is a point half centimeter proximal to triradius "d." A 25 mm^2 area was drawn on the defined areas (Acree, 1999) to estimate the RC. The ridges in 25 mm^2 area were counted to reflect the ridge density count. The variables for both hands were counted for individual within each ethnic population.

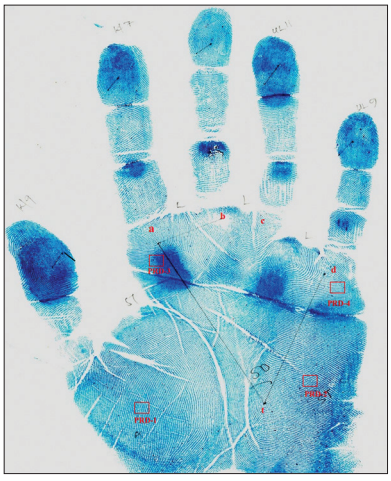

Figure 2: Finger and palmar patterns of the right hand showing finger patterns, palm areas a, b, c, d palm ridge density-1, 2, 3, 4, a-b ridges and atd angle

The study was approved by the Research Ethics Committee of the Ministry of Health (Reference number AD 13/620), and only participants who gave their informed consent were involved in the study.

Data analysis

Univariate analysis of variance (ANOVA) was used to study patterns of anthropometric and dermatoglyphic variations. Multivariate analysis of multiple discriminant analysis was used to examine different set of data for the ethnic populations.

Results

The results for anthropometric and dermatoglyphic univariate ANOVA are presented in Table 1. The *F* values of the anthropometric variables showed differentiation that is statistically significant ($P < 0.05$) for the ethnic groups for each of the variables, except PI, HC, CA (L), PL (R), PW (R), and PW (L). Similarly, the *F* values for the dermatoglyphic variables such as TFRC (L), a-bRC (L), atd (L), and all palm ridge densities for right and left (R and L) hand were significantly different ($P < 0.05$) between the ethnic groups. The results of multivariate analysis of the anthropometric and dermatoglyphic variables are presented in Table 2. It suggests significant discrimination ($P < 0.05$) for anthropometric and dermatoglyphic variables. The palmar dermatoglyphic variables are much more discriminatory when compared to finger dermatoglyphics.

Table 1: Univariate analysis of variance for the anthropometric and dermatoglyphic among ethnic groups

Anthropometry				Dermatoglyphics			
Variable	Wilks' Lambda	*F*	*P*	Variable	Wilks' Lambda	*F*	*P*
WT	0.86	41.90	0.00	TFRC (R)	1.00	0.79	0.46
STH	0.89	30.36	0.00	TFRC (L)	0.99	3.40	0.03
BMI	0.97	7.98	0.00	A (R)	0.99	2.90	0.06
SIH	0.96	9.84	0.00	A (L)	1.00	0.61	0.55
PI	0.99	1.73	0.18	UL (R)	0.99	2.28	0.10
COI	1.00	9.84	0.00	UL (L)	1.00	1.20	0.30
HC	0.98	1.41	0.25	RL (R)	1.00	0.34	0.71
HL	0.99	4.59	0.01	RL (L)	1.00	0.50	0.61
BPD	0.91	3.98	0.02	W (R)	1.00	0.74	0.48
HH	0.87	24.77	0.00	W (L)	1.00	1.33	0.27
NH	0.94	15.39	0.00	a-b RC (R)	0.99	1.55	0.21
LFH	0.94	36.82	0.00	a-b RC (L)	0.96	10.47	0.00
UFH	0.95	66.60	0.00	Atd (R)	1.00	0.09	0.91
FH	0.95	33.68	0.00	Atd (L)	0.98	6.52	0.00
BZD	0.97	6.16	0.00	PRD-1 (R)	0.93	18.9	0.00
CI	0.94	6.64	0.00	PRD-1 (L)	0.94	16.5	0.00
VI	0.79	15.46	0.00	PRD-2 (R)	0.92	21.7	0.00
HLI	0.88	15.30	0.00	PRD-2 (L)	0.89	31.0	0.00
SHMI	0.98	13.50	0.00	PRD-3 (R)	0.85	43.9	0.00
ISH	0.98	13.69	0.00	PRD-3 (L)	0.87	39.4	0.00
MFI	0.88	6.88	0.00	PRD-4 (R)	0.95	14.0	0.00
MUFI	0.90	35.27	0.00	PRD-4 (L)	0.96	12.1	0.00
SNFI	0.98	28.15	0.00				
TULL (R)	0.89	4.41	0.01				
TULL (L)	0.85	31.29	0.00				
UAL (R)	0.82	44.06	0.00				
UAL (L)	0.89	57.09	0.00				
FAL (R)	0.95	31.27	0.00				
FAL (L)	0.94	13.90	0.00				
CA (R)	0.99	16.73	0.00				
CA (L)	0.96	1.93	0.15				
HL (R)	1.00	11.19	0.00				
HL (L)	0.95	0.00	1.00				
MFL (R)	0.98	14.25	0.00				
MFL (L)	0.99	5.24	0.01				
PL (R)	0.96	2.33	0.10				
PL (L)	0.99	11.50	0.00				
PW (R)	1.00	2.25	0.11				
PW (L)	0.94	0.11	0.90				
ULL (R)	0.65	16.22	0.00				
ULL (L)	0.63	138.69	0.00				
LLL (R)	0.92	152.33	0.00				
LLL (L)	0.95	22.37	0.00				
FL (R)	0.81	14.36	0.00				
FL (L)	0.79	58.92	0.00				
FW (R)	0.73	66.77	0.00				
FW (L)	0.75	93.36	0.00				

WT - Body weight, STH - Standing height, HC - Head circumference, HL - Head length, BPD - Biparietal diameter, HH - Head height, NH - Nasal height, UFH - Upper facial height, LFH - Lower facial height, FH - Facial height, BZD - Bizygomatic distance, CI - Cephalic index, VI - Vertical index, HLI - Height length index, HMI - Head modulus index, ISH - Index of the size of head, MFI - Morphological facial index, MUFI - Morphological upper facial index, SNFI - Sagittal Naso-facial index, SIH - Sitting height, R – Right, L – Left, TULL - Total upper limb length, UAL - Upper arm length, FAL - Forearm length, HAL - Hand length, MFL - Middle finger length, PL - Palm length, PW - Palm width, ULL - Upper leg length, LLL - Lower leg length, FL - Foot length, FW - Foot width, CA - Carrying angle, COI - Cormic index, PI - Ponderal index, BMI - Body mass index, TFRC - Total finger ridge count, a-b RC - a-b ridge cousnt, A – arch, UL - Ulnar loop, RL - Radial loop, W – Whorl, atd - atd angle, PRD - Palm ridge density, SHMI - Schmidt's Head Modulus Index

Table 3 shows the standardized discriminant function coefficients reflecting the contribution of the variates in the anthropometry and dermatoglyphics predicting the subjects to be in each of the ethnic group. The structure matrix of

Table 2: Multivariate test statistic, Wilks' λ and *P* value for the extent of differentiation based on set of anthropometric and dermatoglyphic variables

	Function	Eigenvalue	Percentage of variance	Cumulative percentage	Test of function (s)	Wilks' λ	Degree of freedom	Significant
Anthropometry	1	1.53	58.5	58.5	1 through 2	0.19	94	0.00
	2	1.08	41.5	100	2	0.48	46	0.00
Dermatoglyphics	1	0.46	68.6	68.6	1 through 2	0.57	44	0.00
	2	0.21	31.4	100	2	0.83	21	0.00

Table 3: Classification function coefficients of anthropometric and dermatoglyphic variables among the three ethnic groups

Variable	Ethnicity			Variable	Ethnicity		
	Yoruba	Hausa	Igbo		Yoruba	Hausa	Igbo
WT	43.22	43.44	43.15	PL (R)	−0.47	−0.84	−0.49
STH	67.06	67.20	67.16	PL (L)	−0.20	−0.16	−0.12
BMI	−34.29	−34.23	−34.32	PW (R)	−0.17	−0.21	−0.23
SIH	−98.29	−98.20	−98.61	PW (L)	16.77	16.73	17.44
PI	−2.20	−2.19	−2.21	LLL (R)	−2.33	−2.28	−2.57
COI	16,134.57	16,119.00	16,188.96	LLL (L)	4.70	4.63	4.66
HC	1.75	1.77	1.80	FL (R)	4.37	4.28	4.47
HL	550.67	553.07	552.89	FL (L)	−5.58	−4.96	−5.26
BPD	133.33	133.49	135.39	FW (R)	16.39	17.39	17.51
HH	1536.97	1544.31	1538.63	FW (L)	−5.38	−5.32	−5.75
NH	−247.03	−244.72	−245.70	TFRC (R)	−0.04	0.00	−0.06
LFH	174.17	178.34	177.06	TFRC (L)	0.55	0.49	0.52
UFH	96.56	89.89	89.45	a-b RC (R)	−2.07	−2.14	−2.18
BZD	27.91	27.11	27.68	a-b RC (L)	2.87	2.97	2.98
CI	102.41	103.00	102.46	PRD-1 (R)	−0.79	−0.33	−0.72
VI	43.66	44.06	43.64	PRD1 (L)	0.58	0.71	0.47
HLI	−145.50	−146.41	−145.08	PRD-2 (R)	5.35	5.57	5.15
ISH	−3.75	−3.77	−3.76	PRD-2 (L)	3.67	3.64	3.02
MFI	−0.72	−1.53	−1.27	PRD-3 (R)	9.10	8.92	9.07
MUFI	8.71	10.19	10.13	PRD-3 (L)	5.81	5.85	5.23
SNFI	34.12	33.79	33.97	PRD-4 (R)	−4.41	−4.74	−4.65
TULL (R)	0.39	0.38	0.34	PRD-4 (L)	6.49	6.22	6.73
TULL (L)	−1.72	−1.66	−1.67	A (R)	28.61	28.66	28.38
UAL (R)	0.10	0.22	−0.14	A (L)	56.84	57.47	57.96
UAL (L)	0.97	1.10	0.91	UL (R)	36.26	37.02	37.23
FAL (R)	5.04	5.12	5.04	UL (L)	55.82	56.12	56.39
FAL (L)	0.63	0.86	0.65	RL (R)	21.24	21.47	21.55
CA (R)	0.79	0.94	1.08	RL (L)	70.75	70.35	71.75
CA (L)	4.05	3.66	3.93	W (R)	33.44	34.32	34.62
HL (R)	0.37	0.35	0.36	W (L)	51.32	51.39	51.71
HL (L)	−23.97	−23.96	−24.13	atd (R)	1.36	1.43	1.40
MFL (R)	6.23	6.22	6.72	atd (L)	−0.06	−0.05	−0.04
MFL (L)	−4.51	−5.16	−5.01	Constant	−15,969.80	−16,076.28	−16,066.88

WT - Weight, STH - Standing height, HC - Head circumference, HL - Head length, BPD - Biparietal diameter, HH - Head height, NH - Nasal height, UFH - Upper facial height, LFH - Lower facial height, BZD - Bizygomatic distance, CI - Cephalic index, VI - Vertical index, HLI - Height length index, HMI - Head modulus index, ISH - Index of the size of head, MFI - Morphological facial index, MUFI - Morphological upper facial index, SNFI - Sagittal Naso-facial index, SIH - Sitting height, R – Right, L - Left, TULL - Total upper limb length, UAL - Upper arm length, FAL - Forearm length, MFL - Middle finger length, PL - Palm length, PW - Palm width, LLL - Lower leg length, FL - Foot length, FW - Foot width, CA - Carrying angle, COI - Cormic index, PI - Ponderal index, BMI - Body mass index, TFRC - Total finger ridge count, a-b RC - a-b ridge count, A - Arch, UL - Ulnar loop, RL - Radial loop, W - Whorl, atd - atd angle, PRD - Palm ridge density

the variables pooled within groups discriminating variables and standardized canonical discriminant functions. The results showed clustering of the ethnic groups around each ethnic group centroid (a point representing an average location of all people in an area). The clustering of anthropometric and dermatoglyphic variables are shown in Figures 3 and 4. The anthropometric variables showed clustering of the ethnic variables around each of the ethnic centroid when compared with the scattering of the ethnic variables in the dermatoglyphic variables in graphical representation [Figures 3 and 4].

The discriminant power of the anthropometric and dermatoglyphic variables in classifying the membership of

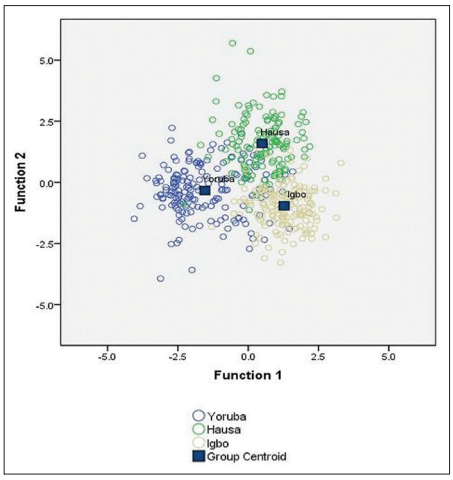

Figure 3: Anthropometric variables' canonical discriminant function showing clustering of the ethnic populations around individual ethnic centroid

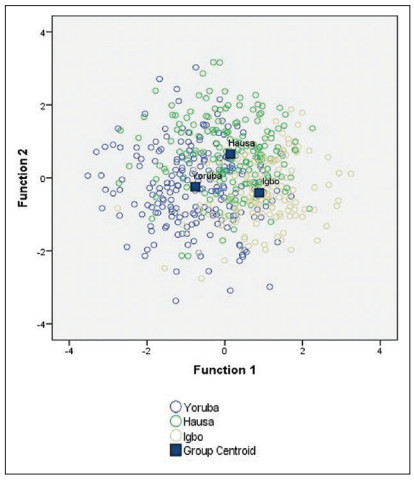

Figure 4: Dermatoglyphic variables canonical discriminant function showing clustering of the ethnic populations around separate centroid

Table 4: Percentage classification of ethnic classifying equation by multiple discriminant analysis of anthropometric and dermatoglyphics variables

	Predicted group membership			
Ethnicity	**Yoruba**	**Hausa**	**Igbo**	**Total**
Anthropometry (%)				
Yoruba	78.2	9.5	12.3	100
Hausa	5.9	82.4	11.8	100
Igbo	4.3	4.3	91.4	100
Dermatoglyphics (%)				
Yoruba	66.8	18.8	14.4	100
Hausa	23.7	57.4	18.9	100
Igbo	18.0	16.7	65.3	100

ethnic populations is shown in Table 4. The anthropometric variables classify Yoruba subject as a member of Yoruba ethnic group in 78.2%, Yoruba as member of Hausa ethnic group in 9.5%, and Yoruba as member of Igbo ethnic group in 12.3%. It classifies Hausas subject as member of Hausa ethnic group in 82.4%, Hausa as member of Yoruba ethnic group in 5.9%, and Hausa as a member of Igbo ethnic group in 11.8%. It classifies Igbo subjects as member of Igbo ethnic group in 91.4%, as member of Yoruba ethnic group in 4.3%, and as a member of Hausa ethnic group in 4.3%. The dermatoglyphics classifies Yoruba subject as Yoruba in 66.8%, as member of Hausa ethnic group 18.8%, and as member of Igbo ethnic group in 14.4%. It classifies Hausa subject as member of Hausa ethnic group in 57.4%, as member of Yoruba ethnic group in 23.7%, and as member of Igbo ethnic group in 18.9%. It classifies Igbo subjects as member of Igbo ethnic group in 65.3%, as member of Yoruba in 18.0%, and as member of Igbo in 16.7%.

Discussion

The population that shares genetic background and environmental factors will have the mean height that is a characteristic of the group. In this study, weight and stature differences of the three ethnic populations with each ethnic group having different shared genetic inheritance are the determinant factors of ethnic population classification. Human quantitative traits of weight and stature are heritable (Maes *et al*., 1997; Turula *et al*., 1990; Perola *et al*., 2007; McEvoy and Visscher, 2009; Tishkoff *et al*., 2009; Wood, *et al*., 2014, Marouli *et al*., 2017). The proportion of the total variation in height due to genetic factors is controlled by multiple genes and environmental factors (Silventoinen *et al*., 2003). The heritability of the difference in stature had been shown not to be part of the growth hormone/insulin-like growth factor 1 pathway (Tishkoff *et al*., 2009). The BMI, COI, and PI for the three ethnic populations are factors of height and weight and contributed to the determinant of the classification. Parental HC is predictive of offspring HC (Taiwo and Adeleye, 2013). Variation had also been shown to exist in cephalometry among major geographic groupings of *Homo sapiens* (Relethford, 1994). This study's anthropometric variables suggest significant differentiation of the three ethnic groups as shown by the multiple discriminant analysis. The significant classification differences exhibited in anthropometry could only be explained by the effect of genetic, dietary, and environmental factors (Roberts and Williamson, 2002). Most of these population groups had come to southwest on business trips and those that are residing in the southwest still adhere to the dietary habits known for that ethnic population. Significant effect of genetic, cultural, and environmental factors on somatometric and craniofacial variability had also been reported for adult of other ethnic populations (Varrela 1990; Buretic-Tomljanovica *et al*., 2007; Sandip *et al*., 2014; Akram *et al*., 2014; Brooke and Larsen, 2014). Numan *et al*. used anthropometric values of HAL in the three major ethnic groups in Nigeria for stature estimation; they showed that variations were present not only between races but also among ethnic groups.

Anthropometric dimensions obtained from subjects of different birth places and regions also showed significant differences (Golalipour 2006; Du *et al*., 2008; Reddy *et al*. 2001). Farkas *et al*. have shown that the great similarities between the North American Whites and the European Caucasians, together with the stable characteristics maintained by Asians and Africans throughout their ethnic populations, can be explained only by considerable influence of inherited genetic factors. This study has shown that anthropometric variates can provide a level of insight into ethnic classification and identification and it can also be a useful tool in portraying ethnohistorical relationships.

Differences in the frequencies of various fingerprint patterns of distinct ethnic groups are well established (Cummins and Midlo, 1961; Maricq, 1972) and dermatoglyphic variables had been used for ethnic groups' geographic patterning (Zhang, 2010). The dermatoglyphics in this study classified subjects into the ethnic groups. Dermatoglyphic variables' differentiation of the three ethnic populations was not as discrete as that of anthropometric variables. It had been reported that dermatoglyphic variables undergo slow rates of evolutionary change and may not depict differences within ethnic level where local level variations were not submerged or where there was no major geographic and ethnic difference (Sachs and Bat-Miriam, 1957; Rothhammer *et al*., 1977; Rudan, 1978; Jantz *et al*., 1982; Reddy and Reddy 1992; Zhang *et al*., 2010). There is low genetic distance and identity among the three ethnic population groups which could be explained by the three groups' inhabiting a region with a history of long migrations and settlements with such a mixture of social and cultural relationships. It is difficult to separate these ethnic population groups within these settlements into neat sociocultural groups. Consistency of genetic and linguistic evolution had been known to be broken by factors such as less isolation, language replacement, or intermarriage. (Sun *et al*., 2013). The anthropometric parameters showed better defined discriminatory power than the dermatoglyphic parameters [Figures 3, 4 and Table 4].

Most ethnic population groups were usually defined based on linguistic and physical characters and geographic birth location of sampled individuals, but Cavalli-Sforza *et al*. had reported that phenotypic characters can constitute a basis for learning about ethnic population evolutionary relationships. This study showed that Nigerian ethnic population groups have anthropometric and dermatoglyphic parameters that are similar due to some shared genetic factors; however, there are still significant quantifiable anthropological parameters that could differentiate them as reflected in the ethnic classification of membership. The anthropometric parameters [Table 3] showed distribution of quantitative values around each ethnic population centroid; it showed higher discrete clustering around the ethnic centroid compared to the distribution of dermatoglyphic quantitative values around each ethnic population centroid. The combined plotting of the three ethnic populations' [Figures 3 and 4] anthropometric and dermatoglyphic parameters showed the extent of ethnic populations' gene flow and admixture among the ethnic populations. The predictive accuracy [Table 4] of anthropometric ethnic classifying equation from multiple discriminant analysis suggests that gene flow from Yoruba to the other two ethnic populations exceeded that of Hausa and Igbo, while Igbo is still the most endogamous of the three ethnic population groups. The less classifying power of dermatoglyphic parameters was consistent with the finding of other workers (Sachs and Bat-Miriam, 1957; Rothhammer *et al.*, 1977; Hawkinson, 1979; Reddy and Reddy, 1992).

Conclusion

This work provides insights into the structure of the ethnic populations, and demonstrate the relationship of the gene flow among Nigeria major ethnic groups through their phenotypic characteristics.

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Conflicts of interest

There are no conflicts of interest.

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Appendix I

Calculation of cephalometric and somatometric indices (Singh and Bhasin, 2004)

$$\text{Cephalic index (length breadth index of head)} = \frac{\text{Maximum head breadth}}{\text{Maximum head length}} \times 100$$

$$\text{Height breadth index (vertical index)} = \frac{\text{Head height}}{\text{Maximum head length}} \times 100$$

$$\text{Height length index} = \frac{\text{Head height}}{\text{Maximum head length}} \times 100$$

Schmidt's Head Modulus Index = Max. Head Length + Max. Head Breadth + Head Height

Index of size of the Head = Max. Head Length × Max. Head Breadth × Max. Head Height

$$\text{Morphological facial index} = \frac{\text{Facial height}}{\text{Bizygomatic breadth}} \times 100$$

$$\text{Morphological upper facial index} = \frac{\text{Upper facial height}}{\text{Bizygomatic breadth}} \times 100$$

$$\text{Sagittal naso - facial index} = \frac{\text{Nasal height}}{\text{Morphological facial height}} \times 100$$

$$\text{Cormic index} = \frac{\text{Sitting height}}{\text{Stature}} \times 100$$

$$\text{Ponderal index)} = \frac{\text{Height (cm}^3\text{)}}{\text{Weight (g)}} \times 100$$