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Variations in Facial Anthropometric Measurements among Major Ethnic Groups in Nigeria: A 3-Dimentional Stereophotogrammetry Analysis

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Abstract

Objectives: The aim of the study is to highlight variations in facial anthropometric measurements among the major ethnic groups in Nigeria using 3D photogrammetry. **Materials and Methods:** This study was conducted in Lagos, Nigeria. Acquisition of 3D facial photographs was done using a Vectra H1 portable 3D photogrammetry imaging system. Descriptive analysis of collected data was done and a test of associations performed using independent samples *t*-test. The level of significance was set at $<.05$. **Results:** The total number of participants in this study was 503. The study population was made up of 302 (60%) males and 201 (40%) females. Mean upper facial height among Yoruba, Igbo, Hausa, and other ethnic groups were 68.93 ± 5.85, 70.18 ± 5.99, 63.79 ± 4.80, and 69.29 ± 5.95 mm respectively, while mean interpupillary distances were 66.99 ± 3.70, 67.34 ± 3.56, 66.73 ± 3.80, and 67.09 ± 3.72 mm respectively. A Tukey posthoc test revealed significant pairwise differences for upper facial height between the Yoruba and Hausa population with a mean difference of 5.15 mm ($P<.001$, 95% CI 2.94-7.35) ($P<.001$, 95% CI 2.94-7.35), and Hausa and Igbo population with a mean difference of 6.39 mm ($P<.001$, 95% CI 3.75-9.03). Multivariate regression analysis confirmed the presence of significant inter-ethnic differences between Hausa ethnic group and the Yoruba ethnic group for midfacial height ($P<.001$), upper lip height ($P=.004$), lower lip height ($P=.003$), total face height ($P=.010$), and orbital fissure width ($P<.001$). **Conclusion:** The result of this study shows that distinct difference does exist in the facial anthropological measurements between the ethnicities included in this study especially in vertical facial measurements.

Keywords

facial anthropometry, 3D photogrammetry, Vectra 3D

Introduction

The face is the primary medium of human identification and the center of human inter-personal interactions. Of all externally visible human characteristics, facial appearance is the most morphologically variable, most distinctive, and recognizable.[1] Therefore, human facial morphology remains a subject of interdisciplinary interest. This interest has resulted in technological leaps which now makes available for the purpose of surgical reconstruction 3D surgical planning, 3D printing of patient specific prosthesis and implants, and even patient educational software. Head and Neck oncologic resection, facial trauma, orthognathic surgery, and management of congenital craniofacial anomalies are all areas that present a challenge to the surgeon with respect to achieving an esthetic and natural outcome especially in the presence of gross anatomic distortions.

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Facial genetics studies have revealed strong morphological divergence on multiple facial features (including the nose, brow ridges, cheeks, and jaw) between Europeans and Han Chinese, suggesting that facial shapes have been strongly shaped by natural selection after sub-populations split from the common ancestor.[2] Such findings have motivated attempts to characterize facial traits among diverse populations like European derived, Asian, and Tanzanians.[3-7] Facial anthropometry as a means of evaluating biological variability within and among different human populations has evolved to the use of non-invasive techniques such as 3D stereophotogrammetry which provides unlimited access to measurements of diverse landmark points of interest without having to make subjects undergo laborious sampling procedures.[8] Previous published studies in the Nigerian population used conventional anthropometry.[9-11] Reports from these studies suggests that hypereuryprosopic is the dominant face type among individuals originating from ethnic groups in the south of Nigeria while this face type is rare among those originating from Northern Nigeria.[12-14] Thus, suggesting ethnicity is a major attributive factor in determining head and face dimensions.[9-11]

Therefore, there is a need to quantify facial traits among Nigerian people using current novel 3D morphometric procedures to concisely quantify these facial traits and better understand the patterns of intergroup variation in facial traits. This aim of this study is to highlight variations in facial anthropometric measurements among the major ethnic groups in Nigeria using 3D photogrammetry. This data is important as Nigeria is the most populous African Nation, with its people spread across West Africa and the world. Furthermore, evidence from genetic analysis has shown the region of southern Nigeria/Cameroon to be the origin of most ethnic nationalities south of the Sahara.[15]

Materials and Methods

This study was conducted in the Craniofacial Research Laboratory of a University Teaching Hospital in Lagos, Nigeria. Lagos, being a commercial hub, is a convergence point for all ethnic groups in Nigeria and provides adequate sampling diversity. Some of these ethnic groups are found widespread in other West African countries (Figure 1).[16] Participant recruitment was between February 2016 and May 2019. Participants recruited were at least 16 years of age, had no history of congenital or acquired facial deformity, no history of facial trauma, or surgical interventions involving the face. The study was approved by the Health Research and Ethics Committee of the institution. All sampling process was conducted under standard laboratory conditions and written informed consent was obtained from each volunteer before recruitment into the study.

Acquisition of 3D facial photographs was done using a Vectra H1 portable 3D photogrammetry imaging system (Canfield Imaging, Parsippany, NJ, USA). Before 3D image capture, each participant was asked to remove any jewelry and pull back any hair that was obstructing the forehead and ears to expose the full facial surface. Image acquisition was done with subjects standing, and directed to keep a neutral facial expression, and gaze fixed at a colored landmark placed permanently on a fixed wall in front of the subject. All images were acquired in the same environment under the same conditions by the same member of the research team. The process of image acquisition using the Vectra H1 SLR camera is well described by Camison et al[17] Three images were acquired for each participant following the manufacturer's guidelines for image acquisition; a right-lateral, frontal, and left lateral image. The images were recorded directly on a PC with the installed Vectra 3D image acquisition software. The images are then stitched automatically by the imaging software to produce a single 3D image. In cases where automatic stitch failed, landmarks were placed by the researcher following the software prompt, and automatic image stitch attempted again. Images are recaptured if this fails. Unstitched and stitched images were stored in individual subject folders labeled with subject recruitment numbers for anonymity.

Facial image surface analysis and measurements commenced after the termination of participant recruitment. For analysis, the stitched image was imported into the surface analysis tool of the imaging software. For analysis, facial evaluation mode was selected, and landmarks were placed. A total of 19 landmarks were placed (Table 1). Ocular, horizontal, and vertical facial measurements were done using these landmarks (Figure 2).

Vertical facial measurements were upper facial height (tr-n), middle facial height (n-sn), lower facial height (sn-gn), also percentages of these facial heights to Total facial height (tr-gn) were also measured. Also, upper lip height (sn-ls), lower lip height (li-gn) were measured. Ocular measurements included interpupillary distance (P_r-P_l), palpebral fissure width (ex-en), and intercanthal distance (en-en). Horizontal facial measurements were upper facial width (zy-zy), nasal base width (al-al), oral commissure width (ch-ch), and the mandibular width/lower facial width (go-go).

Additional data collected included age, gender, and ethnicity. Data collected were entered into Microsoft Excel® sheet 2016 (Microsoft, Raymond, WA) for sorting and subsequently transferred to IBM SPSS Statistics for Windows (Version 21.0. Armonk, NY: IBM Corp) for analysis. Descriptive analysis of collected data was done to derive means, median, and percentages, and test of associations performed using independent samples *t*-test. Also, multivariate regression analysis modeling was performed using ethnicity, sex, weight, height, and age as predictor variables, to identify significant interethnic differences in the facial measures after correcting for the covariates. The level of significance was set at $<.05$.

Result

The total number of participants in this study was 503. The study population was made up of 302 (60%) males and 201

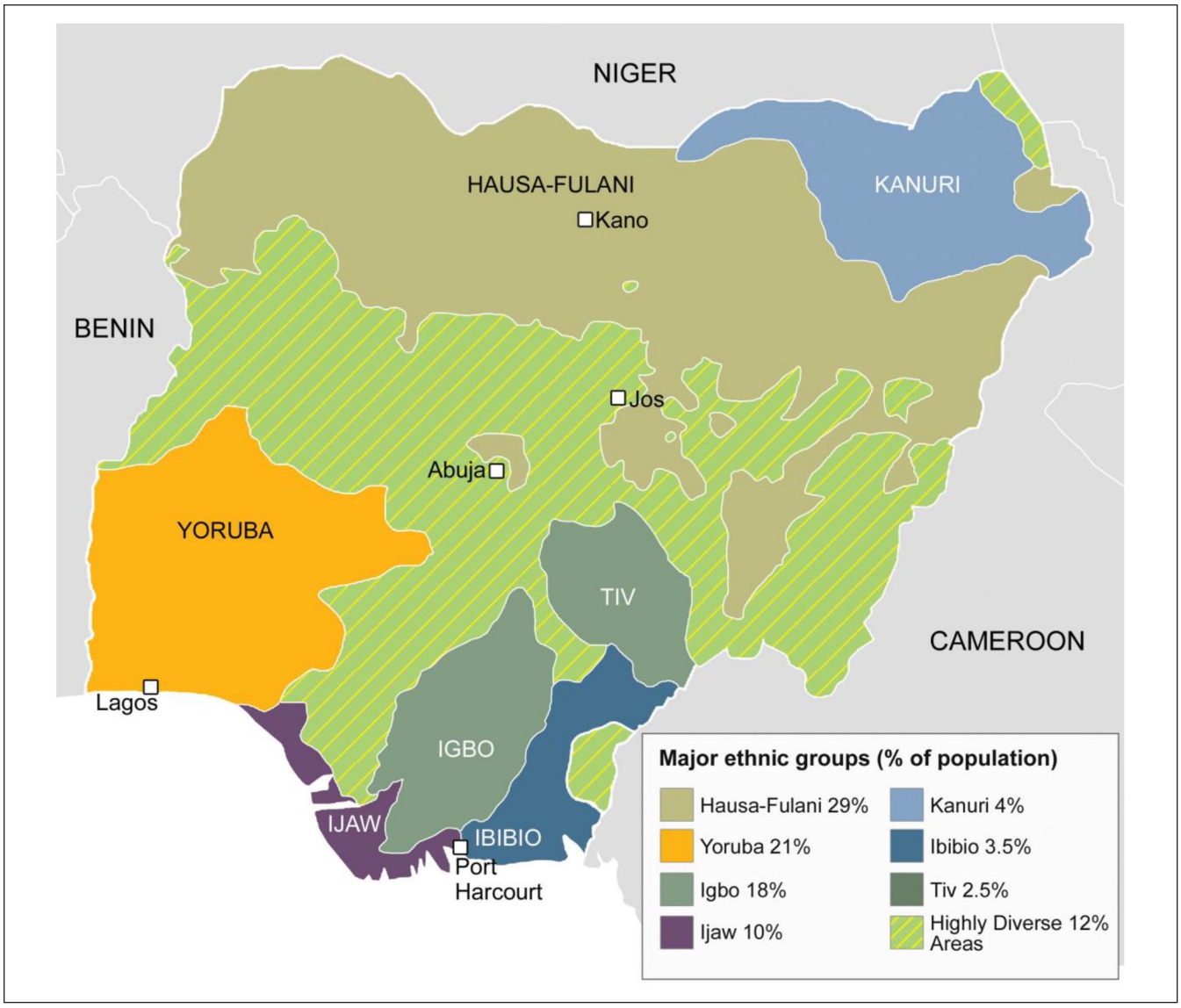
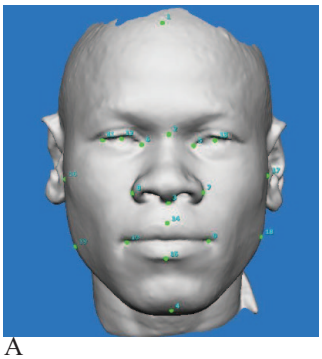


Figure 1. Map of Nigeria showing geographic region of ethnic groups.
Source. Ulrich Lamm, Mapping Nigeria's diversity.[16]

Table 1. Anthropometric Landmarks Used in the Analysis (Adapted from Karatas and Toy[8]).

Landmark	Definition
Trichion (tr)	The point on the hairline in the midline of the forehead
Nasion (n)	The point in the midline of both the nasal root and the nasofrontal suture
Subnasale (sn)	The midpoint of the columella base at the apex of the angle where the lower border of the nasal septum and the surface of the upper lip meet
Gnathion (Gn)	The lowest median landmark on the lower border of the mandible
Labiale superius (ls)	The midpoint of the upper vermilion line
Labiale inferius (li)	The midpoint of the lower vermilion line
Alare (al)	The most lateral point on each alar contour
Chelion (ch)	The point located at each labial commissure
Zygion (zy)	The most lateral point of each zygomatic arch
Gonion (go)	The most lateral point on the mandibular angle close to the bony gonion
Exocanthion (ex)	The point at the outer commissure of the eye fissure
Endocanthion (en)	The point at the inner commissure of the eye fissure
Pupil (p)	Center of the pupil

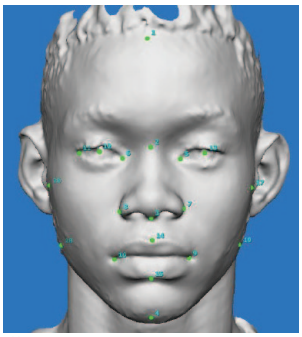


A

Variable – Mean (SD)	
tr-n - 71.30 (6.82)	al-al - 43.50 (5.18)
n-sn - 51.4 (4.35)	ch-ch - 53.66 (5.07)
sn-gn - 71.33 (6.81)	sn-ls - 16.73 (2.86)
TFH - 194.04 (12.44)	li-gn - 37.85 (7.39)
en -en - 35.58 (3.03)	zy-zy - 141.36 (8.20)
p-p - 68.36 (3.43)	go-go - 126.40 (9.78)
ex-en - 30.72 (11.72)	

B

Variable – Mean (SD)	
tr-n - 70.41 (5.71)	al-al - 43.05 (3.18)
n-sn - 50.01 (3.37)	ch-ch - 53.34 (4.90)
sn-gn - 69.41 (6.23)	sn-ls - 15.14 (2.74)
TFH - 189.83 (9.72)	li-gn - 34.35 (4.85)
en -en - 35.68 (3.16)	zy-zy - 141.81 (6.32)
p-p - 68.19 (3.52)	go-go - 127.65 (7.56)
ex-en - 28.26 (2.40)	

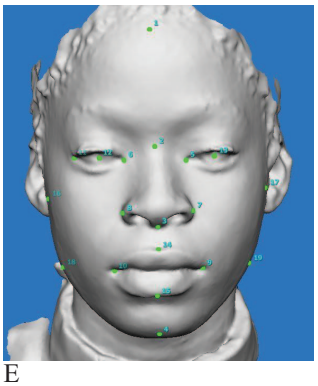


C

Variable – Mean (SD)	
tr-n - 63.7 (4.85)	al-al - 41.73 (2.62)
n-sn - 48.14 (3.17)	ch-ch - 49.54 (4.25)
sn-gn - 68.32 (5.65)	sn-ls - 13.87 (2.63)
TFH - 180.16 (8.8)	li-gn - 34.30 (6.20)
en -en - 35.75 (3.54)	zy-zy - 139.06 (5.88)
p-p - 66.86 (3.73)	go-go - 121.60 (7.50)
ex-en - 26.40 (1.39)	

D

Variable – Mean (SD)	
tr-n - 71.30 (6.82)	al-al - 40.70 (3.36)
n-sn - 50.87 (3.37)	ch-ch - 52.49 (3.29)
sn-gn - 67.42 (6.18)	sn-ls - 14.39 (3.12)
TFH - 185.46 (14.85)	li-gn - 32.66 (3.72)
en -en - 35.27 (2.43)	zy-zy - 138.35 (7.08)
p-p - 66.24 (3.41)	go-go - 123.37 (7.89)
ex-en - 29.59 (2.64)	



E

Variable – Mean (SD)	
tr-n - 66.93 (5.46)	al-al - 39.89 (3.88)
n-sn - 48.93 (3.28)	ch-ch - 51.04 (4.52)
sn-gn - 65.04 (5.17)	sn-ls - 13.81 (2.45)
TFH - 180.9 (9.55)	li-gn - 31.60 (4.55)
en -en - 34.53 (3.3)	zy-zy - 135.98 (6.54)
p-p - 65.35 (3.29)	go-go - 119.70 (11.54)
ex-en - 28.17 (2.42)	

F

Variable – Mean (SD)	
tr-n - 66.1 (3.81)	al-al - 39.80 (6.31)
n-sn - 48.1 (1.70)	ch-ch - 56.41 (6.57)
sn-gn - 71.07 (0.05)	sn-ls - 14.02 (1.06)
TFH - 185.26 (5.47)	li-gn - 38.71 (0.45)
en -en - 30.78 (5.36)	zy-zy - 133.77 (9.05)
p-p - 63.41 (5.68)	go-go - 121.64 (12.34)
ex-en - 28.49 (3.85)	

Figure 2. A 3D photo with landmarks placed in frontal view for A to C Igbo, Yoruba, and Hausa males and D to F Igbo, Yoruba, and Hausa females.

(40%) females, with an age range of 16 to 63 years and mean 29.06 ± 9.88 years (Figure 3). The majority were of the Yoruba ethnic group (64.6%, n = 325). Further details on the ethnic distribution of the participants are shown in Figure 4. The highest mean upper facial height measurements recorded were in Igbo males (71.30 ± 6.82 mm) and the lowest in Hausa males (63.7 ± 4.85 mm). The highest mean midfacial height measurements were in Igbo males (51.40 ± 4.35 mm) and the lowest in Hausa females (48.10 ± 1.70 mm). The highest mean lower facial height measurements were in Igbo

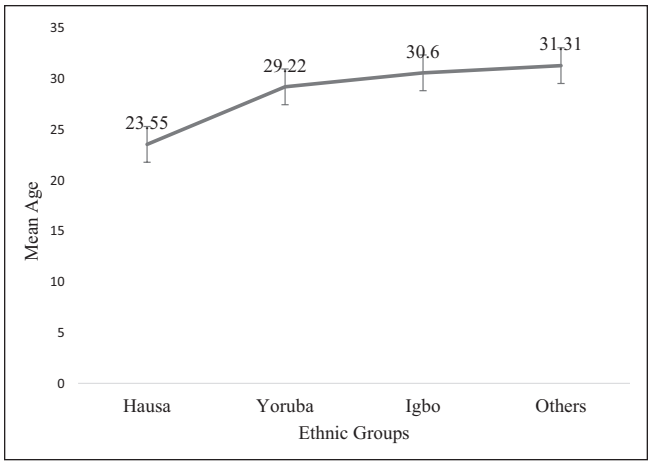


Figure 3. Mean age versus ethnic group.

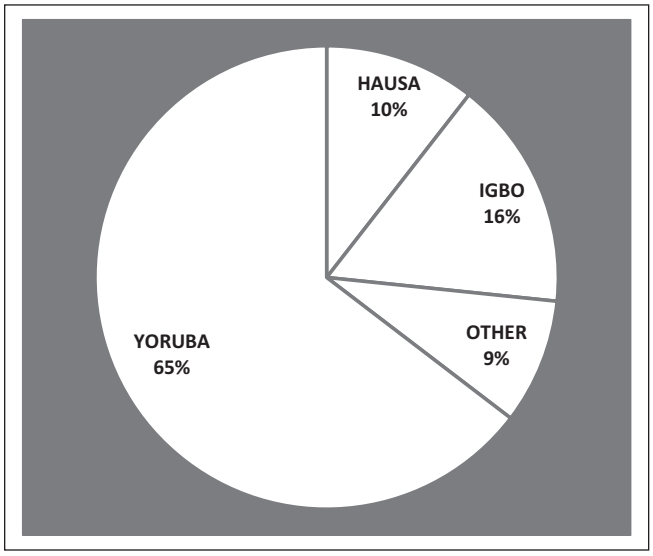


Figure 4. Distribution of ethnic groups among study participants.

males (71.33 ± 6.81 mm) and the lowest was in Yoruba females (65.04 ± 5.17 mm); and highest mean total facial height measurement was recorded in Igbo males (194.04 ± 12.44 mm) and the lowest in Hausa males (180.16 ± 8.8 mm). The highest mean interpupillary distance recorded was in Igbo males (68.36 ± 3.43 mm) and the lowest was in Hausa females (63.41 ± 5.68 mm); the highest mean inner canthal distance was in Hausa males (35.75 ± 3.54 mm) and the lowest was in Hausa females (30.75 ± 5.36 mm). The highest mean palpebral fissure width was recorded in Igbo males (30.72 ± 11.72 mm) and the lowest in Hausa males (26.40 ± 1.39 mm); the highest mean nasal base width was recorded in males of the minor ethnic groups (43.61 ± 2.95 mm) while the lowest was recorded in Hausa females (39.80 ± 6.31 mm). The highest mean oral commissure width was recorded in Hausa females (56.41 ± 6.57 mm) and the lowest in Hausa males (49.54 ± 4.25 mm); the highest mean upper lip height was in Igbo males (16.73 ± 2.86 mm) and the lowest was in Yoruba females (13.81 ± 2.45 mm). The highest mean lower lip height was recorded in Hausa females (38.71 ± 0.45 mm) and the lowest in Yoruba females (31.60 ± 4.55 mm). For mean upper facial width, the highest was in males of the minor ethnic groups (142.17 ± 4.42 mm) and the lowest was in Hausa females (133.77 ± 9.05 mm) while for mean lower facial/mandibular width, highest was in Yoruba males (127.65 ± 7.56 mm) and the lowest was in Yoruba females (119.70 ± 11.54 mm). Further details of descriptive statistics and gender differences in the facial anthropometric measurements among the ethnic groups are shown in Figure 2.

Table 2 shows the Tukey posthoc tests for comparison of the various facial measurements among the various ethnic groups. There was statistically significant difference between group means as determined by 1-way ANOVA for upper facial height ($F(3)=14.78$, $P<.001$), midfacial height ($F(3)=8.41$, $P<.001$), lower facial height ($F(3)=2.95$, $P=.032$), total face height ($F(3)=7.89$, $P<.001$), palpebral fissure width ($F(3)=9.44$, $P<.001$), oral commissure width ($F(3)=5.70$, $P=.001$), and upper lip height ($F(3)=4.62$, $P=.003$). The Tukey posthoc test revealed significant pairwise differences for upper facial height between the Hausa and Yoruba population with a mean difference of 5.15 mm ($P<.001$, 95% CI 2.94-7.35) and Hausa and Igbo population with a mean difference of 6.39 mm ($P<.001$, 95% CI 3.75-9.03). Similarly, significant pairwise differences were detected between the Hausa population and Yoruba and Igbo population for midfacial height (mean difference of 1.42 and 3.01 mm respectively), total facial height (mean difference of 5.69 and 9.56 mm respectively), oral commissure width (mean difference of 2.57 and 3.29 mm respectively), and palpebral fissure width (mean difference of 1.74 and 3.70 mm respectively). Further statistically significant intra ethnic group differences are highlighted in Figure 2.

Furthermore, with the Hausa ethnic group set as the reference group, results of multivariate regression analysis modeling with adjustment made for other variables such as age, height, weight, and gender, confirmed the presence of significant inter-ethnic differences between the reference group and the Yoruba ethnic group for midfacial height ($P<.001$), upper lip height ($P=.004$), lower lip height ($P=.003$), total face height ($P=.010$), and orbital fissure width ($P<.001$). While a significant difference was detected between the reference group and the Igbo ethnic group for Upper face percentage ($P=.025$).

Discussion

Although skin color may seem to differ less, due to the multiethnic nature of the African race, differences in facial morphology becomes pronounced as one moves across the

Table 2. Tukey Posthoc Tests.

Dependent variable	Ethnicity	*P*-value	95% CI
	Hausa		
tr-n	Yoruba	<.001	−7.354 to −2.936*
	Igbo	<.001	−9.032 to −3.751*
	Others	<.001	−8.544 to −2.462*
n-sn	Yoruba	.032	−2.745 to −0.087*
	Igbo	<.001	−4.594 to −1.424*
	Others	.122	−3.398 to 0.262
sn-gn	Yoruba	.762	−1.432 to 3.162
	Igbo	.774	−3.773 to 1.729
	Others	.447	−1.346 to 5.006
TFH	Yoruba	.003	−9.938 to −1.433*
	Igbo	<.001	−14.628 to −4.484*
	Others	.098	−11.096 to 0.614
tr-n%	Yoruba	<.001	−2.473 to −0.843*
	Igbo	.002	−2.316 to −0.368*
	Others	<.001	−3.075 to −0.831*
n-sn%	Yoruba	1.000	−0.693 to 0.741
	Igbo	.976	−0.992 to 0.717
	Others	.985	−0.852 to 1.121
sn-gn%	Yoruba	<.001	0.720 to 2.352*
	Igbo	.005	0.299 to 2.245*
	Others	<.001	0.921 to 3.168*
en-en	Yoruba	.873	−0.879 to 1.613
	Igbo	.996	−1.362 to 1.611
	Others	.673	−0.966 to 2.466
p-p	Yoruba	.963	−1.673 to 1.147
	Igbo	.782	−2.296 to 1.067
	Others	.964	−2.302 to 1.581
ex-en	Yoruba	.019	−3.285 to −0.203*
	Igbo	<.001	−5.538 to −1.860*
	Others	.109	−3.983 to 0.261
ch-ch	Yoruba	.001	−4.364 to −0.769*
	Igbo	<.001	−5.438 to −1.149*
	Others	.068	−4.837 to 0.113
sn-ls	Yoruba	.324	−1.761 to 0.361
	Igbo	.003	−2.988 to 0.457*
	Others	.337	−2.412 to 0.510
li-gn	Yoruba	.362	−0.744 to 3.310
	Igbo	.781	−3.303 to 1.532
	Others	.629	−1.494 to 4.087
al-al	Yoruba	1.000	−1.518 to 1.412
	Igbo	.888	−2.237 to 1.257
	Others	.984	−2.298 to 1.736
zy-zy	Yoruba	.971	−3.149 to 2.223
	Igbo	.833	−4.253 to 2.154
	Others	.908	−4.659 to 2.736
go-go	Yoruba	.240	−6.312 to 0.997
	Igbo	.199	−7.697 to 1.018
	Others	.689	−7.179 to 2.881

*$P < .05$.

continent from west to east, and from north to south. These differences are also present even in individuals of same nation, due to the multiethnic nature of most African countries, especially south of the Sahara. Necessity for facial reconstruction, involving the underlying bony structures or overlying soft tissues only or both, often follows the management of congenital anomalies, facial trauma, head and neck tumor management, and esthetic procedures. Therefore, understanding the subtle differences in facial morphology among individuals of different ethnicities within a race, and tailoring esthetic and reconstructive surgical planning along the lines of this differences will have profound effect on surgical outcome and patient satisfaction. In addition, the skull and the face are integral research subjects in Biological Anthropology being the best indicator of ancestry and sex.[18]

Using a comparative approach, this study evaluates patterns of facial variation and sexual dimorphism among Nigerian ethnic groups. The Nigerian population and by extension people of West African origin exhibit significantly variable face height and width dimensions.[10-12] Evaluation of the total face dimensions shows that Hausa peoples, who are said to be the largest ethnic group in West Africa and spread across many west African countries,[19] tend to have a smaller face compared to people of other Nigerian ethnicities while the Igbo people of majorly South-Eastern Nigeria, have the highest face dimension stipulating an increasing face dimension as one moves from north to south of Nigeria.

Results from this study show that individuals from the Hausa ethnic group, had lower mean values for vertical facial measurements, similar to findings of Akinlolu[20] who reported in their study that the Hausa ethnic group had statistically significantly lower mean values in 60% of facial height measurements (Forehead Height, Physiognomic Face Height, and Lower Face Height) compared to Yoruba and Igbo males. However, the difference in vertical facial dimensions among individuals of Igbo and Hausa ethnicities was not statistically significant. For facial width measurements, our study found Hausa males exhibited a narrower face compared to the Igbo and Yoruba population. This trend is also observable among the females such that Hausa females exhibited a narrower face compared to Yoruba females and Igbo females who had the widest faces. The proximity of the Yoruba and Igbo ethnic groups may be a factor responsible for this observation as both groups occupy the southern territory of Nigeria and flow into neighboring countries such as Cameroun, Benin republic, Togo, and Ghana. These proximity may have resulted in considerable exchange of genetic materials, resulting from a higher level of inter-cultural relationships compared with their relationship with Hausa people of the North.[21] Moreover, genetic analysis including whole genome sequencing studies, suggests that the ethnic groups occupying Southern Nigeria, West, Central, and South Africa originate from same ancestral genetic cluster and have same ethno-linguistic affiliations (Niger-Congo).[15,22]This is in contrast to the Hausa's who genetic studies suggests are of the Afro-Asiatic cluster.

The results from this study depict sexual dimorphism among each of the represented groups of Nigeria as all the facial anthropometric measurements show discrete statistically

significant differences between males and females across the ethnic groups. Nigerian males exhibit longer and wider face dimensions observable from the mean total face heights and width among Igbo and Yoruba samples. A reverse trend was observed in TFH among Hausa people with females having the higher values. However, Hausa males exhibit a wider face than the females; this observation requires validation with a wider sampling of the Hausa population as they were the least represented group in this study, which presents a limitation to the interpretation of our result.

The human face is a an highly complex geometric surface,[23] this is more so when the ability of humans to form facial expressions, which is important in communication, is considered. Therefore, restricting facial phenotypes to linear inter-landmark measurements instead of a cluster of curvature based measurements will be inadequate in presenting a true representation of facial phenotypes.[4,24] This is recognized as a limitation in this present study. Despite this, our analysis presents a more robust understanding of the basic traditional distance-based facial traits which can easily characterize facial morphology among individuals originating from the various ethnic groups of the most populace African nation when compared with other populations. Previously published studies examined and compared vertical facial measurements among Nigerians, and with other West African countries using conventional cephalometric anthropometry and lateral cephalometric radiographs.[10,11] Results presented in this study confirms previously published data, and in addition provides facial width dimensions and utilized a noninvasive 3D stereophotogrammetric approach which can reveal facial soft tissue data concealable by conventional anthropometry.

Although the population from which this study sample was taken is within the geographic boundaries of Nigeria, the ethnic nationalities examined are spread across most of West Africa.[25] In addition, by virtue of the transatlantic slave trade, a large proportion of individuals in the Americas of African descent originated from this region,[26,27] hence, the data presented in this study provides a baseline for future larger population studies.

This study has provided data for facial measurements of a West African subpopulation, using 3D photogrammetry. In addition, the differences between the major ethnic nationalities were highlighted. These dimensions may aid forensic profiling, facial reconstruction, and manufacturing of products such as implants and prothesis for individuals of Nigerian and West African origin.

Declaration of Conflicting Interests

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