Ear biometrics and naso-aural proportions of hausas and yorubas using an image-processing algorithm.

AA Akinlolu[1], R Jaji-Sulaimon[1] and AO Raji[2]
Department of Anatomy[1], University of Ilorin, Ilorin, and
Department of Agricultural Engineering[2], University of Ibadan, Ibadan, Nigeria.

Abstract

Background: Anthropology is the study of human biology and culture. This study aims to develop an image-processing algorithm for computing anthropometric measurements in forensic investigations in order to produce ear biometric databases of Hausas and Yorubas of Nigeria.

Materials and methods: Hausas of Kebbi State (150 males and 150 females, aged 18 to 36 years) and Yorubas of Osun State (150 males and 150 females, aged 15 to 33 years) were selected as subjects after their informed consents were obtained and when established as Hausas or Yorubas by parents and grandparents. Height, Bodyweight and cephalometric parameters (evaluated on ear photographs) were measured on all subjects. The Akinlolu-Raji image-processing algorithm used in this study was developed using modified computer programming principle of row method. Ear Length, Length of Ear Insertion, Ear Breadth, Ear Index, Iannarelli System (1 - 12) of Ear Biometrics and Naso-aural proportion computed from readings of the Akinlolu-Raji image-processing algorithm were analyzed using z-test ($P \leq 0.05$) of 2010 Microsoft Excel statistical software.

Results: Statistical analyses showed non-significant higher values ($P>0.05$) in Hausa and Yoruba males compared to females in most ear parameters. Non-significant higher values ($P>0.05$) of ear parameters were observed in Yorubas compared to Hausas in both gender. Naso-aural proportions were non-significantly higher in Hausa males compared to females, lower in Yoruba males compared to females, higher in Hausa males compared to Yoruba males and lower in Hausa females compared to Yoruba females.

Conclusions: The developed Akinlolu-Raji image-processing algorithm can be employed for computing anthropometric, forensic, diagnostic or any other measurements on 2-D and 3-D images, and data computed from its readings can be converted to actual or life sizes. Males have higher ear sizes compared to females in Hausas and Yorubas. In addition, Yorubas of Osun State have higher ear sizes compared to Hausas of Kebbi State in both gender.

Keywords: *Ear, biometrics, naso-aural proportion, yoruba, hausa, image-processing algorithm, forensic investigations*

Correspondence: Dr. A.A. Akinlolu, Department of Anatomy, Faculty Basic Medical Sciences, University of Ilorin, Ilorin, Nigeria. E-mail: a3akin@gmail.com.

Résumé

Contexte : L'anthropologie est l'étude de la biologie et de la culture humaine. Cette étude vise à développer un algorithme de traitement d'image pour le calcul de mesures anthropométriques lors des enquêtes criminologiques afin de créer des bases de données biométriques auriculaires sur les Hausas et les Yorubas du Nigéria.

Matériels et méthodes : Les Hausas de l'État de Kebbi (150 hommes et 150 femmes âgés de 18 à 36 ans) et les Yorubas de l'État d'Osun (150 hommes et 150 femmes de 15 à 33 ans) ont été sélectionnés comme sujets après que leur consentement a été obtenu et quand établis en tant que Hausas ou Yorubas par les parents et les grands-parents. Les paramètres de taille, de poids corporel et céphalométriques (évalués sur des photographies de l'oreille) ont été mesurés sur tous les sujets. L'algorithme de traitement d'images Akinlolu-Raji utilisé dans cette étude a été développé en utilisant le principe de programmation informatique modifié de la méthode des lignes. Longueur de l'oreille, longueur de l'insertion de l'oreille, largeur de l'oreille, indice de l'oreille, système Iannarelli (1 - 12) de la biométrie de l'oreille et proportion auriculo-nasale calculée à partir de la lecture de l'algorithme de traitement d'images Akinlolu-Raji ont été analysés à l' aide du test z (P d" 0,05) du logiciel statistique Microsoft Excel 2010.

Résultats: Les analyses statistiques ont montré des valeurs supérieures non significatives ($P>$ 0,05) chez les hommes hausa et yoruba par rapport aux femmes pour la plupart des paramètres auriculaires. Des valeurs non significativement plus élevées ($P>$ 0,05) des paramètres de l'oreille ont été observées chez les Yorubas par rapport aux Hausas parmi les deux sexes. Les proportions auriculo-nasales étaient non significativement plus élevées chez les hommes que les femmes hausa, plus bas chez les hommes que les femmes Yoruba, élevé chez les hommes hausa par rapport aux hommes yoruba et moins chez les femmes hausa que les femmes yoruba.

Conclusions: L'algorithme de traitement d'images développé par Akinlolu-Raji peut être utilisé pour calculer des mesures anthropométriques, criminologiques, diagnostiques ou toute autre mesure sur des images 2D et 3D, et les données calculées à partir de ses lectures peuvent être converties en tailles actuelles ou réelles. Les oreilles des hommes sont plus grandes que celles des femmes chez les Hausas et les Yorubas. En outre, les Yorubas de l'État d'Osun ont une taille d'oreille supérieure à celle des Hausas de l'État de Kebbi entre les deux sexes.

Mots clés: *Oreille, Biométrie, proportion auriculo-nasale, Yoruba, Hausa, algorithme de traitement d'image, enquêtes criminologiques*
Yoruba, Hausa, Image-processing algorithm, Forensic investigations

Introduction

Anthropology is the study of human biology and culture while forensic anthropology deals with the establishment of human identity. [1] The ear is directly related to the face and is of relevance in biometric studies and craniofacial surgical reconstructions [2,3]. The ear is the organ of hearing, and is involved in the maintenance of equilibrium and balance [2,3]. It is divisible into three parts, the external, middle and internal ear [2,3]. The shape or appearance of the outer ear had long been noted as a useful physical feature for forensic identification by law enforcement officers [4-6]. The ear becomes a very useful biometric feature when the face may become not completely recognized due to illumination changes, facial expression changes, eye glasses and facial make-up [4-6]. The ear could easily be captured from a distance either in cooperative or non-cooperative subjects, hence ear biometrics is an interesting feature of surveillance investigations [4-6]. Furthermore, the use of earmarks or ear prints left in crime scenes in criminal trials is expanding [7], which further emphasizes the role of ear biometrics in forensic identifications of individuals.

Nigeria is comprised of over two hundred and fifty ethnic groups [8], with the Hausas, Igbos and Yorubas as the three major ethnic groups constituting more than 60 percent of its population [8]. Therefore, to provide further information on ear cephalometry and to pioneer the use of face recognition technology in Nigeria, this study aims to develop an image-processing algorithm which can be used to compute cephalometric measurements for face recognition of individuals of any ethnic group. In addition, this study aims to provide a preliminary forensic ear database of Hausas and Yorubas.

Materials and methods

Pilot-study

A pilot-study was conducted to determine the reliability of the developed Akinlolu-Raji image-processing algorithm using 40 Yoruba subjects (20 males and 20 females), aged 15 to 23 years, who were undergraduate students of Osun State School of Health Technology, Ilesa and Osun State University, Okuku Campus. Informed consents of subjects were obtained in accordance with ethical guidelines of the Helsinki Declaration of 1975, as revised in 2000. Facial parameters evaluated from readings of the algorithm on three-dimensional (3-D) facial photographs were converted to life sizes and the results were statistically compared using t-test of the Statistical Package for the Social Science software Statistics 23, with measurements of same facial parameters computed from readings of the Vernier Caliper (one-dimensional or 1-D anthropometry).

Pairwise comparative statistical analyses of computed mean values of cephalometric parameters (Mean ± SD) in millimeters between Vernier Caliper (1-D anthropometry) and the developed Akinlolu-Raji image-processing Algorithm (3-D anthropometry) measurements in male and female control subjects showed lower or higher, but no significant differences (P_B>0.05) in 100% of measured parameters: Total Face Height (trichion to gnathion), Forehead Height (trichion to nasion), Upper Face Height (trichion to subnasale), Morphological Face Height (nasion to gnathion), Nose Height (nasion to subnasale) and Lower Face Height (subnasale to gnathion). (Figure 1). The Bonferroni correction (P_B) method was employed to reduce the chances of obtaining false-positive results (type I errors) declaring wrong significant difference when no significant difference exists. [9,10].

Selection of subjects and determination of sample size

Letters of approval for conduct of the study were received from managements of Kebbi State University of Science and Technology, Aliero; Adamu Augie College of Education, Argungu; School of Health Technology, Jega and Kebbi State School of Nursing and Midwifery, Birnin Kebbi, from where Hausa subjects (150 males and 150 females, aged 18 to 36 years) were locally selected; and Osun State University, Okuku Campus from where Yoruba subjects (150 males and 150 females, aged 15 to 33 years) were locally selected for the study using the purposive technique or judgment sampling method, [11-15] only when established via distributed questionnaires as Hausas of Kebbi State or Yorubas of Osun State by parents and grandparents. Informed consents were obtained from selected subjects in accordance with ethical guidelines of the Helsinki Declaration of 1975, as revised in 2000.

Data collection and evaluated ear parameters

Data on height and bodyweight, parents and grandparents ethnic origin, local government area, state of origin and ear photographs were obtained from each subject. Photographs of subjects were

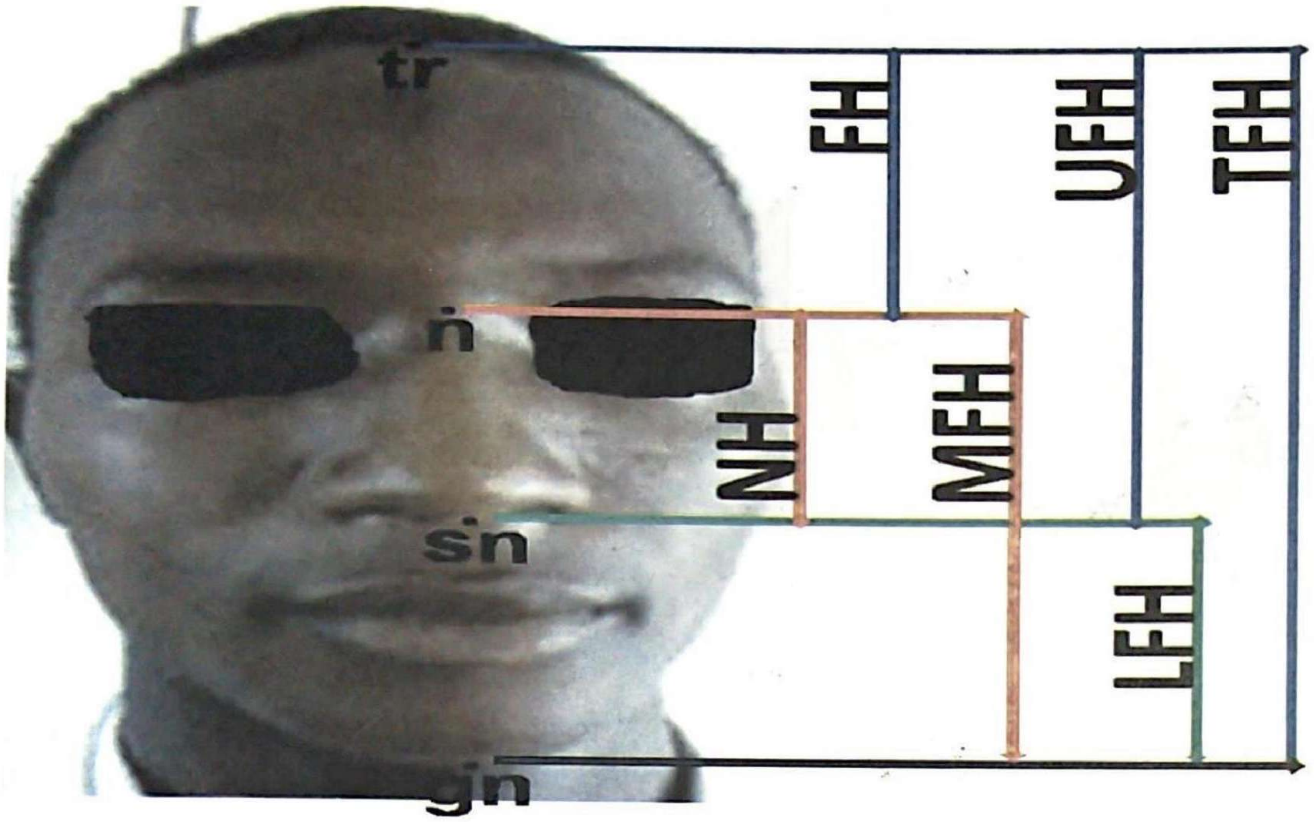

Fig. 1. Biometric Measurements of the Face.
tr = trichion, n = nasion, sn = subnasale and gn = gnathion. TFH = Total Face Height, FH = Forehead Height, UFH = Upper Face Height, NH = Nose Height, MFH = Morphological Face Height and LFH = Lower Face Height.

Fig 2. Cephalometric features of the Ear.
sa = superaurale, sba = subaurale, obs = otobasion superius and obi = otobasion inferius.

1. Helix — 1a. Crus Helicis — 2. Lobule
3. Scaphoid Fossa — 4. Antihelix — 4a and 4b. Crura Antihelicis
5. Triangular Fossa — 6. Antitragus — 7. Concha
8. Incisure Intertragica — 9. Tragus — 10. Opening of External acoustic meatus

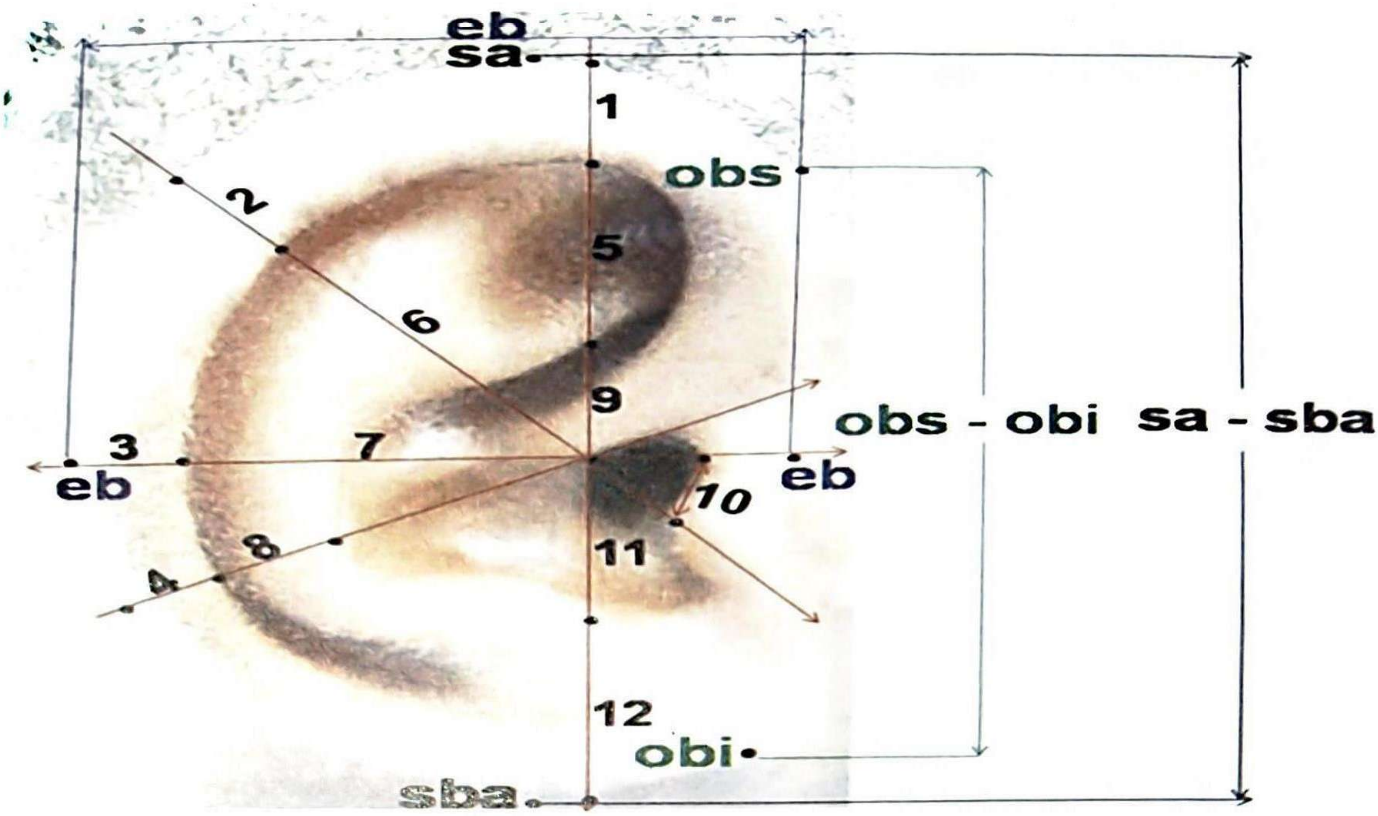

Fig. 3. Biometric Measurements of the Ear.
Height (Length) of the Ear. (sa - sba)
Length of Ear Insertion: (obs - obi)
Ear Breadth: (eb - eb)
Ear Index: Ear Breadth/Ear Length X 100.
Iannarelli 1 - 12 = Iannarelli System of Ear Biometrics, sa = superaurale, sba = subaurale, eb = ear breadth; obs = otobasion superius and obi = otobasion inferius.

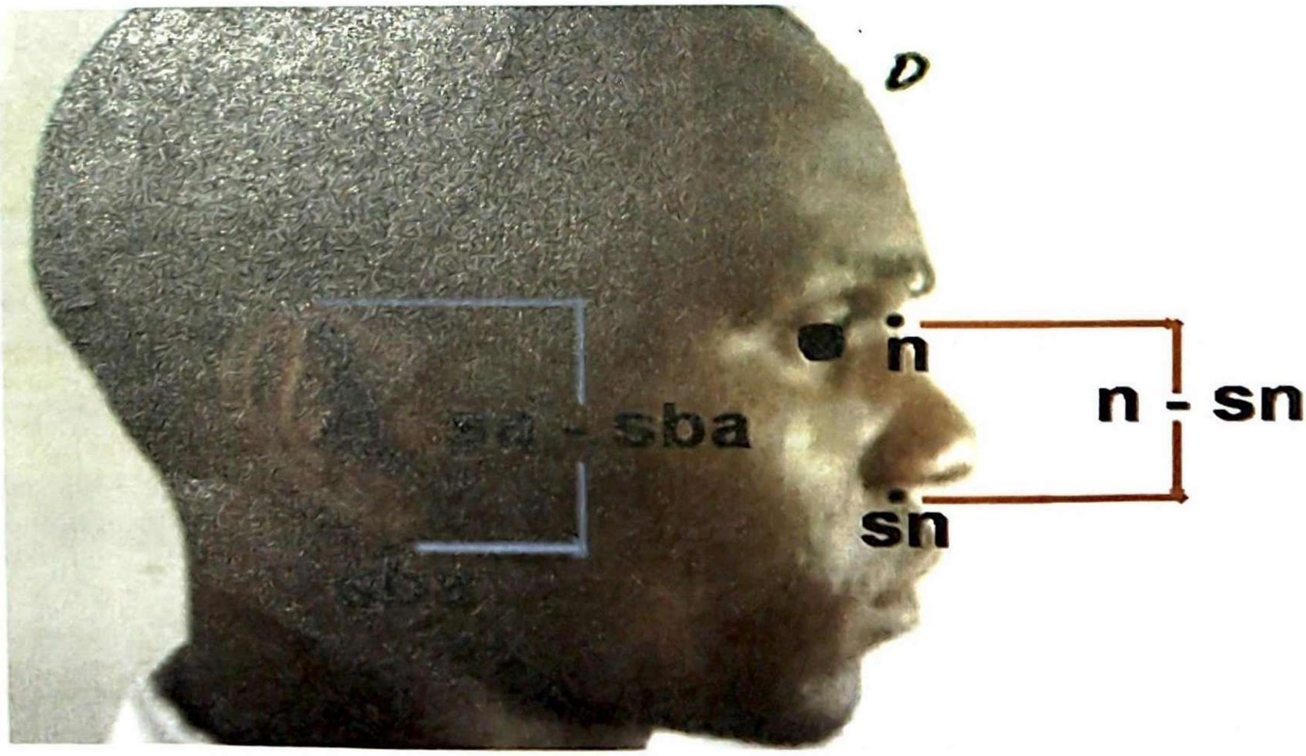

Fig. 4. Naso-aural Proportion.
Naso-aural Proportion: Nose Length (n - sn)/Ear Length (sa - sba).
n = nasion, sn = subnasale, sa = superaurale and sba = subaurale.

taken with 3-D SONY Cyber-shot DSC-HX7V camera (Sony Electronics Incorporated, San Diego, USA) using modified procedures for standardized photography. [15] Ear parameters (in millimeters) were computed from readings of the developed Akinlolu-Raji image-processing algorithm on ear photographs of each subject. Measured height (meters) in Hausas ranged from 1.6 - 1.9 in males and 1.3 - 1.8 in females while the range of Bodyweight in kilograms was 45 - 85 in males and 43 - 70 in females. Measured height (meters) in Yorubas ranged from 1.5 - 1.8 in males and 1.2 - 1.7 in females while the range of bodyweight in kilograms was 46 - 80 in males and 45 - 72 in females.

Height (Length) of the Ear (superauralc - subaurale), Length of Ear Insertion (otobasion superius - otobasion inferius), Maximum Ear Breadth, Ear Index, Iannarelli System (1 – 12) of Ear Biometrics and Naso-aural proportion were evaluated in this study. (figures 2 - 4).

Development of Akinlolu-Raji Image-processing algorithm for face recognition

Akinlolu-Raji image-processing algorithm for forensic face recognition was developed using the modified computer programming principle of row method. [16-18] In the row method, each picture element (pixel) given by a number or three-set of numbers called grey scale depending on the color and texture of the image portion being represented, was considered column by column along a row until all the rows were covered. The grey scale of each cell was confirmed to represent the color of the marked points previously set as the threshold grey scale. The coordinates of any detected point was noted and recorded [16-18]. Since some of the detected points were not at same horizontal or vertical levels, the Pythagoras theorem was used to calculate the pixel distance before converting to actual distance using the pixels of the reference points and their computed distances as read by the Akinlolu-Raji image-processing algorithm [16-18].

Statistical analyses

Data collected from measurements of ear parameters and calculations of indices and proportions were statistically analyzed using the 2010 Microsoft Excel Statistical software. The two sample z-test method (used when the sample size is > 30) was employed for statistical significance pairwise comparisons of computed means of ear parameters by sex and tribe. The alpha value for test of significance was set at $P \leq 0.05$.

Results

Ear biometrics by gender

Statistical analyses of ear measurements (Mean ± S.D. in millimeters) in Hausas showed significantly higher mean value ($P<0.05$) in 6.7% of measured parameters: Iannarelli 5, but non-significantly higher mean values ($P>0.05$) in 46.7% of measured parameters: Ear Length, Length of Insertion, Ear Breadth, Iannarelli 3, 6, 9 and 10 in males compared to females. (table 1). In contrast, there were non-significantly higher mean values ($P>0.05$) in 46.7% of measured parameters: Iannarelli 1, 2, 4, 7, 8, 11 and 12 in females compared to males (Table 3). The ear index was lower in Hausa males than in females. (table 1).

Analyses of ear measurements (Mean ± S.D. in millimeters) in Yorubas showed significantly higher mean values ($P<0.05$) in 26.7% of measured parameters: Ear Length, Length of Insertion, Iannarelli 5 and 11, but non-significantly higher mean values ($P>0.05$) in 60% of measured parameters: Ear Breadth, Iannarelli 1, 2, 6, 7, 8, 9, 10 and 12 in males compared to females. In contrast, there were non-significantly higher mean values ($P>0.05$) in 13.3 % of measured parameters: Iannarelli 3 and 4 in females compared to males. (table 1). The ear index was lower in Yoruba males than in females. (table 1).

Ear biometrics by tribe

Statistical analyses of ear measurements (Mean ± S.D. in millimeters) showed non-significantly higher mean value ($P>0.05$) in 6.7% of measured parameters: Iannarelli 3 in Hausa males compared to Yoruba males. In addition, there were significantly lower mean values ($P<0.05$) in 26.7% of measured parameters: Ear Breadth, Iannarelli 6, 7 and 8 in Hausa males compared to Yoruba males. (Table 2). There were non-significantly lower mean values ($P>0.05$) in 66.7% of measured parameters: Ear Length, Length of Insertion, Iannarelli 1, 2, 4, 5, 9, 10, 11 and 12 in Hausa males compared to Yoruba males (table 2). The ear index was lower in Hausa males than in Yoruba males. (table 2).

Comparative statistical analyses of ear measurements (Mean ± S.D. in millimeters) showed non-significantly higher mean values ($P>0.05$) in 20% of measured parameters: Iannarelli 10, 11 and 12 in Hausa females compared to Yoruba females. In addition, there were significantly lower mean values ($P<0.05$) in 13.3% of measured parameters: Iannarelli 7 and 9 in Hausa females compared to Yoruba females. (Table 2). There were non-significantly lower mean values ($P>0.05$) in 66.7% of measured parameters: Ear Length, Length of

Table 1. Ear Biometrics (Mean ± S.D.) in millimeters by Sex in Hausas and Yorubas.

Cephalometric Parameters	Hausa Males	Hausa Females	Sig. Dif. $P<0.05$	Yoruba Males	Yoruba Females	Sig. Dif $P<0.05$
Ear Length (sa - sba)	64.7 ± 11	62.7 ± 9.2	0.80	77 ± 3.9	63.9 ± 8.3	0.01
Ear Breadth (eb - eb)	35.1 ± 6.3	34.8 ± 6.7	0.95	45.8 ± 4.7	41.1 ± 7.0	0.24
Ear Index = Ear Width/Ear Length X 100	54.3	55.5	NIL	59.5	64.3	NIL
Length of Insertion (obs -obi)	60.1± 9.5	56.4 ± 9.6	0.60	69.4 ± 4.2	57.6 ± 8.6	0.02
Iannarelli 1	5.2 ± 1.5	5.6 ±1.6	0.70	7.1 ± 2.3	6.9 ± 1.3	0.83
Iannarelli 2	4.2 ±0.6	4.9 ±0.9	0.20	5.9 ± 3.0	5.7± 1.7	0.87
Iannarelli 3	4.7 ± 1.0	4.6 ±0.5	0.96	4.6 ± 2.0	4.9 ± 1.8	0.81
Iannarelli 4	4.5 ± 0.2	5.1 ± 1.1	0.30	5.0 ± 2.1	6.3 ± 2.2	0.39
Iannarelli 5	15.7 ± 3.7	11.1 ±2.0	0.04	18.2 ± 4.8	11.7 ± 3.2	0.04
Iannarelli 6	25.1 ± 5.8	21.4 ± 5.4	0.30	34.7 ± 2.9	29.5 ± 5.9	0.11
Iannarelli 7	12.9 ± 3.7	14 ± 4.0	0.70	25.9 ± 1.9	23.8 ± 5.6	0.50
Iannarelli 8	7.9 ± 2.6	8.1 ± 1.4	0.90	11.5 ± 1.8	9.0 ± 1.6	0.05
Iannarelli 9	11.6 ± 4.0	9.9 ± 2.0	0.80	15 ± 3.0	13.9 ± 3.1	0.57
Iannarelli 10	9.9 ± 2.7	9.5 ± 1.6	0.80	10.7 ± 0.7	9.1 ± 2.1	0.13
Iannarelli 11	20.1 ± 3.3	21.5 ± 3.3	0.50	21.9 ± 2.0	18. ± 2.4	0.02
Iannarelli 12	13.8 ± 3.6	16.2 ±1.5	0.20	15.5 ± 2.6	14.6 ± 3.0	0.61

S.D. = Standard Deviations of 150 determinations; Sig. Diff. = Significant Difference; Pd"0.05 = z-test; sa = superaurale; sba = subaurale; eb = ear breadth; obs = otobasion superius; obi = otobasion inferius and Iannarelli 1 - 12 = Iannarelli System of Ear Biometrics.

Insertion, Ear Breadth, Iannarelli 1, 2, 3, 4, 5, 6 and 8 in Hausa females compared to Yoruba females (table 2). The ear index was lower in Hausa females than in Yoruba females. (table 2).

Naso-aural proportions by gender and tribe

Naso-aural proportion was higher in Hausa males compared to females, but lower in Yoruba males compared to females. Naso-aural proportion was higher in Hausa males compared to Yoruba males, but lower in Hausa females compared to Yoruba females. (Table 3).

Discussion

The obtained results of ear measurements (tables 1 and 2) implied sexual dimorphism between males and females of Hausa and Yoruba ethnic groups (with males having higher computed values than females), and that males differ from females in ear sizes. This is in agreement with the findings of earlier studies, which reported sexual dimorphism with males having higher computed values than females in comparisons of the mean values of measurements of Ear Length and/or Ear Breadth, in male and female adults in Maiduguri, Borno State [19], Hausas in Kano, Kano State [20], Australians [21], Italians [22] and India [23]. The results of ear measurements in this study are in disagreement with reported sexual dimorphism, but with males having higher mean value of Ear Width and lower mean value of Ear Length in Urhobos of Abraka, Delta State [24]. Sexual dimorphism between males and females could be due to genetic factors, which vary with gender and auricle expansion which begins earlier in males than in females and which continues till older age [20].

In addition, results of ear measurements (tables 1 and 2), implied that Hausas and Yorubas are of similar ear sizes. However, higher mean values of measured parameters were observed in Yorubas when compared to Hausas in both gender.

The computed mean values in millimetres of Ear Length (64.7 in males and 62.7 in females), Ear Breadth (35.1 in males and 34.8 in females), Length of Insertion (60.1 in males and 56.4 in females) and Ear Index (54.3 in males and 55.5 in females) in Hausas were similar, but higher than mean values of the Ear Length (60.82 in males and 59.46 in females),

Table 2. Ear Biometrics (Mean ± S.D.) in millimeters by Sex and Tribe.

Cephalometric Parameters	Hausa Males	Yoruba Males	Sig. Diff .P<0.05	Hausa Females	Yoruba Females	Sig. Diff. P<0.05
Ear Length (sa - sba)	64.7 ± 11	77 ± 3.9	0.05	62.7 ± 9.2	63.9 ± 8.3	0.84
Ear Breadth (eb - eb)	35.1 ± 6.3	45.8 ± 4.7	0.02	34.8 ± 6.7	41.1 ± 7.0	0.19
Ear Index = Ear Width/Ear Length X 100	54.3	55.5	NIL	59.5	64.3	NIL
Length of Insertion (obs -obi)	60.1 ± 9.5	69.4 ± 4.2	0.08	56.4 ± 9.6	57.6 ± 8.6	0.85
Iannarelli 1	5.2 ± 1.5	7.1 ± 2.3	0.15	5.6 ± 1.6	6.9 ± 1.3	0.19
Iannarelli 2	4.2 ± 0.6	5.9 ± 3.0	0.25	4.9 ± 0.9	5.7 ± 1.7	0.38
Iannarelli 3	4.7 ± 1.0	4.6 ± 2.0	0.94	4.6 ± 0.5	4.9 ± 1.8	0.78
Iannarelli 4	4.5 ± 0.2	5.0 ± 2.1	0.62	5.1 ± 1.1	6.3 ± 2.2	0.33
Iannarelli 5	15.7 ± 3.7	18.2 ± 4.8	0.40	11.1 ± 2.0	11.7 ± 3.2	0.74
Iannarelli 6	25.1 ± 5.8	34.7 ± 2.9	0.01	21.4 ± 5.4	29.5 ± 5.9	0.05
Iannarelli 7	12.9 ± 3.7	25.9 ± 1.9	0.00	14 ± 4.0	23.8 ± 5.6	0.01
Iannarelli 8	7.9 ± 2.6	11.5 ± 1.8	0.03	8.1 ± 1.4	9.0 ± 1.6	0.36
Iannarelli 9	11.6 ± 4.0	15 ± 3.0	0.16	9.9 ± 2.0	13.9 ± 3.1	0.04
Iannarelli 10	9.9 ± 2.7	10.7 ± 0.7	0.50	9.5 ± 1.6	9.1 ± 2.1	0.74
Iannarelli 11	20.1 ± 3.3	21.9 ± 2.0	0.30	21.5 ± 3.3	18. ± 2.4	0.09
Iannarelli 12	13.8 ± 3.6	15.5 ± 2.6	0.41	16.2 ± 1.5	14.6 ± 3.0	0.29

S.D. = Standard Deviations of 150 determinations; Sig. Diff. = Significant Difference; Pd"0.05 = z-test; sa = superaurale; sba = subaurale; eb = ear breadth; obs = otobasion superius; obi = otobasion inferius and Iannarelli 1 - 12 = Iannarelli System of Ear Biometrics.

Table 3. Naso-aural proportion by sex and tribe.

Cephalometric Parameters	Hausa Males	Hausa Females	Yoruba Males	Yoruba Females
Nose Lenght (nasion - subnasale)	39 ± 7.8	34 ± 1.7	43 ± 15	39 ± 8.1
Ear Lenght (superaurale - subaurale)	64.7 ± 11	62.7 ± 9.2	77 ± 3.9	63.9 ± 8.3
Naso-aural Proportion = Nose Lenght/Ear Lenght	0.60	0.54	0.56	0.61

S.D. = Standard Deviations of 150 determinations

Ear Breadth (30.85 in males and 29.82 in females) and Ear Index (50.81in males and 50.24 in females) in Hausas of Kano, Kano State, aged 18 to 25 years [20], Ear Length (56.73 in males and 56.86 in females) of Urhobos in Delta State, aged 6 to 60 years [24], Ear Length (60.4 in males and 57.4 in females) in Indians, aged 17 - 25 years [23] obtained from 1-D anthropometry, Length of Insertion (49.3 in males and 44.3 in females) of Australians older than 18 years of age [21] obtained from two-dimensional anthropometry, lower in males, but higher in females than the mean values of Ear Length (65.7 in males and 59.6 in females) of Australians older than 18 years of age, obtained from 2-D anthropometry [21], and higher than the Ear Length (61.93 in males and 56.11 in females) of Italians, aged 18 – 30 years obtained from 3-D anthropometry [22].

The computed mean values in millimetres of Ear Length (77 in males and 63.9 in females), Ear Breadth (35.1 in males and 34.8 in females), Length of Insertion (69.4 in males and 57.6 in females) and Ear Index (59.5 in males and 64.3 in females) in

Yorubas of Osun State were similar, but higher than the mean values of Ear Length (60.82 in males and 59.46 in females), Ear Breadth (30.85 in males and 29.82 in females) and Ear Index (50.81 in males and 50.24 in females) of Hausas in Kano, Kano State, aged 18 to 25 years [20], Ear Length (56.73 in males and 56.86 in females) of Urhobos in Delta State, aged 6 to 60 years [24], Ear Length (60.4 in males and 57.4 in females) in Indians, aged 17 – 25 years [23] obtained from 1-D anthropometry, Ear Length (65.7 in males and 59.6 in females) and Length of Insertion (49.3 in males and 44.3 in females) of Australians obtained from 2-D anthropometry older than 18 years of age [21] and the Ear Length (61.93 in males and 56.11 in females) of Italians, aged 18 – 30 years obtained from 3-D anthropometry [22].

The observed differences in mean values of ear measurements in this study (in Hausas, aged 18 to 36 years and Yorubas, aged 15 to 33 years) compared to those of previous 1-D anthropometric studies could be due to differences in anthropometric methods, age differences of subjects selected in the different studies, ethnic and regional variations.

The results of Naso-aural proportions implied greater Ear Length than Nose Length in both gender of Hausas and Yorubas. (Table 3). This is in agreement with a previous study which reported greater Ear Length than Nose Length in African-American females, aged 18 to 30 years. [25]. Similarly, Yorubas have greater mean values of Ear Length and Nose Length than Hausas in both sexes.

Conclusions

The developed Akinlolu-Raji image-processing algorithm can be employed for computing anthropometric, forensic, diagnostic or any other measurements on 2-D and 3-D images, and data computed from its readings can be converted to actual or life sizes. Males have higher ear sizes compared to females in Hausas and Yorubas. In addition, Yorubas of Osun State have higher ear sizes compared to Hausas of Kebbi State in both gender.

Recommendations for future studies

Biological determination of ancestral origins of subjects should be carried out to provide definitive and representative anthropometric data as well as determine the true nature of the heterogeneity and ethnic diversity of the Nigerian population.

Acknowledgements

The authors are grateful to the staff and management of the tertiary institutions where subjects were selected for this study.

References

1. Kosa F. Application and role of anthropological research in the practice of forensic medicine. Acta Biol Szegediensis 2000; 44(1-4): 179-188.
2. Champod C, Evett IW and Kuchler B. Earmarks as evidence: a critical review. J Forensic Sci 2001; 46(6): 1275-1284.
3. Moore KL, AMR A and Dalley AF. Clinically oriented anatomy. 5th ed. Williams and Wilkins, Lippincott; 2005, pp. 887 – 912.
4. Garg K. BD Chaurasia's Human Anatomy. Regional and Applied (Dissection and Clinical). Head, Neck and Brain. 4th ed. CBS Publishers and Distributors, New Delhi, India; 2006, pp. 44 – 62.
5. Yuan L, Mu ZM and Xu Z. Using ear biometrics for personal recognition. Advances in biometric person authentication. Computer Sci 2005; 3781: 221 - 228.
6. Yan P. Ear biometrics in human identification. A dissertation submitted to the graduate school of the University of Notre Dame in partial fulfilment of the requirements for the degree of Doctor of Philosophy, graduate program in Department of Computer Science and Engineering, Notre Dame, Indiana, 2006, pp. 1 - 9. Accessed on 27th March, 2018. Available on http://www3.nd.edu/~kwb/PingYanPhD.pdf
7. Abaza A, Ross A, Herbert C, Harrison MAF and Nixon MS. A survey on ear biometrics. ACM Computing Surveys 2013; 45(2): Article22. DOI = 10.1145/2431211.2431221. http://doi.acm.org/10.1145/2431211.2431221
8. National Population Commission. Population and Housing Census of Nigeria. 2015. Accessed on 27th March, 2018. Available on http://www.population.gov.ng/index.php/censuses and http://www.population.gov.ng/images/Vol%2003%20Table%20DSx%20LGAPop%20by%20SDistrict-PDF.pdf
9. David RA, Dennis JS and Thomas AW. Modern business statistics with Microsoft Excel. 5th ed. CENGAGE Learning, USA, 2015, pp. 574.
10. International Business Machines Corporation. The calculation of Bonferroni-adjusted p-values. 2015. http://www-1.ibm.com/support/docview.wss?uid=swg21476685.
11. Farkas LG. Anthropometry of the head and face. 2nd ed. Williams and Wilkins, Raven Press, Lippincott, 1994, pp. 3-56.
12. Ted P. Purposive sampling. *In* The Sage Encyclopedia of Qualitative Research Methods, Volumes 1 and 2, Lisa M. G. (ed), Sage

Publications Incorporated. Thousand Oaks, California, USA. 2008, pp. 697 698.

13. Bacchetti P, Deeks SG and McCune JM. Breaking free of sample size dogma to perform innovative translational research. *Sci* Translational Med 2011; 3: 87. 24. doi:10.1126/scitranslmed.3001628. www.ScienceTranslationalMedicine.org
14. Memon S, Fida M and Shaikh A. Comparison of different craniofacial patterns with pharyngeal widths. J Coll Physicians and Surgeons, Pakistan 2012; 22(5): 302-306.
15. Akinlolu AA. Ear and facial biometrics of Hausas and Yorubas using a novel image-processing algorithm for forensic face recognition. Ph.D. Thesis, Department of Anatomy, University of Ilorin, Nigeria 2016.
16. Raji AO. Discrete element modeling of the deformation of bulk agricultural particulates. Ph.D. Thesis, University of Newcastle-upon-Tyne 1999, https://theses.ncl.ac.uk/dspace/bitstream/10443/871/1/Raji99.pdf
17. Raji AO, Fagboun AA and Dania MK. An approach to detecting defects in food products. Proceedings of the first international conference and 22nd annual conference of the Nigerian Society of Agricultural Engineers, Ibadan, Nigeria 2000; (22): 36-39.
18. Ewemoje, TA and Raji AO. Evaluation of the leaf area index of cowpea using empirical and image processing methods (Vigna unguiculata). J Eng Res 2011; 16(1): 42-52.
19. Ekanem AU, Garba SH, Musa TS and Dare ND. Anthropometric study of the pinna (auricle) among adult Nigerians resident in Maiduguri metropolis. J Med Sci 2010; 10: 76-180.
20. Taura MG, Adamu LH and Modibbo MH. External ear anthropometry among Hausas of Nigeria; the search of sexual dimorphism and correlation. World J Medicine and Med Sci Res 2013 ;1(5) :091-095.
21. Kearney B. Variations of the external ear in an Australian population for the purposes of identification. A Thesis submitted to the University of Adelaide in partial fulfilment of the requirements for the degree of Bachelor of Science, University of Adelaide 2003. Accessed on 27th March, 2018. Available on http://www.eleceng.adelaide.edu.au/personal/dabbott/tamanshud/kearney_oct2003.pdf
22. Sforza C, Grandi G, Binelli M, *et al.* Age- and sex-related changes in the normal human ear. Forensic Sci Intern 2009; 187. 110.e1-110.e7. doi:10.1016/j.forsciint.2009.02.019
23. Deopa D, Thakkar HK, Prakash C, Niranjan R and Barua MP. Anthropometric measurements of external ear of medical students in Uttarakhand Region. J Anatomical Society of India 2013 ;62: 79-83.
24. Eboh DEO. Morphological changes of the human pinna in relation to age and gender of Urhobo people in southern Nigeria. J Exp and Clin Anatomy 2013; 12(2): 68-74.
25. Porter PJ and Olson KL. Anthropometric facial analysis of the African American woman. Arch Facial Plastic Surg 2001; 3: 191-197.