



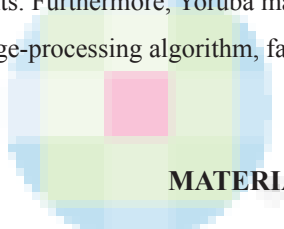
Facial Biometrics of Yorubas of Nigeria Using Akinlolu-Raji Image-processing Algorithm

Adelaja Abdulazeez Akinlolu¹

¹Department of Anatomy, Faculty of Basic Medical Sciences, University of Ilorin, Ilorin, Kwara State, Nigeria

Background: Forensic anthropology deals with the establishment of human identity using genetics, biometrics, and face recognition technology. This study aims to compute facial biometrics of Yorubas of Osun State of Nigeria using a novel Akinlolu-Raji image-processing algorithm. **Materials and Methods:** Three hundred Yorubas of Osun State (150 males and 150 females, aged 15–33 years) were selected as subjects for the study with informed consents and when established as Yorubas by parents and grandparents. Height, body weight, and facial biometrics (evaluated on three-dimensional [3D] facial photographs) were measured on all subjects. The novel Akinlolu-Raji image-processing algorithm for forensic face recognition was developed using the modified row method of computer programming. Facial width, total face height, short forehead height, long forehead height, upper face height, nasal bridge length, nose height, morphological face height, and lower face height 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 analyzes of facial measurements showed nonsignificant higher mean values ($P > 0.05$) in Yoruba males compared to females. Yoruba males and females have the leptoprosopic face type based on classifications of face types from facial indices. **Conclusions:** Akinlolu-Raji image-processing algorithm can be employed for computing anthropometric, forensic, diagnostic, or any other measurements on 2D and 3D images, and data computed from its readings can be converted to actual or life sizes as obtained in 1D measurements. Furthermore, Yoruba males and females have the leptoprosopic face type.

Key words: Forensic anthropology, Yorubas, image-processing algorithm, face recognition



INTRODUCTION

Forensic anthropology deals with the establishment of human identity using genetics, biometrics, and face recognition technology.¹ The face is the best feature which distinguishes an individual.^{2,3} Facial biometrics are vital for human recognition, communication, determination of facial symmetry and beauty, and quantitative evaluation of standardized measurements of parts of the face.^{2,3} To provide further information on the roles of craniofacial cephalometry in forensic science, this study aims to compute facial biometrics of Yorubas of Osun State of Nigeria using a novel Akinlolu-Raji image-processing algorithm.

MATERIALS AND METHODS

Pilot study

A pilot study was conducted to determine the reliability of the Akinlolu-Raji image-processing algorithm using 40 Yoruba subjects (20 males and 20 females), aged 18–23 years, who were undergraduate students at 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

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Corresponding Author: Dr. Adelaja Abdulazeez Akinlolu, Department of Anatomy, Faculty of Basic Medical Sciences, University of Ilorin, Ilorin, Kwara State, Nigeria. Tel: 08062765308. E-mail: a3akin@gmail.com

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the algorithm on three-dimensional (3D) facial photographs were converted to live sizes and the results were statistically compared with measurements of same facial parameters computed from readings of Vernier caliper (1D anthropometry) using *t*-test of the Statistical Package for the Social Science software Statistics 23 developed by the International Business Machines Corporation. The Bonferroni correction (PB) method was employed to reduce the chances of obtaining false-positive results (Type I errors) declaring wrong significant difference when no significant difference exists.⁴⁻⁶

Pairwise comparative statistical analyses of computed mean values of facial parameters (mean $\pm$ standard deviation [SD]) in millimeters between Vernier caliper (1D anthropometry) and Akinlolu-Raji image-processing algorithm (3D 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, long forehead height, upper face height, morphological face height, nose height, and lower face height [Figure 1]. Hence, the image-processing algorithm was confirmed as reliable for further readings of cephalometric (facial) measurements in the main study.

Selection of subjects and determination of sample size in the main study

Letters of approval for conduct of the study were received from the management of Osun State University, Okuku Campus, Osun State, Nigeria, from where undergraduate students (150 males and 150 females, aged 15–33 years) were locally selected as subjects for the main study using the purposive technique or judgment sampling method,^{3,7-10} only

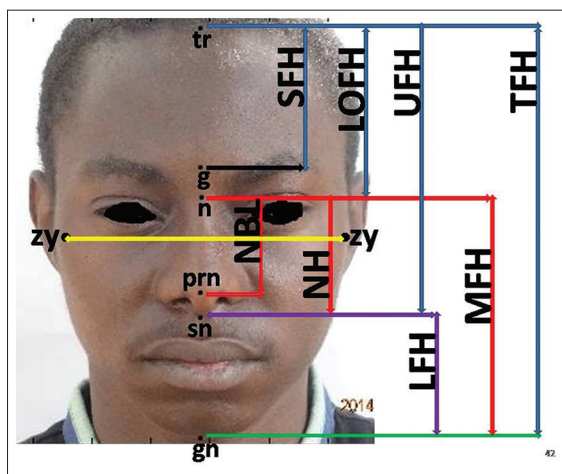


Figure 1: Biometric measurements of the face. tr = Trichion; g = Glabella; n = Nasion; prn = Pronasale; sn = Subnasale; gn = Gnathion and zy = Zygion. Facial Width = Zygion to Zygion; TFH = Total face height (UFH + LFH); SFH = Short forehead height; LOFH = Long forehead height; UFH = Upper face height; NBL = Nasal bridge length; NH = Nose height; MFH = Morphological face height and LFH = Lower face height

when established via distributed questionnaires as 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 facial cephalometric parameters

Data on height and bodyweight, parents and grandparents ethnic origin, local government area, state of origin, and facial photographs were obtained from each subject. Photographs of subjects were taken with 3D SONY Cyber-shot DSC-HX7V camera (Sony Electronics Incorporated, San Diego, USA) using modified procedures for standardized photography.¹¹ Cephalometric or facial parameters (in millimeters) were computed from readings of the Akinlolu-Raji image-processing algorithm on 3D facial photographs of each subject. Height (meters) of subjects ranged from 1.5–1.8 in males to 1.2–1.7 in females while the range of bodyweight in kilograms was 46–80 in males and 45–72 in females.

Distances of the facial width (zygion to zygion), total face height (trichion to gnathion), short forehead height (trichion to glabella), long forehead height (trichion to nasion), upper face height (trichion to subnasale), morphological face height (nasion to gnathion), nasal bridge length (nasion to pronasale), nose height (nasion to subnasale), and lower face height (subnasale to gnathion) were computed in this study [Figure 1]. Facial index (FI) was computed as the percentage proportion of morphological face height to facial width.

Development of the Akinlolu-Raji image-processing algorithm for face recognition

The Akinlolu-Raji image-processing algorithm for forensic face recognition was developed by the Author and Professor Raji, Abdulganiy Olayinka of the Department of Agricultural and Environmental Engineering, Faculty of Technology, University of Ibadan, Ibadan, Oyo State, Nigeria, using the modified computer programming principle of row method.¹²⁻¹⁴ In the row method, each picture element (pixel) given by a number or three-set of numbers called grayscale, 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 grayscale of each cell was confirmed to represent the color of the marked points previously set as the threshold grayscale. The coordinates of any detected point were noted and recorded.¹²⁻¹⁴ 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 selected reference points and their computed distances as read by the image-processing algorithm.¹²⁻¹⁴

For example, computed total face height (trichion to gnathion distance) by the novel image-processing algorithm

was converted to actual life size or distance as follows:

- Manually computed distance between selected two reference points on a scaled graph sheet: 300 mm
- Computed distance between the selected two reference points by Akinlolu-Raji image-processing algorithm on 3D facial image: 273 mm
- Computed total face height (trichion - gnathion distance) using Akinlolu-Raji image-processing algorithm on 3D facial image: 160 mm.

Conversion of computed total face height distance to live size = $160 \times 300/273$ mm
 $= 160 \times 1.099$ mm
 $= 175.8$ mm

Statistical analyses

Data collected from measurements of facial parameters in the main study were statistically analyzed using the 2010 Microsoft Excel Statistical software of personal computer manufactured by Toshiba incorporation. The two sample *z*-test method (used when the sample size is >30) was employed for statistically significant comparisons of computed means of facial parameters between Yoruba males and females. The alpha value for test of significance was set at $P \leq 0.05$.

RESULTS

Biometric measurements of the face

Statistical analyses of measurements of anteromedian aspects of the face (mean $\pm$ SD in millimeters) showed nonsignificant higher mean values ($P > 0.05$) in 87.5% of parameters: Total face height, short forehead height, long forehead height, upper face height, morphological face height, nasal bridge length, and nose height in Yoruba males compared to females [Table 1]. There was statistically nonsignificant lower mean value ($P > 0.05$) in 12.5% of parameters: Lower face height in Yoruba males compared to females [Table 1].

Facial indices and three-section facial profiles of subjects

Computations showed higher percentage ratios of long forehead height and nose height to total face height, but lower percentage ratio of lower face height to total face height in Yoruba males compared to females [Table 2 and Figure 2]. The FI was 91.8 in Yoruba males and 91.4 in Yoruba females.

DISCUSSION

Nigeria is composed of over two hundred and fifty ethnic groups and according to the official records of the National Population Commission, it has a population of over one hundred

Table 1: Facial biometrics by sex in Yorubas

Cephalometric parameters	Yoruba		Significant difference $P \leq 0.05$
	Males	Females	
Total face height (trichion - gnathion)	150 $\pm$ 47	138 $\pm$ 28	0.63
Short forehead height (trichion - glabella)	49 $\pm$ 18	42 $\pm$ 7	0.43
Long forehead height (trichion - nasion)	61 $\pm$ 22	53 $\pm$ 10	0.46
Upper face height (trichion - subnasale)	104 $\pm$ 19	92 $\pm$ 9.5	0.61
Nasal bridge length (nasion - pronasale)	36 $\pm$ 13	32 $\pm$ 6	0.53
Nose height (nasion - subnasale)	43 $\pm$ 15	39 $\pm$ 8.1	0.61
Morphological face height (nasion - gnathion)	89 $\pm$ 26	85 $\pm$ 18	0.80
Lower face height (subnasale - gnathion)	46 $\pm$ 12	46 $\pm$ 15	0.51
Mean $\pm$ SD of 150 determinations in mm; $P \leq 0.05$ =Z-test. SD = Standard deviation			

Table 2: Facial indices and three-section facial profiles by sex in Yorubas

Cephalometric parameters	Yoruba	
	Males	Females
TFH (trichion - gnathion)	150 $\pm$ 47	138 $\pm$ 28
LOFH (trichion - nasion)	61 $\pm$ 22	53 $\pm$ 10
NH (nasion - subnasale)	43 $\pm$ 15	39 $\pm$ 8.1
LFH (subnasale - gnathion)	46 $\pm$ 12	46 $\pm$ 15
MFH (nasion - gnathion)	89 $\pm$ 26	85 $\pm$ 18
FW (zygion - zygion)	97 $\pm$ 32	93 $\pm$ 17
LOFH/TFH $\times 100$ (%)	40.7	38.4
NH/TFH $\times 100$ (%)	28.7	28.3
LFH/TFH $\times 100$ (%)	30.7	33.3
FI=MFH/FW $\times 100$	91.8	91.4

Values of TFH, LOFH, NH, LFH, and FW represent mean $\pm$ SD in mm. TFH = Total face height; LOFH = Long forehead height; NH = Nose height; LFH = Lower face height; MFH = Morphological face height; FW = Facial width; FI = Facial index; SD = Standard deviation

and forty million in 2006.¹⁵ Nigeria comprises 36 states, grouped into six geopolitical zones namely, Northeast, North-Central, Northwest, Southeast, Southwest, and South-South and the Federal Capital Territory. Yorubas are the dominant ethnic group in the six states of Southwest Nigeria (Ekiti, Lagos, Ogun, Ondo, Osun, and Oyo states) and Kwara State of North-Central Nigeria.¹⁵ Osun State according to the National Census of 2006 which is currently in use ranks 19th out of 36 states, and the Federal Capital Territory with a total population of 3,416,959 (1,734,149 males and 1,682,810 females).¹⁵

Anthropology studies human biology and culture.^{16,17} Previous review of the anthropological history of Yorubas and some ethnic groups of Nigeria reported historical migrations, conquests, and/or assimilations of indigenous populations by founders from different ethnic origins and re-definitions of ethnic groups across states and zones of the nation.¹⁸⁻²⁴

Facial biometrics of Yorubas of Nigeria

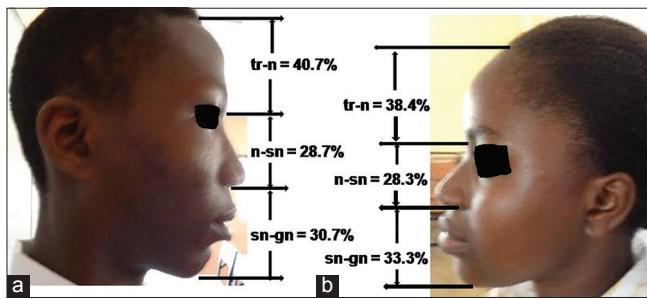


Figure 2: Three-section facial profiles in (a) Yoruba male and (b) Yoruba female. tr = Trichion; n = Nasion; sn = Subnasale; gn = Gnathion and % = percentage

Furthermore, anthropometric data computed using ancestry informative markers and phenotype-based race/ethnicity information usually disagreed.²⁵ Ancestry informative markers should, therefore, be employed for precise characterization of individuals and/or collective biological ancestry to provide definitive anthropometric data in heterogeneous populations.²⁵⁻²⁹

The re-definitions of ethnic groups across Nigeria implied that in the absence of biological determination of ancestral origins of subjects, representative subjects of preliminary anthropometric studies should be selected from local populations under same environmental or epigenetic influence. This opinion agrees with a previous study which noted that perhaps due to regional variations, analyses of anthropometric data obtained from different studies on members of same “ethnic or racial” group produced conflicting results or data.³⁰ In this study, local representative subjects were selected from Yorubas of Osun State.

1D anthropometry identifies soft-tissue landmarks over which calipers or measuring tapes are placed for reading distances between landmarks.^{2,3,8,31} 1D is disadvantaged by excessive time consumption,³² possible distortions of soft tissue by its equipment, which may introduce errors,³² errors of identifications and readings of anthropometric distances between operators, and limited shape information.^{2,31} Digital anthropometry could be 2D or 3D and are employed in face recognition systems for computing biometric parameters.

The face recognition system (2D or 3D) employs computerized algorithms for face recognition and is the most widely used way of identification or authentication of identity in civil and criminal investigations for forensic analyses and face detection purposes.^{33,34} 2D facial recognition system uses anthropometric equipment such as 2D cameras and is limited by physical appearance changes, changes in lighting intensity, aging, pose, and the inability to provide structural information of surface curvature and geodesic distances about the face.³³⁻³⁵

The 3D facial recognition system, in contrast, gives complete and real information of shapes, texture, and color;

represents shapes or landmarks by set coordinates; provides faster data acquisition, and gives more accurate data.^{33,34,36,37} It shows a high level of accuracy and reliability and is more robust to face variations due to different factors. Its pose can easily be corrected by rigid rotations in 3D space while its algorithm is compatible with variations in illumination conditions during image acquisition.^{33,34} It applies to both the 2D and 3D face recognition systems. 3D facial recognition system uses 3D digital image technology devices such as surveillance videos, cameras, and scanners, with 3D anthropometry for computing biometric parameters.^{36,37} Therefore, 3D anthropometry has potentials in growth assessment studies, quantification of facial morphology, assessment of facial deformity, anaplastology, genotypic-phenotypic studies of syndromes, and forensic investigations.^{36,37}

Comparative statistical analyses of 3D biometric measurements of anteromedian aspects of the face in Yorubas showed nonsignificant higher mean values ($P > 0.05$) in 87.5% of parameters: Total face height, short forehead height, long forehead height, upper face height, morphological face height, nasal bridge length, and nose height but showed nonsignificant lower mean value ($P > 0.05$) in 12.5% of parameters: Lower face height in Yoruba males compared to females [Table 1]. The results implied that Yoruba males differ from females in facial biometrics with higher mean values of facial parameters in males than females.

The results agree with established anatomical principle of females having smaller crania with shorter facial features than males.³⁸ In addition, the results are in agreement with those of previous 1D anthropometric studies which reported sexual dimorphism with males having higher mean values of facial parameters than females in Binis of Edo State, aged 16–35 years;³⁹ Igbo of Southeast Nigeria, aged 18–69 years;⁴⁰ Hausas resident in Ilorin,³ Igbo resident in Ilorin,³ and Yorubas of Ilorin, Kwara State, aged 18–30 years;³ and Yorubas resident in Kano⁴¹ and Hausas of Kano, Kano State, aged 17–25 years.⁴¹

Computed mean values of long forehead height showed similar values in Yoruba males: 61 when compared to those of previous 1D anthropometric studies in males of Hausa: 58.7,³ Igbo: 58.2,³ and Yoruba: 65.2,³ aged 18–30 years. However, computed mean values of long forehead height showed lower values when compared to previous 1D studies in young adults (18–35 years) of North American Whites: 67.1 and African Americans (aged 18–30 years): 71.3 males.⁴² Comparisons of mean value of long forehead height in Yoruba females: 53 showed similar value when compared to those of previous 1D data in Hausa females: 52.6,³ but lower value when compared to those of 1D data in females of Igbo: 57,³ and Yoruba: 62.7,³ aged 18–30 years; Korean Americans:

73, aged 18–35 years;⁴³ and North American Whites: 63³⁰ and African Americans: 68.9, aged 18–30 years.³⁰

Furthermore, computed mean values of nose height showed lower values in Yorubas (43 in males and 39 in females) when compared to previous 1D data in Yorubas (41.8 in males and 42.5 in females) and Hausas (56.7 in males and 54 in females) resident in Kano, Kano State, aged 17–25 years⁴¹ and Binis of Edo State (45.7 in males and 44.2 in females), aged 21–25 years.³⁹ The observed differences in computed facial parameters of Yorubas, aged 15–33 years, in this study, when compared to those of previous 1D anthropometric studies could be due to differences in anthropometric methods and age differences of subjects selected in the different studies.

Computations showed higher percentage ratios of long forehead height to total face height and nose height to total face height, but lower percentage ratio of lower face height to total face height in Yoruba males when compared to females [Table 2 and Figure 2]. In addition, the three-section facial profiles of Yoruba females (long forehead height: 38.4%, nose height: 28.3%, and lower face height: 33.3%) were similar to those of African American females, aged 18–30 years (long forehead height: 37.5% females, nose height: 26.1%, and lower face height: 36.4%) obtained through 1D anthropometry.³⁰ The percentage proportion of nose height was significantly shorter compared to percentage proportions of long forehead height and lower face height in Yoruba females. This result is in agreement with the significant shorter percentage proportion of nose height when compared to percentage proportions of long forehead height and lower face height in African American women, aged 18–30 years³⁰ [Figure 3].

The face is classified based on the FI or prosopic index as hypereuroprosopic or very short broad face (FI < 79.9), europrosopic or short broad face (FI of 80–84.9), mesoprosopic or medium round face (FI of 85–89.9), leptoprosopic or long narrow face (FI of 90–94.9), and hyperleptoprosopic or very long narrow face (FI > 95).^{44,45} The facial indices in Yorubas (91.8 in males and 91.4 in females) [Table 2] examined in the present study implied that Yoruba males and females have the leptoprosopic face type.

The leptoprosopic face type observed in Yoruba males and females in the present study is in agreement with previous 1D studies which reported the leptoprosopic face type in Tangales (FI: 92.1 in male and 92.6 in female) and Tera males (FI: 94.1) of Gombe State.⁴⁴ The Leptoprosopic face type observed in Yorubas in the present study is in disagreement with previous 1D studies which reported the hypereuroprosopic face type in Yorubas resident in Ibadan, Oyo State (FI: 77.6 in males and 73.72 in females), and Ibos (FI: 75.49 in males and 73.76 in females) resident in Owerri, Imo State, aged 18–35 years.⁴⁶ In addition, the

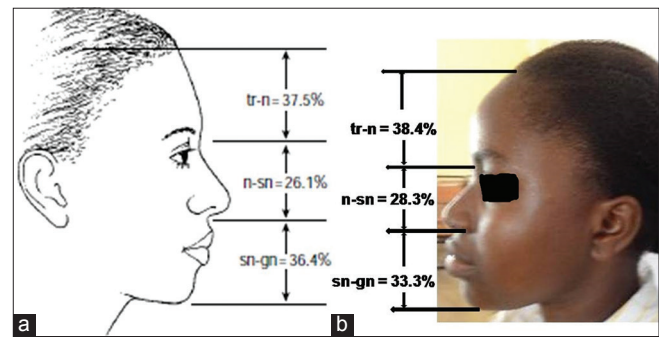


Figure 3: Three-section facial profiles in (a) African American female (30) and (b) Yoruba female. tr = Trichion; n = Nasion; sn = Subnasale; gn = Gnathion and % = percentage

leptoprosopic face type observed in Yorubas of the present study is in disagreement with previous 1D studies which reported dominant mesoprosopic face type in Malays, aged 19–30 years (FI: 90.85 in males and 85.86 in females)⁴⁵ and Indians, aged 18–22 years (FI: 87.19 in males and 86.75 in females)⁴⁷ possibly due to ethnic and regional variations.

The author is not aware of any previous 3D cephalometric study of the face of Yorubas or any other ethnic group of Nigeria after literature review. The 3D facial biometrics of Yorubas of Osun State carried out in this study, therefore, represents a pioneering effort in the use of face recognition technology in Nigeria. In addition, the developed Akinlolu-Raji image-processing algorithm which is an effective biometric measuring tool on digital images of 2D and 3D image devices used in phones, cameras, surveillance videos, or closed-circuit television cameras is of great importance in numerous applications such as automated secured access, automatic surveillance, forensic investigations, fast retrieval of records from databases in police departments, checking for fraud or identity theft, identification of patients in hospitals, and computations of radiographic measurements.

CONCLUSIONS

Akinlolu-Raji image-processing algorithm can be employed for computing anthropometric, forensic, diagnostic or any other measurements on 2D and 3D images, and data computed from its readings can be converted to actual or life sizes as obtained in 1D measurements. Furthermore, Yoruba males and females have the leptoprosopic face type.

Limitations of the study

The biological determination of ancestral origins of subjects was not carried out in this study and presented data are preliminary.

Recommendations for future studies

The biological determination of ancestral origins of subjects should be carried out to provide definitive and representative anthropometric data of Nigerian ethnic groups. This will help to determine the true nature of the heterogeneity and ethnic diversity of the Nigerian population.

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Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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