Applicability of the McNamara analysis in a sample of adult Black South Africans

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SUMMARY

Introduction

Cephalometric norms have been established for the McNamara analysis for different age, racial and ethnic groups.

Aim

To establish McNamara cephalometric norms for a sample of Black South African adults and to compare with Caucasian norms.

Methods

Thirty lateral cephalograms of a sample of eligible untreated Black adult subjects was retrieved from archives in the Department of Orthodontics at the Medunsa Oral Health Centre. They were traced and digitized using Dolphin Imaging® computer software. The McNamara analysis was performed. The one sample t-test was performed to compare study values with McNamara norms. The two sample t-tests were used to determine statistical differences between the data for genders.

Results

The mean age of the study subjects was 24 years (SD=3.9). Two-thirds of the linear measurements were significantly higher than the McNamara norms. The angular measurements of female subjects were significantly higher than McNamara's reference values.

As regards gender differences, almost two-thirds of male linear measurements were higher than females, and the differences were statistically significant in half of the measurements. In contrast, though all higher, female angular measurements showed no statistically significant differences.

Conclusion

Gender and racial differences exist in cephalometric norms measured using the McNamara analysis.

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INTRODUCTION

Radiographic cephalometry is a vital tool for clinical and research orthodontics.[1] Since its introduction by Broadbent[2] in 1931, numerous cephalometric analyses have been described over the years. These analyses are frequently used by orthodontists and maxillofacial surgeons for diagnosis, treatment planning, growth analysis and evaluation of treatment results.[3]

The McNamara[4] analysis is a popular example, composed of eight linear and three angular measurements. The analysis provided a method that is simultaneously sensitive not only to the position of the teeth within a given jaw bone but also to the relationship of the two jaws, as well as the relationship between the jaws and cranial base.[4] The relative positions of the maxilla and mandible, maxillary and mandibular lengths, the height of the face and the position of the incisors are described. It was developed for conventional orthodontic patients as well as for those with skeletal discrepancies requiring orthognathic surgery or growth modification.[5]

Studies have established McNamara norms for various population groups, the data having been found to vary amongst different age, racial and ethnic groups.[6-11] Whilst Barter et al.[12] established norms for Black South African children aged between 11 and 16 years, no McNamara norms for Black adults are available in the literature. This study seeks to determine these values for an adult Black South African sample.

MATERIAL AND METHODS

The study was approved by the Medunsa Research and Ethics Committee (MREC) of the University of Limpopo, Medunsa Campus, South Africa (Project number: MREC/D/213/2012). The study material consisted of lateral cephalograms and study models of untreated Black adult subjects retrieved from the archives in the Department of Orthodontics, University of Limpopo, Medunsa Campus.

A total of 30 lateral cephalograms and study models (12 men and 18 women) were selected for this study. The criteria for selection were the following: Skeletal

Class I; acceptable soft tissue profile[12]; Dental Class I; normal overjet and overbite; no severe crowding; no crossbites; no missing teeth except the third molars; and, no history of orthodontic treatment or orthognathic surgery.

All radiographs had been taken with the Frankfort horizontal plane parallel to the floor, the teeth in centric occlusion and the lips at rest. The analog cephalograms were taken with the Siemens, Orthopantomogram 10® while the digital radiographs were obtained using the Kodak 8000C® X-ray machine. The analog cephalograms were digitized using Vidar Sierra Advantage® X-ray film digitizer. A ruler from the Dolphin software programme was attached to each cephalogram during the digitization process (Figure 1). The calibrations on the ruler served as a reference to enable adjustment for magnification of the image.[8]
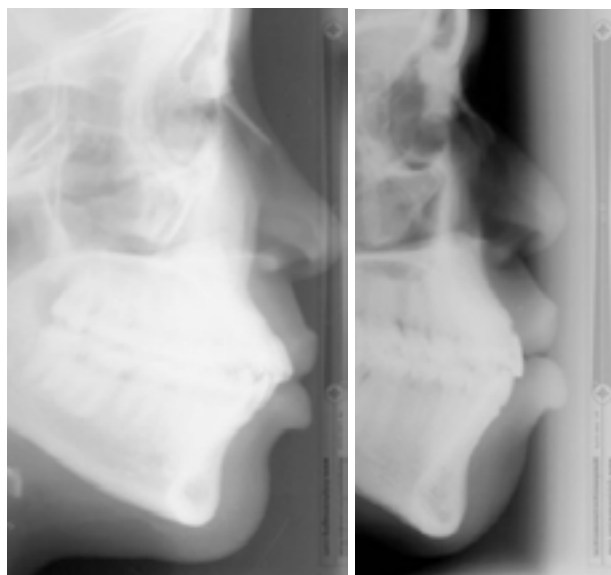

Figure 1: Digitized analog lateral cephalogram with a Dolphin ruler in place.

Dolphin Imaging 11.5 Premium® cephalometric analysis computer software was used to trace and analyze the cephalograms. The landmarks and measurements for assessing skeletal classification and soft tissue profile are shown in Figure 2, and those for the McNamara[4] (1984) analysis are illustrated in Figure 3. All measured variables of the McNamara analysis are shown in Table 1.

To determine the errors associated with landmark identification and measurements, five radiographs were randomly selected, retraced and re-measured by the principal investigator (intra-examiner reliability/error), as well as by the supervisor (inter-examiner reliability) two weeks after the initial measurements. The Pearson Correlation coefficient test was performed to determine intra- and inter-examiner reliability. Arithmetical means and standard deviation were calculated for all variables. A Shapiro-Wilk test was carried out to objectively assess the normality of distribution of the measured variables.

The mean values obtained from the sample for all the variables were compared with the McNamara[4] norms (Ann Arbor sample) by a one-sample *t* test. The mean values for male and female subjects were compared by a two-sample *t* test. The level of significance was set
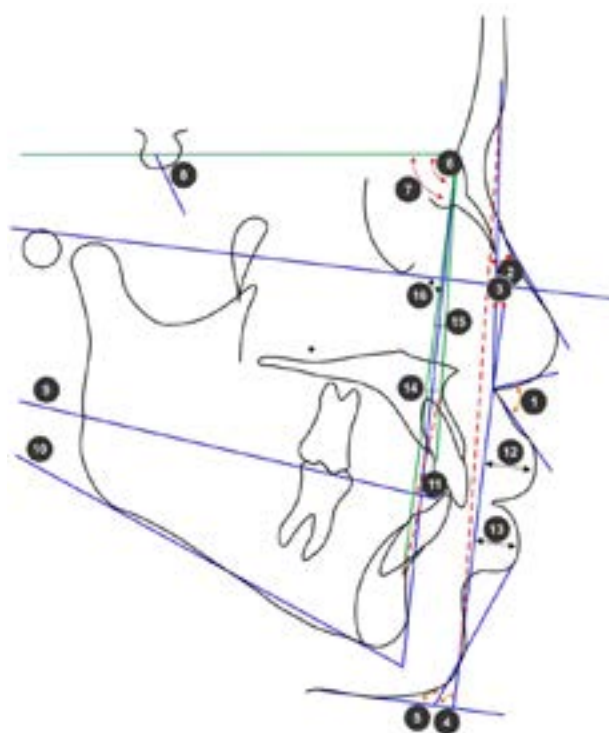

Figure 2: Linear and angular measurements to verify that a patient had skeletal Class I pattern and acceptable soft tissue profile 1) nasolabial angle, 2) nasofacial angle, 3) facial contour angle, 4) lower face-throat angle, 5) lower lip-chin-throat angle, 6) SNB, 7) SNA, 8) Y-axis, 9) occlusal plane, 10) mandibular plane angle, 11) Wits, 12) B-line upper lip, 13) B-line lower lip, 14) convexity, 15) ANB 16) face-plane.
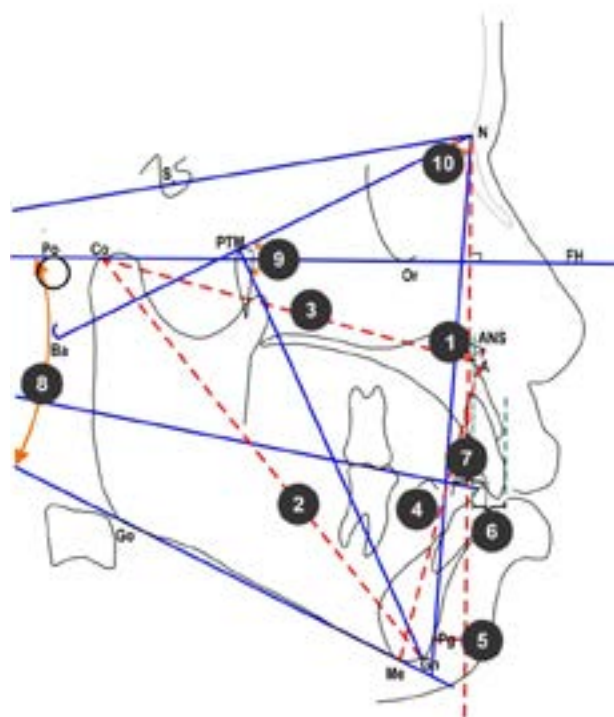

Figure 2: Landmarks, linear and angular measurements used for McNamara (1984) analysis 1) Distance from Point A to nasion perpendicular line, 2) Distance from condylion to gnathion, 3) Distance from condylion to Point A, 4) Distance from anterior nasal spine to menton, 5) Distance from point pogonion to the nasion perpendicular, 6) Distance from labial surface of upper incisor to Point A vertical, 7) Distance from tip of lower incisor to A-Pogonion line, 8) Angle between FH plane and Go-Me line, 9) Angle formed by intersection of N-Ba and PTM-Gn lines, 10) Angle formed by intersection of SN and NA lines.

at $p \leq 0.05$. All statistical analyses were performed under the advice of a statistician and were processed using the Statistical Analysis System (SAS) 9.2 computer software programme.

Table 1. Different linear and angular measurements of McNamara (1984)

Measurements	Definition
Maxilla to cranial base	
Nasion perpendicular to point A (mm)	Distance from Point A to nasion perpendicular line
SNA angle	Angle formed by intersection of SN and NA lines
Mandible to maxilla	
Effective mandibular length (mm)	Distance from condylion to gnathion
Effective midfacial length (mm)	Distance from condylion to Point A
Maxillomandibular differential (mm)	Midfacial length subtracted from mandibular length
Lower anterior facial height (mm)	Distance from anterior nasal spine to menton
Mandibular plane angle	Angle between FH plane and Go-Me line
Facial axis angle	Angle formed by intersection of N-Ba and PTM-Gn lines
Mandible to cranial base	
Pogonion to nasion perpendicular (mm)	Distance from point pogonion to the nasion perpendicular
Dentition	
Upper incisors to point A vertical (mm)	Distance from labial surface of upper incisor to Point A vertical
Lower incisors to A-Po line (mm)	Distance from tip of lower incisor to A-Pogonion line

RESULTS

The sample demographics are illustrated in Table 2.

There was no statistically significant difference between the ages of male and female subjects. The Shapiro-Wilk test revealed that more than 90% of the variables were normally distributed ($p > 0.05$). The intra- and inter-examiner reliability tests showed the correlation coefficient exceeded 0.8 indicating that the method of measurement was reliable and reproducible.

Gender differences in the study sample

Table 3 shows a comparison of the measured variables between male and female subjects. The mean values for four linear measurements (effective mandibular length; effective mid-facial length; maxillomandibular differential; and anterior lower facial height) were significantly larger in males than in females. The other four linear measurements (nasion perpendicular to Point A; pogonion to nasion perpendicular; upper incisor to Point A vertical; and lower incisors to A-Po line) and three angular measurements (SNA; mandibular plane; facial axis angle) showed no statistically significant difference between male and female subjects.

Comparison between study and Ann Arbor male sample

Table 4 shows a comparison of the measured variables between the study and the Ann Arbor male sample. The mean values for two linear measurements (upper

Table 2. Sample distribution by age and gender

Sample (n)	Number	Mean age (years)	SD	Median	Minimum	Maximum	p-value
Males	12	25.1	5.09	24.0	20	39	
Females	18	23.3	2.81	23.0	20	29	0.294
Total	30	24	3.90	23.5	20	39	

SD = standard deviation; p-value level of significance □ 0.05.

Table 3. Comparison of measured variables between males and females of the study sample

Parameters	Male Mean	Female Mean	Mean difference	t-value	p-value	95% CI for mean difference
Maxilla to cranial base						
Nasion perpendicular to point A (mm)	1.32	3.84	2.53	1.89	0.0693	-0.214 – 5.269
SNA angle (°)	83.23	85.81	2.58	1.81	0.0807	-0.336 – 5.492
Mandible to maxilla						
Effective mandibular length (mm)	129.63	123.50	6.13	-3.50	0.0016	-9.717 – -2.542
Effective midfacial length (mm)	98.51	95.53	2.98	-2.55	0.0164	-5.379 – -0.591
Maxillomandibular differential (mm)	31.12	28.03	3.09	-2.97	0.0060	-5.219 – -0.959
Lower anterior facial height (mm)	77.08	73.65	3.43	-2.05	0.0499	-6.855 – -0.001
Mandibular plane angle (°)	22.60	23.43	0.83	0.69	0.4981	-1.651 – 3.315
Facial axis angle (°)	-1.45	0.27	1.73	1.60	0.1209	-0.485 – 3.937
Mandible to cranial base						
Pogonion to nasion perpendicular (mm)	-3.43	-0.77	2.67	1.14	0.2650	-2.136 – 7.469
Dentition						
Upper incisors to point A vertical (mm)	8.45	9.59	1.15	1.65	0.1107	-0.279 – 2.571
Lower incisors to A-Po line (mm)	6.47	7.26	0.79	1.08	0.2893	-0.707 – 2.285

CI = confidence interval; p-value level of significance ≤ 0.05; t = value of statistical test

incisors to point A vertical and lower incisors to A-Po line) were significantly larger in the study than for those of the Ann Arbor male sample.

The mean value for one angular measurement (facial axis angle) was found to be significantly smaller in the study sample than in the Ann Arbor sample. The mean values for the other six linear measurements (nasion perpendicular to point A; effective mandibular length; effective midfacial length; maxillomandibular differential; lower anterior facial height; and, pogonion to nasion perpendicular) and two angular measurements (SNA and mandibular plane angle) were not statistically significant.

Comparison between study and Ann Arbor female sample

Table 5 shows the comparison of the measured variables between the study sample and Ann Arbor female sample.

The mean values for six linear measurements (nasion perpendicular to Point A; effective mandibular length; effective midfacial length; lower anterior facial height; upper incisors to Point A vertical; and, lower incisors to A-Po line) and one angular (SNA angle) measurement were significantly larger in the study sample than in the Ann Arbor females. The mean values for the other two linear measurements (maxillomandibular differential and pogonion to nasion perpendicular) and two angular measurements (facial axis and mandibular plane angles) were not statistically significant.

DISCUSSION

This study set out to establish McNamara norms for a population of adult Black South Africans, compare that data with Ann Arbor population norms, and examine for gender differences in the measurements.

Table 4. Statistical comparison of linear and angular measurements between study and Ann Arbor male sample

Parameters	Study sample (n = 12)			Ann Arbor sample (n = 38)	p-values
	Mean	t-value	95% CI of mean	Mean	
Maxilla to cranial base					
Nasion perpendicular to point A (mm)	1.32	1.89	-1.02 – 3.65	1.1	0.8419
SNA angle (°)	83.2	1.81	80.55 – 85.92	83.9	0.5957
Mandible to maxilla					
Effective mandibular length (mm)	129.6	-3.50	126.2 – 133.1	132.3	0.1172
Effective midfacial length (mm)	98.5	-2.55	96.47 – 100.6	99.8	0.1934
Maxillomandibular differential (mm)	31.1	-2.97	29.12 – 33.12	32.5	0.1561
Lower anterior facial height (mm)	77.1	-2.05	73.68 – 80.47	74.6	0.1367
Mandibular plane angle (°)	22.6	0.69	20.56 – 24.63	21.3	0.1888
Facial axis angle (°)	-1.5	1.60	-3.17 – 0.26	0.5	**0.0290**
Mandible to cranial base					
Pogonion to nasion perpendicular (mm)	-3.4	1.14	-7.16 – 0.29	-0.3	0.091
Dentition					
Upper incisors to point A vertical (mm)	8.5	1.65	7.06 – 9.83	5.3	**0.0004**
Lower incisors to A-Po line (mm)	6.5	1.08	4.94 – 7.99	2.3	**0.0001**

CI = confidence interval; p-value level of significance ≤ 0.05; t = value of statistical test

Table 5. Statistical comparison of linear and angular measurements between study and Ann Arbor female sample

Parameters	Study sample (n = 18)			Ann Arbor sample (n = 38)	p-values
	Mean	t-value	95% CI of mean	Mean	
Maxilla to cranial base					
Nasion perpendicular to point A (mm)	3.84	1.89	2.09 – 5.60	0.4	**0.0007**
SNA angle (°)	85.8	1.81	84.06 – 87.56	82.4	**0.0007**
Mandible to maxilla					
Effective mandibular length (mm)	123.5	-3.50	121.4 – 125.6	120.2	**0.0036**
Effective midfacial length (mm)	95.5	-2.55	94.00 – 97.06	91.0	**0.0001**
Maxillomandibular differential (mm)	28.0	-2.97	26.77 – 29.29	29.2	0.0661
Lower anterior facial height (mm)	73.7	-2.05	71.74 – 75.56	66.7	**0.0001**
Mandibular plane angle (°)	23.4	0.69	21.80 – 25.06	22.7	0.3602
Facial axis angle (°)	0.3	1.60	-1.23 – 1.77	0.2	0.9203
Mandible to cranial base					
Pogonion to nasion perpendicular (mm)	-0.8	1.14	-4.03 – 2.49	-1.8	0.5126
Dentition					
Upper incisors to point A vertical (mm)	9.6	1.65	8.78 – 10.40	5.4	**0.0001**
Lower incisors to A-Po line (mm)	7.3	1.08	6.46 – 8.05	2.7	**0.0001**

CI = confidence interval; p-value level of significance □ 0.05; t = value of statistical test.

Four linear measurements relating maxilla to the mandible demonstrated a statistically significant difference between the male and female sample. The effective mandibular length, effective mid-facial length, maxillomandibular differential and lower anterior facial height values in males were significantly larger than in females. These findings were in agreement with several other studies.[4,6-8,10,11]

These findings are an indication that male subjects have larger mandibular and maxillary skeletal structures than females. This finding could be related to the well-known time differences in craniofacial growth; male subjects grow for a longer period of time and therefore have larger maxillary and mandibular skeletal structures than females.[13-15]

No statistically significant difference was found in the two angular measurements for vertical dimension, linear measurement for the position of the mandible and linear measurement of the positions of the upper and lower incisors. However, the female sample demonstrated a more vertical tendency as measured by the mandibular plane angle, a more protrusive mandibular position and more protrusive upper and lower incisor positions. These findings are similar to data previously reported with regard to the vertical dimension,[4,6,8,10] the mandibular position,[8] and the upper[4,6] and lower[4,6] incisors position.

Comparison between study sample and Ann Arbor male sample

Only three variables (facial axis angle; upper incisor to Point A vertical; lower incisor to APO line) were found to be significantly different between the current study and the Ann Arbor sample. The facial axis angle in the present study sample was smaller (more negative, i.e. -1.5° versus 0.5°) than that of the Ann Arbor sample. The mean value of upper incisors to Point A vertical in this study was 3.2 mm larger compared with the Ann Arbor male sample. The lower incisor to APO measurement was 4.2 mm greater than the McNamara norms.

These findings were in agreement with those of a number of researchers for both upper and lower incisor positions.[6-8,10] Furthermore, the findings in this study concur with those of other studies with regards to the facial axis angle.[6,11]

The other eight variables showed no statistically significant differences between the two groups. However, the mean values for the effective mandibular length, effective maxillary length and pogonion to nasion perpendicular were larger in the Ann Arbor male sample. On the contrary, the mean values of the nasion perpendicular to point A and mandibular plane angle were larger in the Black male sample. Similar findings have been reported for effective mandibular and maxillary lengths.[6,7,10,11] Additionally, larger lower anterior facial height values have also been found.[6,8,10]

The results of the current study suggest that Black subjects have protrusive upper and lower incisors (bimaxillary protrusion) as well as an increased lower anterior facial height. A combination of increased lower facial height with relatively shorter maxilla and mandible (a finding in the current study although not statistically significant) further suggests that Black subjects of the present study have a tendency to downward and backward rotation of the mandible and a convex facial profile compared with Caucasians.

Comparison between study sample and Ann Arbor female sample

A comparison of the female results showed that the values of seven (7) out of eleven (11) variables were statistically significantly larger in the present study compared with the McNamara norms. These variables are: SNA angle; nasion perpendicular to point A; effective mandibular length; effective maxillary length; lower anterior facial height; upper incisors to point A; and lower incisors to APO. Except for the Saudis[8] mandibular and maxillary lengths, the values from the present study revealed larger figures than any reported previously (Table 6).

Authors	McNamara		Miyajima et al.		Basciftci et al.		Al-Barakati and Talic		Nahidh		Gu et al.		Present study	
Year	1984		1996		2004		2007		2010		2011		2014	
Country	USA		Japan		Turkey		Saudi Arabia		Iraq		China		South Africa	
Gender	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Sample	38	73	26	28	50	55	36	29	33	42	25	40	12	18
NP-A (mm)	1.1	0.4	2.5	2.3	0.7	0.2	-2.0	-0.2	1.6	0.7	1.0	0.0	1.3	3.8
SNA (°)	83.9	82.4	82.2	82.1	83.3	81.9	-	-	83.8	81.8	85.1	83.6	83.2	85.8
Co-Gn(mm)	134.3 [132.3]*	120.2	125.5	118.8	126.4	117.8	133.4	124.9	121.4	111.0	125.4	119.4	129.6	123.5
Co-A (mm)	99.8	91.0	91.4	86.3	95.1	90.4	101.7	98.2	93.2	85.5	92.0	87.5	98.5	95.5
MM diff (mm)	34.5 [32.5]**	29.2	34.1	32.5	31.3	27.4	31.8	26.8	28.2	25.7	33.4	31.9	31.1	28.0
LAFH (mm)	74.6	66.7	75.1	72.7	75.1	68.3	76.1	68.9	68.8	63.4	74.9	69.4	77.1	73.7
FMPA (°)	21.3	22.7	22.3	26.1	-	-	24.9	25	21.7	23.9	-	-	22.6	23.4
FAA (°)	0.5	0.2	-4.2	-3.5	-1.3	-1.0	2.8	2.9	-0.6	-0.2	-5.4	-2.2	-1.5	0.3
Pog-NP (mm)	-0.3	-1.8	0.3	-1.7	-1.5	-1.8	-6.1	-5.9	-0.1	-1.4	-3.2	-6.6	-3.4	-0.8
UI-PA Vert (mm)	5.3	5.4	5.7	6	-	-	6.2	4.3	6.4	5.9	5.2	4.5	8.5	9.6
LI-A-Pog (mm)	2.3	2.7	4	4.9	2.6	2.3	4.4	3.6	4.0	4.0	4.1	4.1	6.5	7.3

Table 6. Mean values of variables comprising the McNamara analysis of adult samples from different population groups

* and ** are revised values for effective mandibular length and maxillomandibular differential respectively (McNamara & Brudon, 2001).

The current findings with regard to the position of maxilla differ from the results of other studies that found the SNA to be smaller than that of the McNamara norms.[6,7,10] Similar results of smaller mean values of point A to nasion perpendicular were reported in two studies.[8,11]

A similar trend of smaller values than the McNamara norms was found with regard to effective mandibular and maxillary lengths.[6,7,10,11] By contrast, several studies reported greater values than the McNamara norms for the lower anterior facial height,[6-8,11] upper incisor to point A vertical[6,10] and lower incisors to APO.[6,8,10,11]

The interpretation of the current findings suggests that the Black female subjects had prognathic maxillae (larger SNA and nasion perpendicular to point A), larger mandibles (effective mandibular length) and maxillae (effective maxillary length), longer lower anterior facial height and procumbent upper (upper incisors to point A vertical) and lower incisors (lower incisors to APO). In addition, the mandible was also protrusive, even though the values were not statistically significant.

These findings further suggest that a combination of larger maxilla, protrusive maxilla and maxillary incisors together with larger mandible, protrusive mandible and mandibular incisors (bimaxillary skeletal and dental protrusion) is a characteristic feature of the current female study subjects.

Bimaxillary protrusion has been established as a common feature among the general Black population as well as among Black South African subjects.[16-20] Our study sample subjects, therefore, appear to have facial features shared with other Black individuals from other parts of the world.

Limitation of the study

The sample size in this study was small. However, it was representative of the target population. A large number of significance tests were also carried out on the data. These two factors increase the possibility of making type I and II errors.

CONCLUSION

Within the limitations of the current study, the following conclusions can be drawn:

- There are significant gender differences in the study sample, with male subjects having significantly larger mandibles, maxillae and lower anterior facial height structures.

- The present male study subjects demonstrated a significantly smaller facial axis angle, and significantly more procumbent upper and lower incisors compared with the Ann Arbor sample.

- The females from this study were found to have significantly larger and protrusive maxillae, significantly larger but non-significantly protrusive mandibles, significantly greater lower anterior facial heights, and significantly procumbent upper and lower incisors compared with the Caucasian Ann Arbor sample.

- The Ann Arbor (McNamara) norms may be applicable to the male study sample except for the facial axis angle, upper incisors to Point A vertical and lower incisors to A-Po line measurement. The Ann Arbor norms are, however, not applicable to the female study sample.

- A more comprehensive survey including a larger sample drawn from a wider population is indicated to confirm the results of this study.

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