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Investigation of the osteometry of the skull of the one-humped camels. Part II: sex dimorphism and geographical variations in adults

Ahmed Yahaya[1], James O. Olopade[2,*], Hyelduku D. Kwari[1], Ibrahim M. Wiam[1]

[1] Department of Veterinary Anatomy, University of Maiduguri, Maiduguri, Nigeria
[2] Department of Veterinary Anatomy, University of Ibadan, Ibadan, Nigeria

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Summary

Sexual dimorphism in the skull of different species has been of importance in archaeological, forensic and anatomical studies; also, a variation in phenotypic and genetic traits across geographic space is a recurring phenomenon in biological species. This study investigated 10 adult camels from each of three geographical locations in northern Nigeria, for sex- and location-based variations in the skulls. In one location, male skulls had greater absolute osteometric values but there were no significance differences in relative proportions between sexes. Moreover, all index values (skull, cranial and facial) indicate no sexual dimorphism in all locations. There were some variations in the osteometry of the frontal region, and neurocranial volume between the locations. In addition it was observed that the skull index of Nigerian camels was similar to the Malha type documented in literature but wide variations exist in many other craniometric dimensions of the skull. This suggests a definite difference in phenotype and probable origin.

Key words

Adult; anatomy; domestic animals; skull; morphometry; sexual characteristics

Introduction

Sexual dimorphism in the skull of different species has been of importance in archaeological, forensic and anatomical studies (Bornholdt *et al.*, 2008). While classical differences can be seen in phenotypic characters of the skull between sexes in some species (Olopade, 2006) they may be marginal in others, requiring precise morphometric examinations to distinguish them (Mazak, 2004; Virgl *et al.*, 2009). In certain species, some skull growth features are sexually dimorphic in adults and might be related to specific anatomical functions. Such functions may include an enhanced auditory capacity, a need for increased development of the cranial musculature, and also the necessity of increased mandibular strength necessary for mastication (Monterio *et al.*, 2003); thus in cases where similarity in skull shape between sexes is found, it has been associated with factors like a similar diet (Virgl *et al.*, 2009).

Variation in phenotypic and genetic traits across geographic space is a recurring phenomenon in biological species (Monterio *et al.*, 2003). Differences in skull shape and size has been noticed in the same animal breeds based on geographical locations (Endo et

* Corresponding author. Email addresses: jkayodeolopade@yahoo.com, jo.olopade@mail.ui.edu.ng.

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al., 2005). Phenotypic differentiation has become relevant not only for accessing underlying genetic differentiation, but also because the observed phenotypes are products of a complex interface among morphogenetic rules, ecological phenomena, and evolutionary effects (Oster *et al.*, 1988; Murray, 1990, 2000; Levin and Pacala, 1997). Monterio et al. (2003) showed in rats that the dorsal, lateral and ventral views of the skull and the mandible were significantly associated with specific environmental variables.

Camels (*Camelus dromedarius*) in Nigeria are concentrated in the arid and semiarid zones of the country. Their introduction into northern Nigeria can be linked to the caravan trade through different routes (Ritter, 1988; Bernus, 1990). There is however a scarcity of information on the effect of sex and geographical variation in these species based on skull morphometry. To expand this knowledge, the present study examines different osteometric indices in adult camels from different geographical regions of the northern Nigeria.

Materials and methods

A total of thirty adult camels of both sexes (over five years of age) in Nigeria from North East (NE; N = 10), North Central (NC; N = 10) and North West (NW; N = 10) were used for our investigations. The animal age was estimated using dental formula (Williamson and Payne, 1978). The camel heads were obtained after slaughter in the main abattoirs and the skulls were macerated (Ozcan *et al.*, 2010). A total of 28 craniometric indices were used in the measurements (in dorsal view, lateral view, ventral view, and medial view upon sagittal skull sectioning) which are described herein and most are depicted in Figs. 1-6.

Mean values and standard error of the mean were obtained for each parameter. Independent values *t* test was used to analyze gender difference within each location. One-way analysis of variance (ANOVA) was employed to analyze the variations across the three locations; means were separated using least significant difference test.

Craniometric measurements and indices

1. Inter-orbital width (**IOW**): Minimum distance between the upper edges of the orbits measured across the tip of the skull (Fig. 1).
2. Inter-canthi distance (**ICD**): Minimum distance between the median margins of the orbits (Fig. 1).
3. Facial triangle breadth (**FTB**): Breadth, i.e. base (on a transversal line) of the triangle created by the bifurcation of the external sagittal crest (Fig. 1).
4. Facial triangle length (**FTL**): Length of the oblique side of the triangle created by the bifurcation of the external sagittal crest (Fig. 1).
5. Facial triangle height (**FTH**): Height (on a sagittal line) of the triangle created by the bifurcation of the external sagittal crest (Fig. 1).
6. Facial triangle area (**FTA**): ½ FTB x FTH.
7. Maximum width of the neurocranium (**WNC**): Distance from the most lateral point of the cranial cavity on the left to most lateral point of the cranial cavity on the right (Fig. 2).
8. Maximum zygomatic width (**ZGW**): Maximum distance between the zygomatic arches (Fig. 2).
9. Cranial length (**CL**): Distance from nuchal crest to the junction of the left and right nasofrontal sutures on the median plane (Fig. 2).

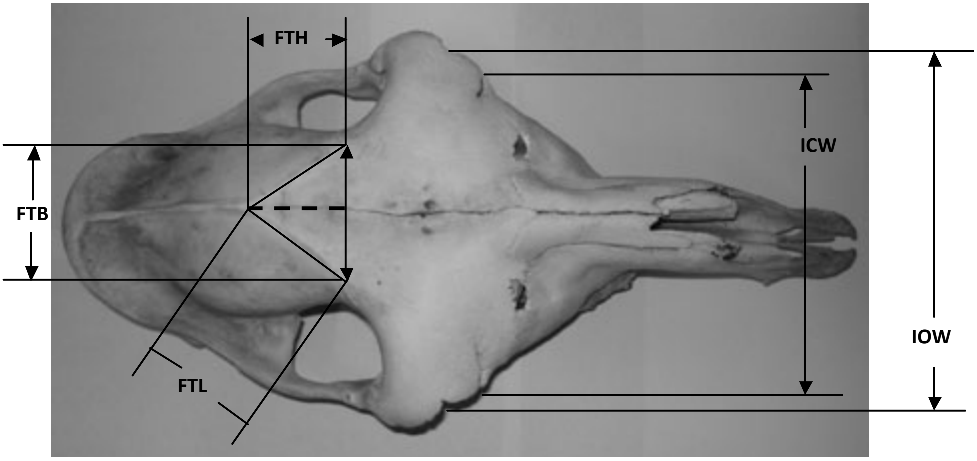

Figure 1 – Camel skull (dorsal view) showing the inter-orbital width (IOW), inter-canthi distance (ICD), nasal length through the mid-line (NL 1), nasal length along the side (NL 2), nasal width (NW), facial triangle breath (FTB), facial triangle length (FTL) and facial triangle height (FTH).

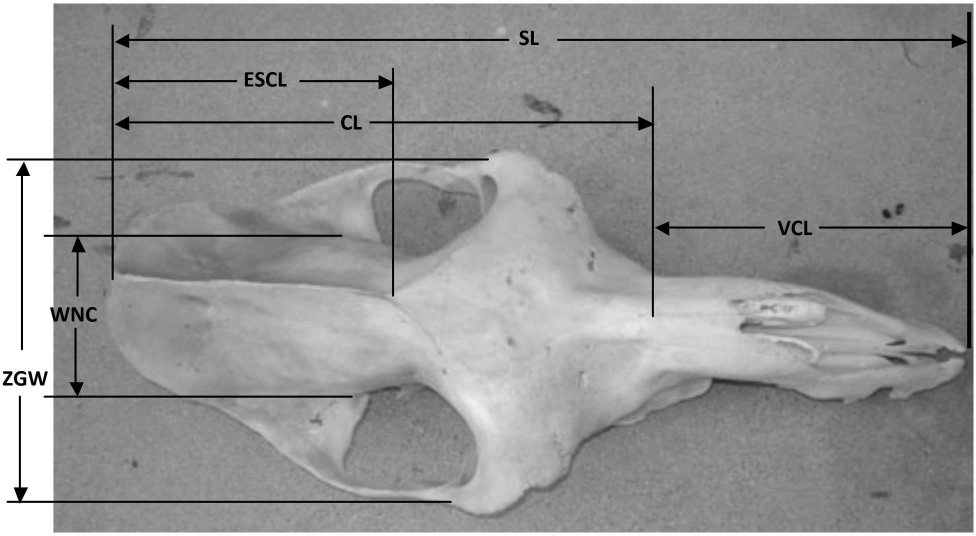

Figure 2 – Camel skull (dorsal view) showing maximum width of the neurocranium (WNC), maximum zygomatic width (ZGW), cranial length (CL), viscerocranial length (VCL), external sagittal crest length (ESCL) and skull length (SL).

10. Cranial index (**CI**): (WNC x 100) / CL.
11. Viscerocranial length (**VCL**): Distance from the junction of the left and right naso-frontal sutures in the median plane to the anterior end of the inter-incisive suture (Fig. 2).

12. Facial index (**FI**): (ZGW x 100) / VCL.
13. External sagittal crest length (**ESCL**): Distance from the caudal extremity of the external crest to the origin of its cranial bifurcation (Fig. 2).
14. Skull length (**SL**): Maximum dimension of the skull when laid on an even surface from the cranial tip of the incisive bones to the caudal level of the nuchal crest (Fig. 2).
15. Distance between the left and right depression (**DMXD**): Distance between the ventral bony limit of the left maxillary depression rostral to the second upper premolar measured over the nasal bone to the corresponding point on the right side (Fig. 3).
16. Skull height (without mandible) (**SH**): Length from the level of the highest point of the frontal bone to the base of the jugular process (Fig. 3).
17. Orbital circumference length (**OBCL**): Maximum circumference of the orbit, along the rim (Fig. 3).
18. Orbital horizontal diameter (**OBHD**): Maximum horizontal diameter of the orbit (Fig. 4).
19. Orbital vertical diameter (**OBVD**): Maximum vertical diameter of the orbit (Fig. 4).
20. Condylobasal length (**CBL**): Length of the skull measured from the cranial tip of the incisive bones to the rear surface of the occipital condyles (Fig. 4).
21. Basal length (**BL**): Length from the cranial alveolar end of the mandible to the occipital condyles at the level of the jugular process (Fig. 4).
22. Whole skull height (**WSH**): Distance from the highest level of the external sagittal crest to the lowest level of the mandible (Fig. 4).
23. Mandibular depth (**MD**): Distance measured from the point of bifurcation of the external sagittal crest to the lowest point of the angle of the mandible (Fig.4).
24. Mandibular index (**MI**): (MD x 100) / BL.
25. Skull index (**SI**): (ZGW x 100) / SL.
26. Neurocranium height (**NCH**): Vertical distance from the deepest indentation of the sella turcica to the inner layer of the cranium roof (Fig. 5).

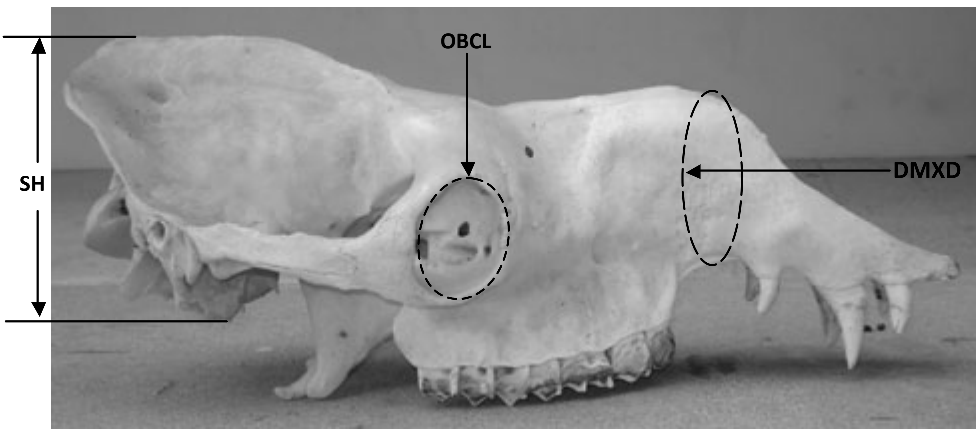

Figure 3 – Camel skull without the mandible (lateral view) showing orbital circumference length (OBCL), distance between the left and right depression (DMXD) and skull height (SH).

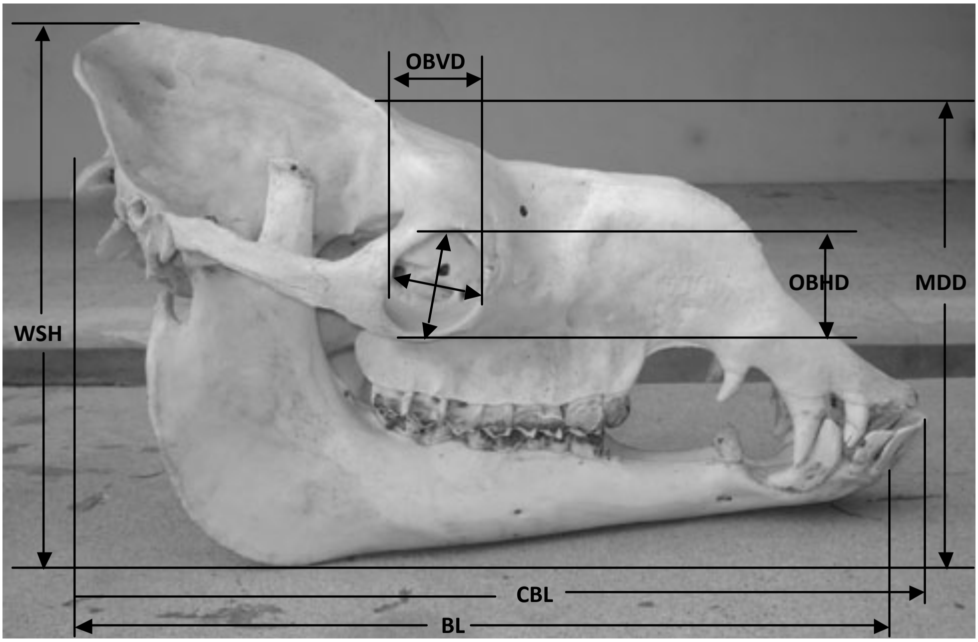

Figure 4 – Camel skull with the mandible (lateral view) showing orbital horizontal diameter (OBHD), orbital vertical diameter (OBVD), basal length (BL), condylobasal length (CBL) and whole skull height (WSH).

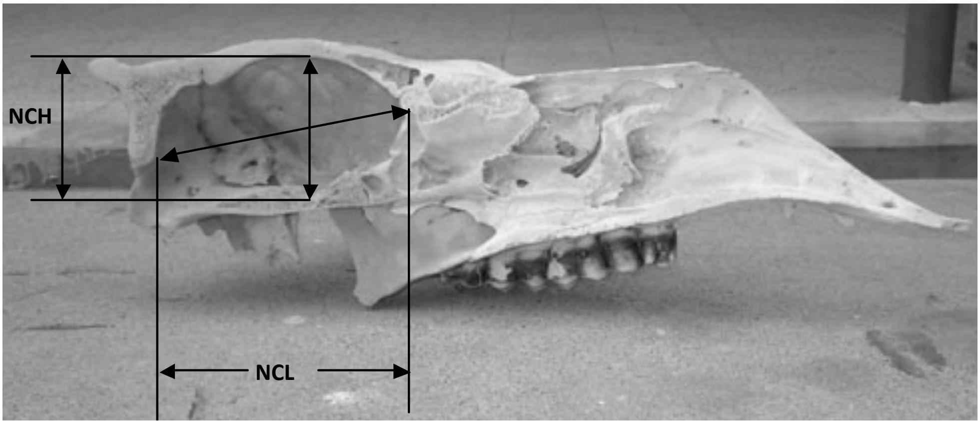

Figure 5 – Sagittal sections of the skull of the camel showing neurocranium height (NCH) and neurocranium length (NCL).

27. Neurocranium length (**NCL**): Length along the midline from the deepest indentation of the frontoethmoidal junction to the inner aspect of the external occipital protuberance (Fig. 5).
28. Neurocranium volume (**NCV**). The volume of the neurocranium in milliliters;

measured by using fresh plasticine to block all the foramina of the intact skull and filling the neurocranium with fine quality millet grains through the foramen magnum to the level of the distal border of the foramen. The millet was then emptied into a measuring cylinder to determine the volume.

Results

The results obtained in this study are shown in Tables 1-5. Maiduguri camels had significantly longer width of the neurocranial cavity than those from Sokoto while the camels from both Maiduguri and Kano had significantly wider cranial cavities than those from Sokoto. The neurocranium volume decreased from Maiduguri to Kano to Sokoto camels; the difference between Maiduguri and Sokoto camels was significant. The Sokoto and Kano camels did not exhibit sexual dimorphism in any parameter studied while the Maiduguri camels showed sexual dimorphism for several parameters, with values higher for males than females.

Discussion

The results of this study show that the male camels from Maiduguri possess bigger skulls than the females as seen by significantly higher and longer skull (SL, BL, WSH, MD and SH), and longer viscerocranial length. Unfortunately, we were not able to weigh the camels at the time of this study. The higher values obtained might be body size dependent, because of insignificant differences in relative proportions, that is, in the index values (skull facial and cranial) between sexes, indicating that the observed sexual dimorphism in skull shape may be proportional to differences in size as reported by Cardini and Elton (2007).

The dorsal view of the camel skulls revealed a relatively smaller surface for Sokoto camels particularly in the region of the temporal line and frontoparietal junction. This is evidenced by relatively smaller frontal triangle (FTA, FTL, FTB and FTH) and these osteometric differences may affect the anatomic presentation of the internal frontal sinus, which is worthy of further investigation. The frontal sinus has the most complex and variable drainage of any paranasal sinuses (Daniels *et al.*, 2003). In addition, the Sokoto camels have the smallest maximum neurocranial width (WNC), however, the relatively long cranial length of these camels accounted for the lack of significant difference in the cranial index when compared with camels from Maiduguri and Kano.

The values of the WNC and subsequently the cranial index in this study was however far smaller then the 15.96 cm and 72.9 respectively in adult malha camels in Saudi Arabia (Alsagair and ElMougy, 2002). In contrast, the maximum zygomatic width (MZW) obtained in the malha camel were similar to Nigerian camels but wide variations in the viscerocranial length being far shorter in Nigerian camels meant that the latter had far larger values for the facial index. The longer VCL thus depicts a longer nasolabial region for the malha camels.

There were no major differences in the morphometric dimensions from the lateral view. In particular the orbitometrics of the camels between the three different locations were similar with orbits presenting similar vertical and horizontal diameters

Table 1 – Osteometric measures and indices of adult camels in Nigeria (appreciable from a dorsal view).

	MD	MMD	FMD	KN	MKN	FKN	SK	MSK	FSK
Inter-orbital width (IOW)	19.30 ± 0.22	19.44 ± 0.18	19.16 ± 0.42	19.14 ± 0.37	19.74 ± 0.58	18.54 ± 0.30	18.95 ± 0.40	19.76 ± 0.59	18.14 ± 0.25
Inter-canthi distance (ICD)	16.51 ± 0.21	16.78 ± 0.34	16.24 ± 0.22	16.49 ± 0.31	17.00 ± 0.40	15.98 ± 0.37	16.14 ± 0.37	16.96 ± 0.43	15.32 ± 0.30
Maximum width of the neurocranium (WNC)	9.78 ± 0.11[a]	9.70 ± 0.18	9.86 ± 0.14	9.63 ± 0.07	9.64 ± 0.02	9.62 ± 0.14	9.41 ± 0.13	9.62 ± 0.18	9.20 ± 0.15
Maximum zygomatic width (ZGW)	21.43 ± 0.20	21.88 ± 0.26[c]	20.98 ± 0.11	21.25 ± 0.40	22.12 ± 0.40	20.38 ± 0.44	20.85 ± 0.38	21.26 ± 0.73	20.44 ± 0.12
Cranial length (CL)	26.94 ± 0.43	27.40 ± 0.66	26.48 ± 0.55	27.25 ± 0.48	28.38 ± 0.53	26.12 ± 0.35	26.58 ± 0.45	27.02 ± 0.87	26.14 ± 0.24
Viserocranial length (VCL)	20.51 ± 0.34	21.20 ± 0.44[c]	19.82 ± 0.27	19.71 ± 0.36	19.96 ± 0.47	19.46 ± 0.56	19.87 ± 0.34	20.40 ± 0.45	19.34 ± 0.44
External sagittal crest length (ESCL)	13.01 ± 0.36	13.90 ± 0.19	12.12 ± 0.40	13.42 ± 0.54	14.66 ± 0.38	12.18 ± 0.65	13.05 ± 0.55	14.14 ± 0.76	11.96 ± 0.42
Distance between the left and right maxillary depression (DMXD)	21.96 ± 0.40	22.64 ± 0.45	21.28 ± 0.52	21.65 ± 0.37	22.44 ± 0.39	20.86 ± 0.40	21.28 ± 0.64	22.74 ± 0.74	19.82 ± 0.49
Facial Triangle Breath (FTB)	6.71 ± 0.18[b]	6.80 ± 0.23	6.62 ± 0.31	6.79 ± 0.16[b]	N/A	N/A	5.99 ± 0.24	6.22 ± 0.32	5.76 ± 0.36
Facial Triangle length (FTL)	5.86 ± 0.15[b]	5.84 ± 0.19	5.88 ± 0.26	5.93 ± 0.22[b]	5.68 ± 0.26	6.18 ± 0.33	5.06 ± 0.22	4.94 ± 0.25	5.18 ± 0.38

(Continued)

Table 1 – Continued.

	MD	MMD	FMD	KN	MKN	FKN	SK	MSK	FSK
Facial Triangle Breath (FTH)	4.78 ± 0.10^{a}	4.80 ± 0.16	4.76 ± 0.14	4.57 ± 0.27	4.20 ± 0.32	4.94 ± 0.40	4.18 ± 0.21	4.08 ± 0.21	4.28 ± 0.38
Facial Triangle area (FTA)	15.72 ± 0.72^{b}	15.96 ± 1.08	15.48 ± 1.05	15.56 ± 1.05^{b}	14.24 ± 1.52	16.88 ± 1.33	12.39 ± 0.84	12.30 ± 0.69	12.48 ± 1.63
Cranial index (CI)	36.37 ± 0.67	35.50 ± 1.06	37.24 ± 0.69	35.47 ± 0.68	34.02 ± 0.68	36.92 ± 0.74	35.43 ± 0.50	35.66 ± 0.99	35.20 ± 0.36
Facial Index (FI)	104.59 ± 1.53	103.20 ± 2.44	105.98 ± 1.89	107.98 ± 2.06	110.96 ± 2.26	105.00 ± 3.08	105.00 ± 1.29	104.12 ± 1.73	105.88 ± 2.03

MD: Maiduguri camels; MMD: Male Maiduguri camels; FMD: Female Maiduguri camels; SK: Sokoto camels; MSK: Male Sokoto camels; FSK: Female Sokoto camels; KN: Kano camels; MKN: Male Kano camels; FKN: Female Kano camels. Measures are in cm, indices in per cent. Figures indicate mean ± standard error of the mean.
a: significantly different at 0.05 level of significance between MD and SK.
b: significantly different at 0.05 level of significance compared to SK
c: significantly different at 0.05 level of significance between MMD and FMD.
N/A: not available

Table 2 – Osteometric measures and indices of adult camels in Nigeria (appreciable from a lateral view)

	MD	MMD	FMD	KN	MKN	FKN	SK	MSK	FSK
Condylobasal length (CBL)	45.99 ± 1.35	48.28 ± 0.58	43.70 ± 2.29	46.59 ± 0.65	47.76 ± 0.75	45.13 ± 0.58	45.97 ± 0.89	47.56 ± 1.24	44.38 ± 0.87
Skull length (SL)	47.86 ± 0.74	49.42 ± 0.80[c]	46.30 ± 0.79	47.47 ± 0.83	49.44 ± 0.86	45.50 ± 0.65	46.86 ± 0.89	48.26 ± 1.38	45.46 ± 0.81
Basal length (BL)	43.58 ± 0.63	44.88 ± 0.61[c]	42.28 ± 0.74	43.61 ± 0.59	44.02 ± 1.07	43.10 ± 0.23	43.13 ± 0.83	44.56 ± 1.20	41.70 ± 0.82
Whole skull height (WSH)	25.90 ± 0.50	26.90 ± 0.44[c]	24.90 ± 0.65	25.37 ± 0.44	26.14 ± 0.52	24.60 ± 0.56	24.61 ± 0.78	26.40 ± 1.01	22.82 ± 0.37
Mandibular depth (MD)	23.61 ± 0.30[a]	24.24 ± 0.32[c]	22.98 ± 0.31	22.99 ± 0.21	23.30 ± 0.26	22.68 ± 0.29	22.42 ± 0.55	23.30 ± 0.89	21.54 ± 0.45
Skull height, without mandible (SH)	11.14 ± 0.24	11.76 ± 0.16[d]	10.52 ± 0.19	10.69 ± 0.19	10.98 ± 0.23	10.40 ± 0.26	10.55 ± 0.24	11.06 ± 0.31	10.04 ± 0.21
Orbital circumference length (OBCL)	19.56 ± 0.28	19.80 ± 0.53	19.32 ± 0.20	19.07 ± 0.21	19.08 ± 0.41	19.06 ± 0.15	18.90 ± 0.20	18.82 ± 0.30	18.98 ± 0.30
Orbital horizontal diameter (OBHD)	6.01 ± 0.07	6.10 ± 0.13	5.92 ± 0.05	5.92 ± 0.05	5.92 ± 0.06	5.92 ± 0.09	5.86 ± 0.05	5.82 ± 0.09	5.90 ± 0.05
Orbital vertical diameter (OBVD)	5.99 ± 0.12	6.12 ± 0.21	5.86 ± 0.10	5.93 ± 0.08	6.06 ± 0.12	5.80 ± 0.09	5.80 ± 0.07	5.86 ± 0.08	5.74 ± 0.12
Mandibular Index (MI)	54.12 ± 0.56[a]	54.00 ± 0.47	54.24 ± 1.09	53.33 ± 0.70	53.04 ± 1.23	53.62 ± 0.81	51.93 ± 0.84	52.26 ± 1.17	51.60 ± 1.32
Skull Index (SI)	44.80 ± 0.60	44.24 ± 0.81	45.36 ± 0.90	44.77 ± 0.43	44.74 ± 0.32	44.80 ± 0.85	44.52 ± 0.48	44.04 ± 0.60	45.00 ± 0.75

Headline abbreviations as in table 1. Measures are in cm, indices in per cent. Figures indicate mean ± standard error of the mean.
a: significantly different at 0.05 level of significance between MD and SK.
c: significantly different at 0.05 level of significance between MMD and FMD
d: significantly different at 0.01 level of significance between MMD and FMD

Table 3 – Osteometric indices of adult camels in Nigeria (appreciable from a medial view)

	MD	MMD	FMD	KN	MKN
Neurocranium volume (NCV)	582.50 ± 14.24[a]	606.00 ± 21.6	559.00 ± 12.8	563.50 ± 13.17	568.00 ± 24.63
Neurocranium height (NCH)	8.00 ± 0.09	8.13 ± 0.03	7.87 ± 0.15	7.80 ± 0.09	7.93 ± 0.03
Neurocranium length (NCL)	16.88 ± 0.24	17.27 ± 0.20	16.50 ± 0.31	16.45 ± 0.22	16.80 ± 0.15

	FKN	SK	MSK	FSK
Neurocranium volume (NCV)	559.00 ± 12.79	521.00 ± 14.75	541.00 ± 22.7	501.00 ± 16.3
Neurocranium height (NCH)	7.67 ± 0.15	7.72 ± 0.12	7.70 ± 0.25	7.73 ± 0.09
Neurocranium length (NCL)	16.10 ± 0.31	16.73 ± 0.16	16.97 ± 0.24	16.50 ± 0.12

Headline abbreviations as in Table 1. Measures in cm, NCV is in ml. Figures indicate mean ± standard error of the mean.
a: significantly different at 0.05 level of significance between MD and SK.

unlike that seen in humans (Weaver *et al.*, 2010). The skull lengths also showed similarity between locations in the camels but were slightly smaller (maximum mean of 47.9 cm) than the malha type camels (50.5 cm); so since the MZW was similar, the skull index of the Nigerian camels and the malha type showed similarity in values.

The neurocranial lengths and heights were similar for all adult camels; however, the neurocranial capacity was significantly larger in Maiduguri and Kano than in Sokoto camels. This is most likely due to the larger width of the neurocranium in the former. The value of 311 ml obtained in malha camels is far smaller than those obtained in Nigeria, where a minimum mean value of 521 ml was obtained. These significant differences in neurocranial volume within Nigerian camels and between them and those of the malha type could relate to differences in brain volume (Manjunath, 2002).

This study shows that the skull index of Nigerian camels and of those of the malha type are similar while wide metric variations exist in many other dimensions of the skull. This suggests that the malha type camels differ in phenotype and probably in origin from the Nigerian camels; the latter are not traditional animals to the region (Mohammed and Hoffmann, 2006) but migrants from countries northern to Nigeria.

In conclusion, our data show the pattern on the skull profile of camels in Nigeria depending on sex and geographical location, providing information potentially important for basic and clinical anatomy, breeding studies and phenotypic profiling of camels.

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