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Original Research Article

Craniometric indices of the skull of adult Nigerian indigenous Pigs (*Sus scrofa*)

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ABSTRACT

The structure of the skull is a unique feature of each animal that allows for individual, breed and species differentiation. Craniometric analyses involve the determination of skull dimensions between anatomically-defined landmarks and such dimensions are useful in assessing the contributions of genetic and environmental components to an individual's development. The present study was designed to investigate 35 craniometric indices of 24 adult Nigerian indigenous pigs (NIP) skulls (10 males and 14 females). The data obtained were analysed using the Student's t-test (p≤0.05) and Pearson Correlation (p≤ 0.05). The study revealed that 42.8% of the measured parameters were higher in males. The skull length was 23.02±0.35cm and 22.02±0.25cm, skull width was 11.01±0.18cm and 11.01±0.17cm, whole skull index was 63.26±1.60 and 65.07±0.48, and foramen magnum index was 104.15±2.70cm and 98.03±1.70cm, for males and females respectively. These values were however not statistically significant (p>0.05) between both sexes. The skull of the NIP was categorised as dolichocephalic, according to its cephalic index (63.26±1.60). The orbit of the NIP appeared slightly oval in shape, having a relatively higher vertical diameter than the horizontal diameter. The mandibular length was statistically longer in male skulls (19.02±0.41cm) when compared to female skulls (18.04±0.26cm). The skull length showed a significant positive association with the skull width and the nasal bone length, while the foramen magnum width showed a significant positive association with the foramen magnum index. Data generated provide important information on the skull of NIP which can be used for comparative anatomical, developmental, forensic, and clinical studies.

Keywords: Comparative anatomy, craniometry, neurocranial volume, Nigerian indigenous pigs.

INTRODUCTION

The Pig, *Sus scrofa,* belongs to the super-order *Ungulata,* with the other hoofed mammals, the order *Artiodactyla* and Family *Suidae* (Myers *et al*., 2022), and having around 500 species, with varied shape, size, colour and reproductive potentials (Rothschild, 2004; Wiener and Wilkinson, 2011; Wilkinson *et al*., 2013; Osei-Amponsah *et al*., 2017). The Nigerian indigenous pig (NIP), also called the Nigerian local pig or the West African dwarf pig, is as small-bodied omnivore with a short forehead, an elongated snout, and medium-sized, partly-erect prominent ears. They have narrow body conformations with relatively long legs, which have two functional and non-functional hooved digits, respectively. Their rumps are slightly raised, and their coiled or straight tails terminate as tassels. They are predominantly black-coloured, moderately-sized and very precocious, producing up to 7 piglets per litter. They are able to withstand heat and periods of food scarcity, with a reduced growth rate and poor carcass characteristics. They are usually found living within human communities, raised under semi-intensive management (Pathiraja and Oyedipe, 1990; Yalden, 2001; Adeola *et al*., 2013; AU-IBAR, 2015).

The structure of the skull is a unique feature of each animal that allows for identification of not only species and breeds, but also individuals (Jashari *et al*., 2022). Craniometric analysis involves the determination of skull dimensions between anatomically-defined landmarks (Christensen *et al*., 2019). Since the phenotypic appearance of the head of animal species is greatly influenced by the shape of the skull (Kunzel *et al*., 2003), craniometry is useful in ancestral estimation due to geographical variations in cranial sizes and shapes by identifying patterns in shape and size of skulls, beyond gross appearances (Christensen *et al*., 2019). Craniometric dimensions are regarded as useful indicators of an individual's healthy development (Košinová *et al*., 2022), and are important yardsticks in the assessment of animal breeds and the contributions of genetic and environmental components to individual development (Onar 1999; Onar *et al*., 2001; Endo *et al*., 2002). They are also of clinical importance, in the regional anaesthesia of an animal's head

(Hall *et al.,* 2000; Olopade and Onwuka, 2007; Olopade and Okandeji, 2010), for interpreting the biokinetics and biomechanics of mastication (Tera *et al.*, 1998), in the study of skull sexual dimorphism (Onar *et al*., 2001), in the areas of taxonomy, forensics and anthropology, comparative anatomy, implantology and stereotaxic practices (Choudhary and Singh, 2016; Jashari *et al*., 2022). In humans, craniometry has been used in the areas of plastic surgery and genetic counselling (Ulcay and Kamaşak, 2021).

Craniometry has been reported in domestic and wild animals, including camel (Yahaya *et al*., 2011), cats (Kunzel *et al*., 2003; Uddin *et al*., 2013), cattle (Monfared, 2013; Gambo *et al*.,2019; Choudhary *et al*., 2020), dogs (Onar, 1999; Igado *et al*., 2014), goats (Olopade and Onwuka 2007; Shawulu *et al*., 2008; Olopade and Onwuka, 2009; Samuel *et al*., 2013), rabbit (Salih, 2013), sheep (Baranowski, 2017; Gundemir *et al*., 2020), antelope (Choudhary *et al*., 2014), sun bear (Kalita *et al*., 2019), and lion (Mohammed, 2019). In pigs, craniometry has been reported in skulls of wild, domestic and local pigs (Endo *et al*., 2002; Olopade and Okandeji, 2010; Okandeji, 2012; Constantinescu *et al.*, 2014; Choudhary, 2017; Choudhary *et al*., 2018; Doley *et al.*, 2018; Iqbal *et al.*, 2020). However, there appears to be no available information on the craniometric indices of the skulls of adult Nigerian indigenous pigs. This study was therefore designed to provide these craniometric data, which may serve as a baseline for comparative anatomical, clinical and gender variation studies, in a continuing effort to provide information on this breed of pig.

MATERIALS AND METHODS

EXPERIMENTAL ANIMALS

For this study, 24 (10 males and 14 females) skulls of adult NIP were used. The skulls were obtained from live pigs used for another research and Ethical approval was obtained for the study. Animal selection was based on parameters of apparent good health and absence of cranial deformities. The age of each skull was obtained from available records of live pigs, prior to slaughter, and varied between 24-51 months. The animals used were restrained and slaughtered by quick decapitation at the atlanto-occipital joint. The severed heads were prepared using a modification of the hot water maceration technique described by Okandeji (2012). Pictures of the skulls were taken with a Nikon COOLPIX L320® (16.1 Megapixels) digital camera.

CRANIOMETRIC INDICES MEASURED

A total of 35 mandibular, maxillofacial and craniometric indices were obtained, as adapted from Onar *et al* (2001); Endo *et al* (2002); Olopade and Okandeji (2010); and Choudhary *et al.*, (2019). Measurements were taken using a metric rule, digital Vernier calliper, a pair of dividers and pieces of twine. All the measured parameters are as described below:

1. Skull length **(SL):** length of the skull measured from the front of the pre-maxillary bones to the most caudal surface of the occipital bone.
2. Skull height **(SH)**: Distance from the nuchal crest to the ventral tip of the jugular process.
3. Whole skull height **(WSH):** Distance from the highest level of the frontal bone (nuchal crest) to the lowest level (base) of the mandible.
4. Skull width **(SW)**: Maximum distance between the two zygomatic arches.
5. Whole skull index **(WSI):** WSH÷SL x 100
6. Height of Occipital bone **(HOC)**: Distance from base of the occipital condyle to the starting point of sagittal crest
7. Foramen Magnum height **(FMH**): Distance of the mid-vertical height of the foramen magnum.
8. Foramen Magnum width **(FMW)**: Largest width of the foramen magnum.
9. Foramen Magnum index **(FMI):** FMH÷FMW×100
10. Inter-condylar width **(icW**): Distance between the lateral ends of the condyles of the occipital bone.
11. Inter-paracondylar Width **(IPW)**: Widest breath between the most lateral ends of the para-condylar process.
12. Horizontal diameter of orbit **(HDO):** Distance between the rostral and caudal margins of the orbit.
13. Vertical diameter of orbit (**VDO**): Distance between the dorsal and ventral margin of the orbit.
14. Length of orbit **(LOR)**: Maximum circumference of the orbit, from rim to rim. It includes HDO and VDO.
15. Orbital index**:** VDO÷HDO×100
16. Inter-canthi distance **(ICD)**: Minimum distance between the media margins of the orbits.
17. Inter-orbital distance **(IOD)**: Distance between the cranial rims of the zygomatic processes of the frontal bone.
18. Length of maxillary bone **(LmB)**: Maximum rostro-caudal extent of the maxilla.
19. Height of maxillary bone **(HmB)**: Maximum dorso-ventral extent of the maxilla.
20. Frontal bone length **(FBL):** Distance from the parieto-frontal suture to the fronto-nasal suture.
21. Nasal Bone Length **(NBL)**: Overall extent of the nasal bone from the rostral end of the frontal bone to the rostral tip of the nasal bone.
22. Width across nasal bone **(WNB):** Maximum distance across the nasal bones or maximum distance between the naso-maxillary sutures.

23. Length of Pre-Maxilla Bone **(Lpm):** Maximum rostro-caudal distance of the pre-maxilla bone.
24. Height of Pre-Maxilla Bone **(Hpm)**: Maximum dorso-ventral extent of the pre-maxilla.
25. Parietal Bone Length **(PBL)**: Distance from the occipito-parietal to the parieto-frontal sutures.
26. Length of Lacrimal Bone **(LlB)**: Distance from the fronto-lacrimal suture to the junction (suture) between the lacrimal and maxilla bones.
27. Height of Lacrimal Bone **(HlB)**: Distance from the fronto-lacrimal suture to the junction (suture) between the lacrimal and zygomatic bones.
28. Length of Zygomatic Bone **(Lzy)**: Maximum rostro-caudal extent of zygomatic bone.
29. Height of Zygomatic Bone **(Hzy)**: Maximum dorso-ventral extent of zygomatic bone.
30. Neurocranial Volume **(NCV):** Volume of neurocranium in ml; all the foramina of the intact skull were blocked with plasticine and the neurocranium was filled with rice grains from the foramen magnum. When full, the grains were emptied into a measuring cylinder to determine the volume, by reading off from the calibration on the cyclinder.
31. Mandibular Length **(MDL)**: Maximum distance of the lower jaw from the top of the dental bone to the most caudal projection of the mandibular condyle.
32. Length of Ramus **(RAM):** Diagonal distance of the ramus of the mandible, between the cranial and caudal angles. The cranial angle of the ramus of the mandible is located caudal to the last molar tooth while the caudal angle is located ventral to the caudal border.
33. Oral Height of Ramus **(OHR)**: Distance from the base of the mandible to the highest level of the coronoid process.
34. Middle Height of Ramus **(MHR)**: Distance from the base of the mandible to the lowest point/ level of the coronoid fossa.
35. Aboral Height of Ramus **(AHR):** Height of the vertical ramus from the highest level of the condylar process to the base of the mandible.

Data Analysis

Data obtained were expressed as mean ± standard error of mean. Statistical analysis was done using the Student's *t*-test at $\alpha_{0.05}$ and Pearson Correlation ($p \leq 0.05$) using GraphPad Prism (version 7.0).

RESULTS

In this study, the details of the craniometric parameters of adult skulls of Nigerian indigenous pigs were presented to highlight observable sexual dimorphic differences noticed in this breed using a total of 35 skull parameters. Results showed that 15 of the 35 craniometric parameters taken on the adult NIP skulls had higher values in males compared to females. The skull length was 23.02±0.35cm and 22.02±0.25cm, skull width was 11.01±0.18cm and 11.01±0.17cm, whole skull index was 63.26±1.60 and 65.07±0.48, and foramen magnum index was 104.15±2.70cm and 98.03±1.70cm, for male and female indigenous pig skulls respectively. These values were however not significant ($p>0.05$) different between both sexes. Three sexual dimorphic parameters were observed in this study: the height of lacrimal bone (HLB) and mandibular length (MDL) were significantly ($p \leq 0.05$) longer in male skulls while the females had significantly higher values for the length of lacrimal bone (LLB) ($p \leq 0.05$). The mean values and standard deviations of the skull measurements are as stated in Table 1.

The skull width showed a significant corresponding increase (positive correlation) to the skull length (r=.898), while the foramen magnum width also showed a positive correlation to the foramen magnum index (r=.8701) (Table II).

DISCUSSION

The results from this present study showed that male pigs had slightly higher osteometric measurements than females. This observation was similar to the report of Brudnicki (2005), in wild and domestic pig skulls from Poland but different from what was reported in mongrel pigs by Okandeji & Olopade (2010) and Okandeji *et al*. (2023).

The skull length and width observed in this study were lower than the reports in Zovawk pigs (Choudhary *et al*., 2019), Indian wild pig (Choudhary *et al*., 2017), Indigenous pigs of North-East India (Sarma *et al*., 2002) and domesticated pigs of Mizoram (Doley *et al*., 2018), respectively, showing that the NIP was smaller than the aforementioned breeds of pigs. The skull length is reported to be crucial in facilitating inter-species taxonomic classification (Jashari *et al*., 2022).

The skull index, also known as the cephalic index, was slightly lower than the result obtained in mongrel pigs (Okandeji, 2012) and Indian wild pig (Choudhary *et al.*, 2017), but higher than what was reported in Indigenous pigs (Sarma *et al*., 2002), domesticated pigs (Doley *et al*., 2018), and the Zovawk pigs (Choudhary *et al*., 2019). An index of below 75 implies that the skull is long and narrow, when viewed from the top (Bognar *et al*., 2021). With a skull index of 63, the Nigerian indigenous pig may be described as being dolichocephalic, similar to what was reported by Choudhary *et al.* (2017), in the Indian wild pig.

The mean FMH and FMW values in the male and female adult NIP skulls were relatively constant and were similar to what was reported by Doley *et al*., (2018) in domesticated pigs in India but higher than the report of Olopade & Okandeji (2010) in mongrel pigs, and that of

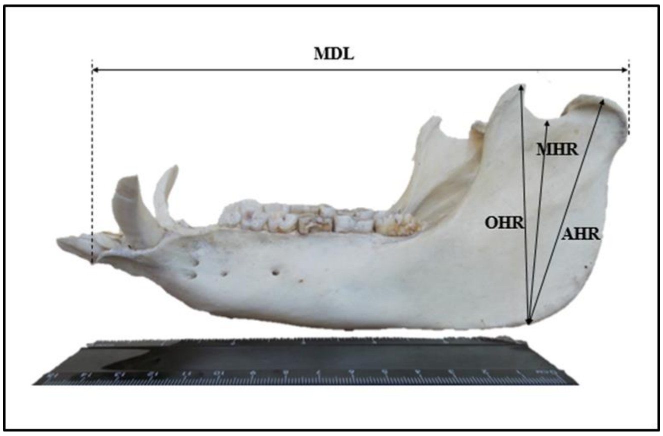

Figure I: Lateral view of the mandible of Nigerian indigenous pig showing mandibular length (MDL), oral height of mandible (OHR), middle height of mandible (MHR) and aboral height of mandible (AHR).

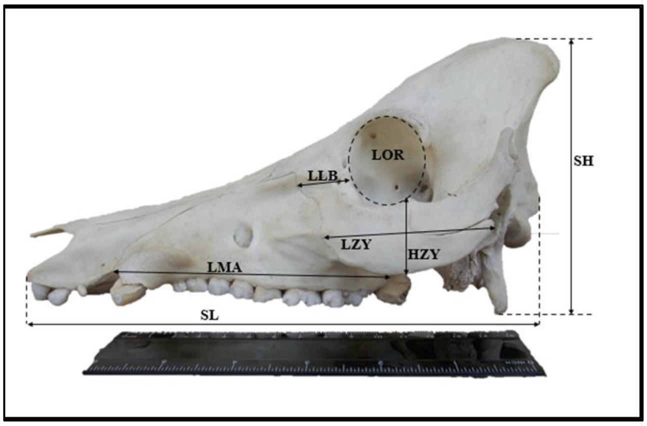

Figure II: Lateral view of the skull of Nigerian indigenous pig showing skull height (SH), skull length (SL), length of lacrimal bone (LLB), Length of maxilla (LMA), height of zygomatic bone (HZY), length of of zygomatic bone (LZY), Length of orbit (LOR) distance (IOD).

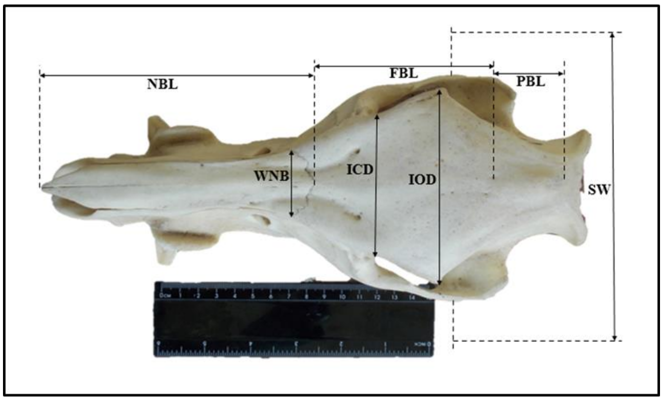

Figure III: Dorsal view of the skull of Nigerian indigenous pig showing skull width (SW), nasal bone length (NBL), width of nasal bone (WNB), facial bone length (FBL), parietal bone length (PBL), inter-canthi distance (ICD) and inter-orbital distance (IOD).

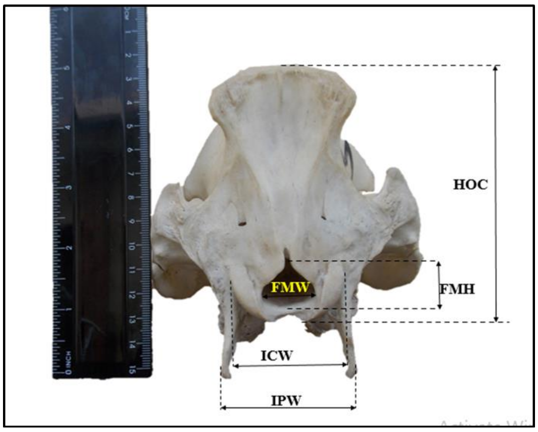

Figure IV: Caudal view of the skull of Nigerian indigenous pig showing height of occipital bone (HOC), foramen magnum height (FMH), foramen magnum width (FMW), inter-condylar width (ICW) and inter paracondylar width (IPW).

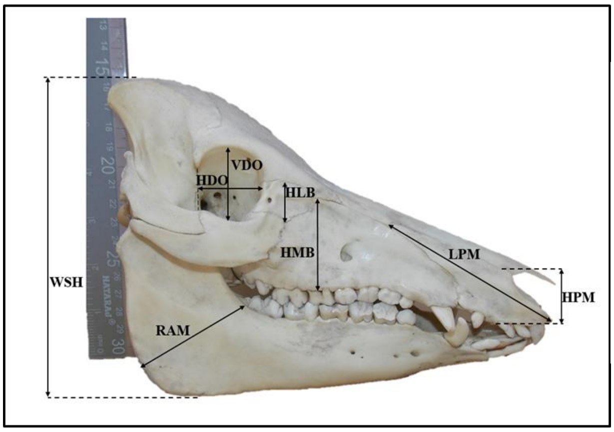

Figure V: Lateral view of the whole skull of Nigerian indigenous pig showing whole skull height (WSH), height of lacrimal bone (HLB), height of maxilla bone (HMB), height of premaxilla bone (HPM), length of premaxilla bone (LPM), vertical diameter of orbit (VDO), horizontal diameter of orbit (HDO) and length of ramus (RAM).

Table I: Craniometric parameters of the skulls of Nigerian indigenous pigs

Parameters	Male (n=10)	Female (n=14)	Parameters	Male (n=10)	Female (n=14)
SH (cm)	11.01 ± 0.28	11.02 ± 0.23	**LLB (cm)**	2.44 ± 0.05	2.61 ± 0.07*
WSH (cm)	14.23 ± 0.44	14.25 ± 0.24	**HLB (cm)**	1.92 ± 0.18*	1.72 ± 0.07
SL (cm)	23.02 ± 0.35	22 ± 0.25	**LZY (cm)**	6.31 ± 0.10	6.33 ± 0.08
SW (cm)	11.01 ± 0.18	11.01 ± 0.17	**HZY (cm)**	2.63 ± 0.11	2.64 ± 0.09
WSI (%)	63.26 ± 1.60	65.07± 0.48	**LMA (cm)**	9.93 ± 0.21	9.62 ± 0.16
HOC (cm)	5.81 ± 0.18	5.84 ± 0.13	**HMA (cm)**	4.64 ± 0.10	4.58 ± 0.06
ICW (cm)	4.50 ± 0.05	4.53 ± 0.06	**LPM (cm)**	10.02 ± 0.19	10.01 ± 0.20
IPCW (cm)	4.80 ± 0.08	4.70 ± 0.06	**WCR (cm)**	4.71 ± 0.11	4.92 ± 0.10
FMH (cm)	2.11 ± 0.06	2.02 ± 0.05	**NBL (cm)**	13.02 ± 0.22	13.02 ± 0.20
FMW (cm)	2.03 ± 0.03	2.05 ± 0.03	**WNA (cm)**	2.83 ± 0.07	2.93 ± 0.07
FMI (%)	104.15 ± 2.70	98.03 ± 1.70	**FBL (cm)**	7.42 ± 0.17	7.28 ± 0.10
NCV (cm^3)	80.03 ± 2.30	82.32 ± 1.60	**PBL (cm)**	3.43 ± 0.09	3.51 ± 0.09
HDO (cm)	3.12 ± 0.04	3.24 ± 0.06	**MDL (cm)**	19.02 ± 0.41*	18.04 ± 0.26
VDO (cm)	3.23 ± 0.04	3.30 ± 0.04	**RAM (cm)**	5.55 ± 0.10	5.42 ± 0.09
LOR (cm)	12.02 ± 0.08	12.04 ± 0.17	**AHR (cm)**	9.45 ± 0.28	9.43 ± 0.15
OI (%)	106.24 ± 1.89	105.41 ± 2.06	**OHR (cm)**	8.96 ± 0.24	8.92 ± 0.14
ICD (cm)	5.94 ± 0.12	5.82 ± 0.1	**MHR (cm)**	8.13 ± 0.26	8.21 ± 0.13
IOD (cm)	8.24 ± 0.14	8.13 ± 0.13			

*: Significant difference (p≤ 0.05)

Table II: Correlation coefficients (Pearson's correlation) of craniometric indices in the Nigerian Indigenous pig

	SH	SL	FMW	FMI
MDL	0.830**	0.862	-	-
FMH	0.079	0.052	0.701	0.870
FMW	-	-	-	0.8701**
NCV	0.751	0.757	-	-
SW	0.934	0.898**	-	-
NBL	0.800	0.873**	-	-
FBL	0.884	0.719	-	-

**Significant (p≤ 0.05)

Choudhary *et al.*, (2019) in Zovawk pig. The values were however lower than the report of Sarma *et al*. (2002) in dum pigs Although the shape of the foramen magnum is believed to be constant, with age (Simoens *et al.,* 1994), irregularly formed foramen magnum is a very crucial clinical problem and it has been implicated as one of the causes of Chiari's syndrome in humans (Nishikawa *et al*., 1997; Marin-Padilla & Marin-Padilla, 1977; Karagoz *et al*., 2002; Nash *et al*., 2002).

The FMI obtained from this study was higher than the result obtained in Zovawk pig (Choudhary *et al*., 2019) and domestic pigs (Okandeji *et al*., 2023). In comparison to other species, the FMI in this study was lower than what was reported in the West African Dwarf goat (102.5; Olopade & Onwuka, 2005), American Staffordshire terrier new-borns (106.82; Chroszcz *et al.*, 2006) and the one humped camel (109.37; Yahaya *et al*., 2012). These reports show variability in the foramen magnum due to the age and species of the animals (Uddin *et al*., 2013). A foramen magnum index less than 100 suggests a relatively wide foramen magnum. Since the FMI provides direct numerical information on the shape and size of the foramen magnum, the disparity between different species and breeds of animals with FMI below or above 100 could provide a strong reason for doing comparative morphometric studies of the medulla oblongata and spinal cord (Simoens *et al*., 1994; Dyce *et al*., 2002).

The NCV is thought to be indicator of brain weight and may have a correlation with the weight of the head (Okandeji *et al.*, 2023). In this study, the NCV was slightly higher in female skulls than males, with mean values of 82ml and 80ml respectively. The values obtained were lower than the report of Okandeji *et al*. (2023), in domestic pigs, with mean values of 106.86ml and 96.43ml, in the females and males, respectively. This result contradicts the findings of Brudnicki (2005), who reported that males of the wild boar and domestic pigs from Poland had higher cranial volumes. It may be due to individual and inter-breed existence of significant differences in the shapes and sizes of the skull (Uddin *et al*., 2013). Golalipour *et al.* (2005) suggested that in Iranian citizens, the brain volume had a direct relationship with the neurocranial volume, which implies that female pigs used for this study possibly had heavier brains, due to larger braincases, compared to the males. A higher NCV may result in increased susceptibility to conditions that lead to increased intra cranial pressure (Igado, 2011). Since brain weight is considered to be 85-90% of the content of the neurocranium, (Uddin *et al*., 2013), the brain density of this breed of pigs can be evaluated from this data, making the NIP a suitable model for studies on intracranial pressure.

The mean values of HDO, VDO and LOR were obtained from this study were somewhat similar to the values reported by Olopade *et al*., (2011). The dimensions were however higher for HDO and lower for VDO in the report of Choudhary *et al.*, (2019), in Zovawk pigs, and higher for both indices in indigenous pigs of North-East India (5.12cm and 3.66 cm, respectively), by Sarma *et al*. (2002). The orbit of the NIP appears slightly oval in shape, having a relatively higher vertical diameter than the horizontal diameter, with incomplete caudal margins. This observation was similar to the report in Dum pigs, Zovawk, and Indian wild pig (Sarma *et al.* (2002; Choudhary *et al.*, 2017; Choudhary *et al*., 2019). The orbital index in this study was greater than 100, and this was similar to the report of Olopade *et al.* (2011) who reported the value of 110. The similarity in the values of both sexes in the NIP suggests that optical physiology may be similar in both (Olopade *et al*., 2011).

The mean mandibular length (MDL) of the NIP was similar to that of wild Pig (Endo *et al*., 1998) whereas the Indian wild pig and Zovawk Pig had higher MDL values (Choudhary *et al*., 2017; Choudhary *et al.*, 2019). Olopade and Okandeji (2010) however reported a lower MDL value for mongrel pigs. The male skulls had significantly longer mandibles, similar to the report of Endo *et al*. (1998) in Japanese wild pig. This report was, however, contrary to the report of Olopade and Okandeji (2010) on mongrel pigs, where female pigs had significantly longer mandibles. The observed differences may be attributable to the age and breed of the pigs used for each study. Herring (1972) posited that significant differences in craniometric measurements become more marked with advancing age, as sexual dimorphism appears to be more noticeable in adults, with higher values favouring the males. This may be attributed to their wider canine teeth which ultimately affect mandibular lengths. In wild pigs, mandibular length has been reported to be influenced by the head and body lengths (Endo *et al*., 2002), as body size is thought to contribute to sexual dimorphism in several mammal groups, males being the larger sex (Wiig & Anderson, 1986; Loison *et al*., 1999; Ventura *et al.*, 2002). Therefore, a lower mandibular length further suggests that the NIP is smaller in body size, compared to other exotic breeds or wild pigs. A strong positive correlation between the mandibular length and skull length, and skull weight means that mandibular length may be a good indicator of the weight and length of NIP skulls.

CONCLUSION

The craniometric values of the skulls of adult NIP showed that this breed appears to be different from other breeds of pigs. The variation in sex and species are suggestive of different genetic pool, food availability, the ecotype in which the animals are found and adaptation influences, reflecting in varying craniometric values. Data generated provide important information on the skull of NIP which can be used for comparison with other breeds of pig. It will also be useful for comparative anatomical, developmental, forensic, and clinical studies.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest with respect to the research, authorship and publication of this article.

REFERENCES

Adeola, A.C., Oseni, S.O. & Omitogun, O.G. (2013). Morphological characterization of indigenous and crossbred pigs in rural and peri-urban areas of southwestern Nigeria. *Open Journal of Animal Sciences*, *3(*3), 230–235.

AU-IBAR. (2015). Local African Pig. *African Union Inter-African Bureau for Animal Resources*. Retrieved from http://www.au-ibar.org/2012-10-01-13-08-42/features/series/know-youranimalsseries/local-african-pig

Baranowski P. (2017). Craniometric characteristics and cranial indices of Polish health sheep ram -Extended data. *International Journal of Morphology,* 35(1), 133-140.

Bognar Z., Szabo D., Dees A. & Kubiniyi E. (2021). Shorter heads dogs, visually cooperative breeds, younger and playful dogs form eye contact faster with an unfamiliar human. *Scientific Report* 11(1), 1-11.

Brudnicki, W. (2005). Comparison of craniometric features and cranial cavity volume in domestic pig (*Sus scrofa forma domestica*) and wild boar (*Sus scrofa*) in view of development. *Folia biol*ogica. (Kraków) 53 (Suppl.), 25-30.

Choudhary O.P. (2018). Applied anatomy of the head region of local Mizo pig (Zovawk) and its clinical implications during regional anaesthesia. *International Journal of Morphology*, 37(1), 196-204.

Choudhary O.P., Kalita P.C., Keneisenuo B., Konwar P.J., Doley A., Kalita. A. & Gundemir O. (2020). Applied anatomy of the maxillofacial and mandibular regions of Indian Mithum (*Bos frontalis*) and its clinical significance in regional anaesthesia. *Indian Journal of Animal Research, 55*(10), 1177-1183.

Choudhary O.P., Kalita P.C., Doley J.P. & Kalita A. (2017). Applied anatomy of the head region of the Indian wild pig (*Sus scrofa*) and its clinical value during regional anaesthesia. *Journal of Animal Research,* 7(2), 339-344.

Choudhary, O.P & Singh, I. (2016). Morphological and Radiographic Studies on the Skull of Indian Blackbuck (Antilope cervicapra). *International Journal of Morphology*, 34(2), 775-783.

Choudhary, O.P. & Singh, I. (2014). Applied anatomy of the maxillofacial and mandibular regions of the Indian blackbuck (*Antilope cervicapra*). *Journal of Animal Research,* 5(3), 497-500.

Christensen, A.M., Passalacqua, N.V. & Bartelink, E.J. (2019). Ancestry estimation. In Christensen, A.M., Passalacqua, N.V. & Bartelink, E.J. (Eds.). Forensic Anthropology (2nd Edition). Academic Press, 271-306.

Chroszcz A., Janeczek M., Wojnar M. & Pospieszny N. (2006). Morphological analysis and morphometry of the Foramen Magnum of the American Staffordshire terrier breed newborns. *Medycyna Weterynaryjna*, 62(9), 1002-1004.

Constantinescu R., Cosier V., Cocan D. & Miresan V. (2014). Comparison of craniometric features between domestic pig (*Sus scrofa forma domestica*) and wild boar (*Sus scrofa*) from Transylvania region. *Bulletin University of Agriculture Sciences and Veterinary Medicine, Faculty of Animal Science and Biotechnologies* 71(2).

Doley, P.J., Kalita, P. C., Kalita, A., Choudhary, O.P. & Das, H. (2018). Morphological study on the skull of wild boar of Mizoram (*Sus scrofa*). *International Journal of Livestock Research*, 8(6), 185-193.

Doley, P.J., Tolenkhomba, T.C., Kalita, P.C., Kalita, A., Choudhary, O.P. & Das, H. (2018). Morphometrical studies on the skull of non-descript domesticated pigs of Mizoram. *Journal of Experimental Zoology India*, 21(2), 967-975.

Dyce K.M, Sack W.O., Wensing C.J.G. (2002). *Textbook on Veterinary Anatomy*. (3rd Edition). W. B. Saunders Company.

Endo H., Hayashi Y., Sasaki M., Kurosawa Y., Tanaka K., Yamazaki K. (2000). Geographical Variation of the Mandible Size & Shape in the Japanese Wild Pig (*Sus scrofa leucomystax*). *Journal of Veterinary Medicine Science*; 62(8), 815-820.

Endo H., Hayashi Y., Yamazaki K., Motokawa M., Pei J., Lin L., Chou C., & Oshida T. (2002). Geographical variation of the mandible size (*Sus scrofa*) from Taiwan and Japan. *Zoological Studies,* 41(4), 452-460.

Endo H., Maeda, S., Yamagiwa, D., Kurohmaru, M., Hayashi Y., Hattori, S., Kurosawa Y., and Tanaka K., (1998). Geographical Variation of the Mandible Size and Shape in the Ryukyu Wild Pig (*Sus scrofariukiuanus*). *Journal of Veterinary Medicine Science,* 60(1), 57-61.

Gambo B.G., Yahaya A., Abdulhamid M.B. & Olopade J.O. (2019). Sexual dimorphism in osteometric indices of Kuri cattle skulls. *Nigeria Journal of Physiological Society*, 34(2), 159-165.

Golalipour M.J., Jahanshaei M. & Haidari, K. (2005). Estimation of cranial capacity in 17-20 years old in South East Caspian Sea border (North Iran). *International Journal of Morphology,* 23(4), 301-304.

Gundemir O., Duro S., Jashari T., Kahvecioglu O., Demircioglu I. & Mehmeti H. (2020). A study of morphology and morphometric parameters on skull of the Badhoka autochthonous sheep breed in Kosovo. *Anatomy Histology Embryology,* 49(3), 365-371.

Hall L.W., Clarke K.W. & Trim C.M. (2000). *Wrights Veterinary Anaesthesia and Analgesia* (10thEdition). ELBS and Baillière Tindall, London.

Herring S.W. (1972). The role of canine morphology in the evolutionary divergence of pigs and peccaries. *Journal of Mammalogy*, 53(3), 500–512.

Hohl L. S. L., Sicuro F. L., Azorit C., Carrasco R. & Rocha-Barbosa O. (2014). Age and sex related geometrical variation of Ramus mandibulae of *Sus scrofa's* (Mammalia: Artiodactyla) jaws. *International Journal of Morphology,* 32(4), 1282-1288.

Igado O.O., Omobowale T.O., Ajadi R. A. & Nottidge. H.O. (2012). Craniofacial morphometrics and macro-neurometrics of the fruit bat (*Eidolon helvum*). *European Journal of Anatomy,* 16(3), 172-176.

Igado O.O. (2011). Neurometry and neurocraniometry of the Nigerian local dog (*Canis lupus familiaris). Journal of the Veterinary Anatomy* 4(2), 99-101.

Igado O.O. & Ekeolu O.K. (2014). Morphometric investigation of the occipital area of the Adult Nigerian local dogs. *African Journal of Biomedical Research,* 17(2), 125-128.

Iqbal A., Sarwar G., Khan A.M., Waseem M.T., Iqbal A., Ahmad R.M., Ameen M. (2020). Craniometrical analysis of wild boar (*Sus scrofa*) from northern Punjab, Pakistan. *Punjab University Journal of Zoology*, 35(1), 157-165.

Jashari,T., Duro, S., Gündemir, O., Szara, T., Ilieski, V., Mamuti, D. & Choudhary, O.M. 2022. Morphology, morphometry and some aspects of clinical anatomy in the skull and mandible of Sharri sheep. *Biologia*, 77(2), 423-433.

Karagoz F., Izgi N., KapijcjogluSencer S. (2002). Morphometric measurements of the cranium in patients with Chiari Typ I malformation and comparison with the normal population. *Acta Neurochirurgica* 144:165-171.

Košinová, k., Turek, J, Cukor, Linda, J. R., Häckel, M. & Hart, V. (2022). The Application of 3D Imaging as an Appropriate Method of Wildlife Craniometry: Evaluation of Accuracy and Measurement Efficiency. *Animals,* 12(23), 3256. https://doi.org/ 10.3390/ani12233256.

Künzel W., Breit S., Oppel M. (2003). Morphometric investigations of breed specific features in feline skulls and considerations on their functional implications. *Anatomia, Histologia, Embryologia,* 32(4), 218–223.

Loison, A., Gaillard, J.M., Pélabon, C. & Yoccoz, N.G. (1999). What factors shape sexual size dimorphism in ungulates? *Evolutionary Ecology Research* 1(5), 611-633

Marin-Padilla M., Marin-Padilla T. M. (1977). Developmental abnormalities of the occipital bone in human chondrodystrophies (achondroplasia and thanatophoric dwarfism). *Birth defects original article series*, 13 (3D), 7-23.

Mohamed R. (2019). Anatomical and radiographic study on the skull and mandible of the African lion (*Panthera leo*). *Journal of Morphological Sciences,* 36(3), 174-181.

Monfared, A. L. (2013). Gross anatomical measurements of the head region of the Iranian native cattle (*Bos taurus*) and their clinical value for regional anaesthesia. *Global Veterinary Journal,* 10(2), 219-22.

Myers, P., Espinosa, R., Parr, C. S., Jones, T., Hammond, G S. and Dewey, T.A. 2022. The Animal Diversity Web (online). Accessed at https://animaldiversity.org/accounts/Sus/classification

Nash J., Cheng J. S., Meyer G.A., Remler B. F. (2002). Chiari type I malformation: overview of diagnosis and treatment. *Wiscon. Medical Journal,* 101(8), 35-40.

Nishikawa, M., Sakamoto, H., Hakuba, A., Nakanishi, N., & Inoue, Y. (1997). Pathogenesis of Chiari malformation: a morphometric study of the posterior cranial fossa. *Journal of neurosurgery*, *86*(1), 40–47.

Okandeji, M. E. (2012). Cranio-morphometric indices of the skull of mongrel pigs (*Sus scrofa*) in Southwestern Nigeria (Masters dissertation submitted to the Department of Veterinary Anatomy, Faculty of Veterinary Medicine, University of Ibadan).

Okandeji, M.E., Olude, M.A. & Olopade, J.O. (2023). Craniometric study of the skull of domestic pigs (*Sus scrofa*) in South Western Nigeria. Accepted for publication in the *Tropical Veterinarian*, 44

Olopade J.O. (2003). The Morphometry of the craniofacial and maxillofacial regions of the West African dwarf goats (*Capra hircus*). M. Sc. thesis, Department of Veterinary Anatomy, University of Ibadan, Ibadan, Nigeria.

Olopade J. O. & Okandeji M. E. (2010). A study of some rostrofacial indices related to regional anaesthesia of porcine: Implications as an animal model for dental research. *Nigerian Journal of Physiological Sciences,* 25(2), 159-164.

Olopade J. O. & Onwuka S. K. (2005). Some aspects of the clinical anatomy of the mandibular and maxillofacial regions of the West African Dwarf Goat in Nigeria. *International Journal of Morphololology*, 23(1), 33–36.

Olopade J.O. & Onwuka S.K. (2006). An Osteometric study of the skull of the West African dwarf goat from South Eastern Nigeria: Mandibular and maxillofacial features. *Nigerian Veterinary Journal,* 27(2), 66-70.

Olopade J.O. & Onwuka S.K. (2007). Osteometric studies of the skull of Red Sokoto (Maradi) goats (*Capra hircus*): Implications for regional anaesthesia of the head. *International Journal of Morphololology* 25(2), 407-410.

Olopade O.O., Igado O.O., Nwafor C. I., Alamu A.O. & Onwuka S.K. (2011). Some aspects of the craniofacial indices and macro neurometrics of the Nigerian local pig (*Sus scrofa*). *Italian Journal of Anatomy and Embryology,* 116(1), 38-44.

Olopade, J.O., Igado, O.O., Azeez, I.A. & Okandeji, M.E**.** (2011): Morphometric studies of the eyeball and orbital region of the Nigerian local pig (*Sus scrofa*); *Tropical Veterinarian,* 29(1), 34-40.

Olopade, J.O. & Onwuka, S.K. (2009). Morphometric analysis of the skull of the Sahel goat breed: basic and clinical anatomy. *Italian Journal of Anatomy and Embryology= Archivio Italiano di Anatomia ed Embriologia*, *114*(4), 167-178.

Onar V., Mutuş R. & Kahvecioğlu K.O. (1997) Morphometric analysis of the foramen magnum in German shepherd dogs (Alsatians). *Annals of Anatomy*, 179(6), 563-568.

Onar V. (1999). A morphometric study of the skull of the German Shepherd Dog (Alsatian). *Anatomia, Histolologia, Embryologia,* 28(4), 253-256.

Onar V., Ozcan S. & Pazvant G. (2001). Skull typology of the adult male Kangal dog. *Anatomia, Histolologia, Embryologia,* 30(1), 41-48.

Osei-Amponsah R., Skinner B.M., Adjei D.O., Bauer J., Larson G., Affara N.A. & Sargent C.A. (2017). Origin and phylogenetic status of the local Ashanti Dwarf pig (ADP) of Ghana based on genetic analysis. *BMC Genomics,* 18(1), 193.

Pathiraja N. & Oyedipe E. (1990). Indigenous Pig of Nigeria. *Animal Genetic Resources,* 7,63-70.

Raberin M., Laumon, B. Martin, J.L. & Brunner, F. (1993). Dimensions and form of dental arches in subjects with normal occlusions. *American journal of orthodontics and dentofacial orthopedics,* 104(1), 67-72.

Reimert I., Bolhuis J.E., Kemp B. & Rodenburg T.B. (2013). Indicators of positive and negative emotions and emotional contagion in pigs. *Physiology and Behavior* 109, 42-50.

Rothschild, M.F. 2004. Porcine genomics delivers new tools and results: This title piggy did more than just go to market. *Genetical Research, 83(*1), 1–6.

Samuel O.M., Olopade J.O., Korzerzer M.R., & Onwuka S.K. (2013). Craniometric evaluation of some cranial indices of clinical significance in goats (*Capra hircus*) from the middle-belt region of Nigeria case for population surveillance and eco-migration. *European Journal of Zoological Research,* 2(4), 89-97.

Salih, K.M. 2013. Gross Anatomical and Morphometrical Studies to the Skull Bones of the local Rabbit (*Oryctohlagus cuniculus*). *Basrah Journal of Veterinary Research,* 12(2), 267-277.

Sarma K., Sarma M., Goswani R.N., Devi J., & Sarma P. (2002). Craniometry of Indigenous pigs (*Sus scrofa*) of the North-East India. *Indian Journal of Animal Science,* 72(1), 13-15.

Shawulu, J.C., Kwari, H.D., & Olopade, J.O. (2008). Morphology of the bone of the skull in the Sahel ecotypes of goats (*Capra hircus*) in Nigeria. *The Journal of Veterinary Anatomy,* 4(2), 1-13.

Simoens, P., Poels, P. & Lauwrens H. (1994). Morphometric analysis of the foramen magnum in Pekingese dogs. *Animal Journal of Veterinary Research,* 55(1), 34-39.

Tera, S., Mutus, R. & Kahvecioglu, K. O. (1998). Morphometric analysis of the foramen magnum in German Shepherd dogs (Alsatian). *Animal Anatomy,* 179(6), 563-568.

Uddin, M., Sarker M.H.R., Hossain M.E., Islam M.S., Hossain, M.B. & Shil, S.K. (2013). Morphometric investigation of neurocranium in domestic cat (*Felis catus*). *Bangladesh Journal of Veterinary Medicine,* 11(1), 69-73.

Ulcay, T. & Kamaşak, B. (2021). Evaluation of craniometric measurements in human skulls. *Journal of Health Sciences and Medicine,* 4(1), 38-44.

Ventura J., Salazar M., Perez-Hernandez R. & Lopez-Fuster M.J. (2002). Morphometrics of the genus Didelphis (*Didelphimorphiadidelphidae*) in Venezuela. *Journal of Mammalogy*, 83(4), 1087-1096.

Wiener, P., & Wilkinson, S. (2011). Deciphering the genetic basis of animal domestication. *Proceedings of the Royal Society B: Biological Sciences,* 278(1722), 3161–3170.

Wiig O. & Anderson T. (1986). Sexual size dimorphism in the skulls of Norwegian Iynx. *Acta Theriologica,* 31(12), 147-155.

Wilkinson, S., Lu, Z.H., Megens, H.-J., Archibald, A.L., Haley, C., Jackson, I.J., … Wiener, P. 2013. Signatures of diversifying selection in European pig breeds. *PLoS Genetics 9*.4:e1003453.

Yahaya A., Olopade, J.O. & Kwari, H.D. (2011). Clinical implication of craniometric indices of the one-humped camel (*Camelus dromedarius*) to oral health and clinical regional anaesthesia of the head. *Journal of Veterinary Anatomy*, 4(1), 19-31.

Yalden D. (2001). The Return of the Prodigal Swine. *Biologist,* 48(6), 259-262.