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Craniometric study of the skull of domestic pigs (*Sus scrofa*) in South Western Nigeria

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ABSTRACT

Studies related to the craniofacial anatomy of the skull of domestic animals are vital for understanding spatial relationships of organs in the head region and the effects of genetics and the environment on sexual dimorphisms. This present study was designed to investigate 15 metrics of craniofacial features of 26 domestic pigs (large White breed) (12 males and 14 females), aged 6 to 17 months. Average values were obtained and expressed as mean ± standard deviation and analysed using the Student "t" test ($p<0.05$) and Pearson correlation ($p < 0.05$ and $p < 0.01$). This study showed that about 80% of the measured parameters were higher in females, compared to males. The mean neurocranial volume was significantly higher in females (106 ± 8.38 ml) when compared to the males (96 ± 8.56 ml), while the mean values for maximum height and length of the braincase (Neurocranium) were 6.40 ± 0.69cm and 8.33 ± 0.35cm and 6.24 ± 0.60cm and 8.44 ± 0.32cm for the males and females respectively. Although the braincase index values were observed to be higher in pigs above one year of age, it was only significantly higher ($p < 0.05$) in females above one year of age when compared to those below one year. This study reveals sexual dimorphism with a female bias, in the neurocranial volume. The data obtained, therefore, provide added information that can be useful in the comparative skull typology of pigs and the field of porcine neuroanatomy research.

KEYWORDS: Craniometric, neurocranial volume, sexual dimorphism, mongrel pigs

INTRODUCTION

The Pig, *Sus scrofa,* belongs to the super-order *Ungulata* with the other hoofed mammals in the order Artiodactyla (Dyce *et al.*, 2002). Stout-bodied, short-legged omnivores with thick, sparsely bristled skin, pigs have long mobile snouts, small tails and hooves; and possess two functional and two non-functional digits. Pigs are regarded as highly intelligent animals (Broom *et al.*, 2009), and they can be trained to perform various tasks and tricks (Angier, 2009). They are also considered to be prolific and fast-growing livestock that have efficient feed and waste utilisation and conversion potentials (Ajala, 2007). Although pigs have high economic importance, surgical procedures are often restricted to a few regions of the body (Dyce *et al.*, 2002). Thus, detailed information on porcine anatomy is becoming increasingly important.

Morphometric studies of the skull reflect the contributions of genetic and environmental components to individual development (Gürbüz et al., 2018). They also describe genetic and eco-phenotypic variation and are the foundations of some clinical and surgical practices (Wehausen and Ramey, 2000), which enables the surgeon to visualize details of structures relevant to the case at hand (Dyce *et al.*, 1996). Similarly, the different foramina of the skull are of clinical importance in regional anaesthesia around the head (Hall *et al.*, 2000).

Morphometric studies of the skull of pigs include those reported on Japanese pigs (Endo *et al*., 2002), domestic pigs and wild pigs from the Transylvania region (Constantinescu *et al.*, 2014), the Indian wild pig (Choudhary, 2017), wild boar of Mizoram (Doley *et al.*, 2018), and in the skull of wild boar from northern Punjab, Pakistan (Iqbal *et al.*, 2020).

Studies have shown the craniofacial anatomy of the skull of domestic animals to be vital for understanding the spatial relationships of organs within the region (Olopade and Onwuka, 2005), the effects of genetics and the environment on the development of craniofacial features (Onar *et al*., 1997), and for the study of sexual dimorphism (Paiva and Segre, 2003). The aim of this work, therefore, was to study the craniometric indices of domestic pigs (*Sus scrofa*) in a continuing effort to provide baseline information on the anatomy of the skull of these pigs in Nigeria.

MATERIALS AND METHODS

All animal handling and experimental procedures were carried out by the University of Ibadan-Animal Care and Use of Research Ethics Committee (UI-ACUREC). A total of 26 skulls (14 females and 12 males) of domestic pig heads were used for this study. The animals were selected during the ante-mortem examination at the Bodija abattoir in Ibadan (7°23'47''N 3°55'0''E), South Western Nigeria, based on parameters of apparent good health and absence of cranial deformities. They were restrained and humanely slaughtered by a quick decapitation at the atlanto-occipital joint. The severed heads were frozen at -20°C and later prepared according to a modification of the hot water maceration technique, as described by Onar (1999) and Olopade (2003). The heads were grouped by sex and age (above 1 year and below 1 year), and the age of each pig head was estimated through dental eruption (St Clair, 1975), and varied between 6 and 17 months.

A total of 15 parameters were determined, as adapted from Onar *et al.* (2001); Kunzel *et al.* (2003); Olopade and Onwuka (2006). Measurements were taken using the metric rule, vernier callipers, a measuring cylinder, a pair of dividers and twines. Data obtained were analysed using the Student "t" test at $p < 0.05$ and Pearson Correlation at $p<0.05$ and $p<0.01$. All analyses were done using the Statistical Package for Social Sciences (SPSS) version 15 and data was presented as mean ± SD. All linear parameters were recorded in centimetres. Parameters are indicated in Fig. 1 – 4.

The landmarks and methodology of each value obtained are described below:

1. **WEIGHT OF HEAD (WOH):** Weight of decapitated head (in kilograms).
2. **FRONTAL BONE LENGTH (FBL):** Length from the occipito-frontal suture to the fronto-nasal suture.
3. **NASAL BONE LENGTH (NBL):** Overall length of the nasal bone from the rostral end of the frontal bone to the rostral tip of the nasal bone.

4. **SKULL LENGTH 1 (SL-1):** Length from the nuchal eminence to the alveolar margin (front of the pre-maxillary bones)
5. **NEUROCRANIAL LENGTH 1 (NCL):** Length from the deepest indentation of the fronto-ethmoid junction to the distal surface of the cranium, at the level of the cranial surface of the squamous part of the occipital bone.
6. **NEUROCRANIAL HEIGHT (NCH):** Distance from the deepest indentation of the sella turcica to the inner layer of the roof of the cranium, along a vertical line.
7. **NEUROCRANIAL VOLUME (NCV):** Volume of the 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 measured in cm^3
8. **MAXIMUM HEIGHT OF BRAINCASE (NEUROCRANIUM) (MHBC):** Distance from the ventral surface of the sphenoid bone, along a vertical line, to the outer layer of the cranial roof (frontal bone)
9. **MAXIMUM LENGTH OF BRAINCASE (NEUROCRANIUM) (MLBC):** Length from the deepest indentation of the fronto-ethmoidal junction to the squamous surface of the occipital bone, along a straight line
10. **MAXIMUM BRAINCASE INDEX (BCI):** MHBC/MLBC×100
11. **SKULL LENGTH 2 (SL-2):** Length of the skull measured from the front of the pre-maxillary bones to the rear surface of the occipital condyles.
12. **SKULL HEIGHT (SH):** Distance from the nuchal crest to the ventral tip of the jugular process
13. **FORAMEN MAGNUM HEIGHT (FMH):** Mid-vertical height of the foramen magnum
14. **FORAMEN MAGNUM INDEX (FMI):** Foramen magnum height×100/foramen magnum width (%)
15. **FORAMEN MAGNUM WIDTH (FMW):** Largest width of the foramen magnum

RESULTS

Female values were higher within the group in all examined parameters except in FMW, though not statistically significant. Male parameters were generally higher within the group in animals above 1 year, though none was statistically significant. However, four parameters (NCL, MLBC, NCV and FMI), exhibited a reverse order in which younger pigs had higher parameters than in older ones. Results obtained showed that 80% of the parameters measured had higher values in females when compared to the males. These included WOH, NCL, MLBC, NCV, SL-1, SL-2, NBL, FBL, FMH, FMW and FMI, with only the NCV showing statistical significance. ($p \leq 0.05$). The mean values and standard deviations of the skull measurements are stated in Table 1.

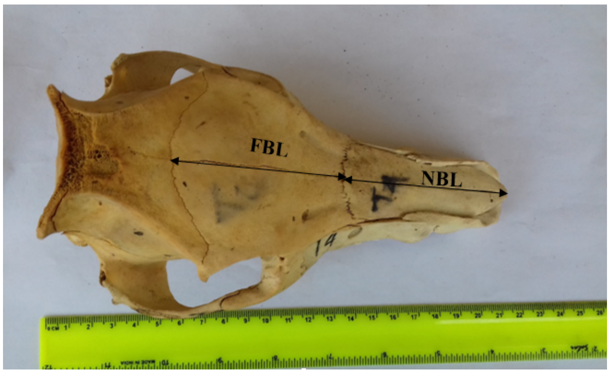
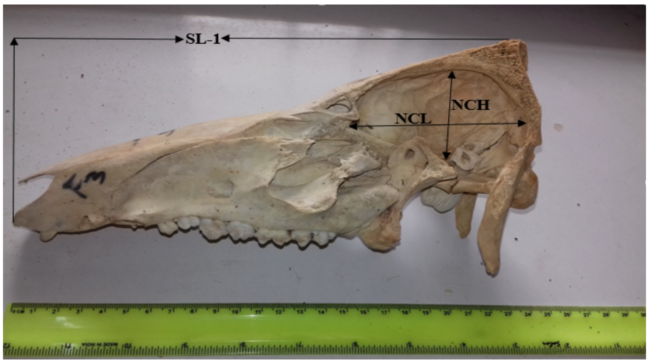


Figure 1: Picture of the dorsal view of the skull of the domestic pig indicating the landmarks of the Nasal Bone Length (NBL) and the Frontal Bone Length (FBL) parameters

Figure 2: Mid-sagittal view of the skull of the domestic pig indicating the landmarks of the Skull Length 1 (SL-1), Neurocranial Length (NCL) and Neurocranial Height (NCH).



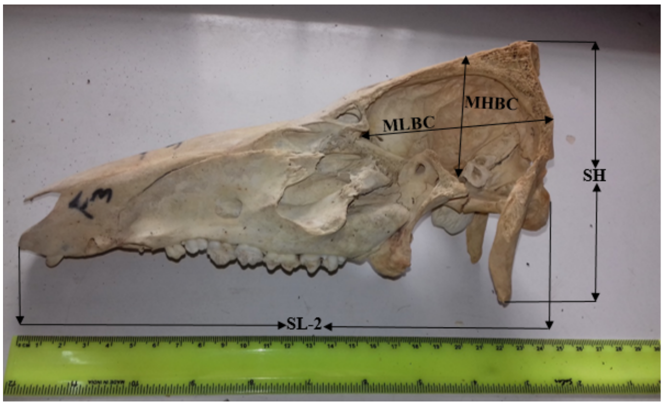


Figure 3: Mid-sagittal view of the skull of the domestic pig indicating the landmarks of the Maximum Height of Braincase (MHBC), Maximum Length of Braincase (MLBC), Skull Height (SH) and Skull Length 2 (SL-2)

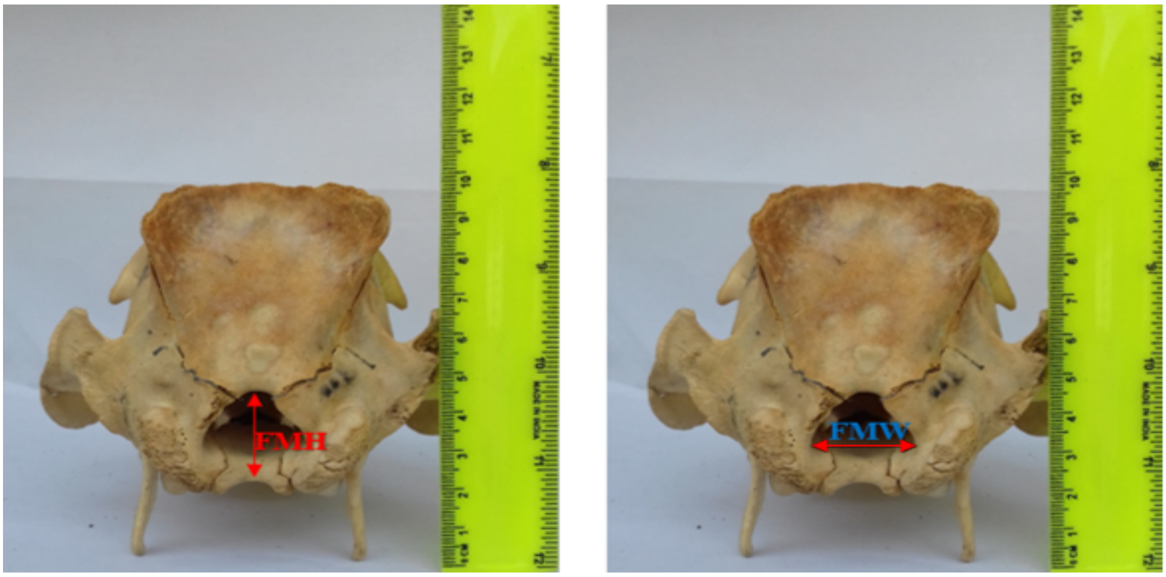


Figure 4: Caudal view of the skull of the domestic pig indicating the landmarks of the Foramen Magnum Height (FMH) and the Foramen Magnum width (FMW)

Table 1: Morphometric Parameters between both sexes in the skull of the Pig

INDICES	MALE TOTAL (n=12)	Males <1YR (n=8)	Males >1YR (n=4)	FEMALES TOTAL (n=14)	Females <1YR (n=8)	Females >1YR (n=6)
WOH (kg)	1.96±0.56	1.80±0.58	2.28±0.39	2.00±0.45*^{b}	1.74±0.45^{b}	2.34±0.40^{b}
NCL (cm)	8.06±0.32	8.21±0.36	7.87±0.14	8.13±0.28	8.08±0.32	8.22±0.25
NCH (cm)	5.25±0.38	5.10±0.41	5.41±0.33	5.09±0.18	5.06±0.22	5.13±0.10
MHBC (cm)	6.40±0.69	6.34±0.88	6.47±0.55	6.24±0.60	5.96±0.42	6.70±0.60
MLBC cm)	8.33±0.35	8.50±0.38	8.11±0.18	8.44±0.32	8.32±0.28	8.59±0.35
BCI %	77.55±7.25	75.44±8.36	79.66±6.39	75.72±5.94*^{b}	71.89±4.79^{b}	80.51±2.93^{b}
NCV (ml)	96.43±8.56**	99.25±6.13	92.67±11.24	106.86±8.38**	106.86±8.38	107.67±4.93
SH (cm)	10.71±1.30	10.35±1.50	11.35±0.56	11.03±1.16*^{b}	10.37±1.10^{b}	11.81±0.67^{b}
SL-1 (cm)	20.94±2.03	20.52±2.05	21.51±2.30	22.26±2.11	21.18±1.85	23.57±1.32
SL-2 (cm)	21.06±1.96	20.15±2.18	22.20± 0.89	21.88±2.57*^{b}	19.74±1.47^{b}	23.59±1.84^{b}
NBL (cm)	10.30±1.39	9.70±1.05	11.68±1.14	11.03±1.56	10.45±1.58	11.73±1.37
FBL (cm)	7.18±0.59	7.11±0.78	7.34±0.37	7.42±0.48	7.16±0.78	7.81±0.25
FMH (cm)	1.83±0.21	1.76±0.25	1.89±0.17	2.00±0.36	1.72±0.59	1.97±0.10
FMW (cm)	2.00±0.24	1.98±0.22	2.07±0.36	2.07±0.28	2.16±0.39	1.97±0.10
FMI %	90.20±14.68	90.57±20.30	89.63±6.07	92.80±15.01	79.06±7.35	101.97±10.41

* Significant difference (p<0.05) between age groups within sex.
**Significant difference (p<0.05) between males and females.

DISCUSSION

From this study, it was observed that female pigs had higher osteometric measurements than male pigs. This observation is similar to the result obtained in domestic pigs in Southwestern Nigeria, by Olopade and Okandeji. (2010), and in the Red Sokoto goats, by Olopade and Onwuka (2002), where the females had higher osteometric measurements when compared with the males, but different from the report of Brudnicki (2005), in wild and domestic pig skulls from Poland. This observation of higher female osteometric values may be more of a genetic feature or maybe because variations exist in the ages of the male and female animals used for the research.

The NCV is a reflection of the brain weight and may have a relationship with the weight of the head. In this study, the NCV was higher in the females, when compared to the result obtained in the males, and follows the general trend of the females having higher dimensions in most of the skull parameters. This result contradicts the findings of Brudnicki (2005), who reported that males of the wild boar and domestic pigs had higher cranial volumes. This may be due to the existence of significant differences in the skull shapes and sizes between the various breeds and individuals (Uddin *et al.*, 2013).

Brudnicki (2005) also reported a correlation between the length of the neurocranium and the volume of the cranial cavity. This observation correlates with our findings, where the females had longer NCL and higher NCV, although the values of the NCL between sexes showed no significant difference. Golalipour *et al.* (2005) reported that there was a direct correlation between cranial volume and brain volume in humans in Iran, therefore, the values obtained in this study could give a more accurate estimation of the brain volume of this breed of pigs. The observation of a higher NCV in the females, from this study, is similar to the result obtained in the Red Sokoto goats, by Olopade and Onwuka (2002), where the females had heavier brains than the males. This female bias indicates a sexual dimorphism in the neurocranial volume; thus, indicating that females in this study generally have larger braincases and possibly greater brain masses than the males. A higher NCV could imply that the females used in this study may be prone to conditions of increased intracranial pressure, in comparison to the males (Igado 2011). Since brain weight is considered to be 85-90% of the cranial content (Uddin *et al*., 2013), the brain density of this breed of pig can be assessed from this data, making it a good model for intracranial pressure studies.

While the phenotypic appearance of the head is thought to be influenced by the shape of the skull and is considered to be strongly related to breed-specific skeletal features (Kunzel *et al.,* 2003), the shape of the skull is probably influenced by the relationship between the length of the facial and nasal bones, and the dimensions of the braincase. Kunzel *et al.* (2003) reported that a reduction in the length of the face correlated with an increase in the width and height of the braincase. The mean values for MHBC and MLBC, from this study, did not reveal any significant differences in both sexes. However, the older females had higher values for the braincase height and length, when compared to the older males. Kunzel *et al.* (2003) also reported that skull length parameters can be influenced by skeletal features like the shape of the external occipital protuberance or the shape of the foramen magnum and that the MHBC may be considered to be the determinant of the shape of the skull. These skeletal features could be responsible for the varying shapes of the skulls of different breeds of pigs.

Although the FMW was higher in the younger females, compared to the older females used in this study, age appeared to play a significant role in the values obtained for the WOH, SL-2, SH and BCI. This could suggest significant and rapid growth in the bony braincase and skull, including the head and soft tissues, in pigs less than a year compared to those older than a year. The higher skull length may be attributed to increased growth in the length of the snout (nasal bone) and facial bone (Kunzel *et al.,* 2003) and the skull height will have considerable effects on the braincase. Females have a precocious growth from 1 year and above and this may be a consideration in pigs meant for fattening in West Africa. This observation in the females could be due to genetic or hormonal influences, as it has been reported that female pigs appear to grow faster than their male counterparts, after weaning (Dunshea, 2001). In the males, no statistical significance was observed in all parameters, between the young and old but the NCL, NCV, MLBC, and FMI were higher in younger subjects. These parameters are all linked to the braincase and these reductions may be the reason for higher values in females than in males.

The mean FMH and FMW values obtained in this study were smaller than those obtained in Dum pigs and Wild boars (Sarma *et al.,* 2002; Iqbal *et al*., 2020), but higher than what was obtained in the local Mizoram pig (Choudhary *et al*., 2019). These differences could be attributed to the influence of geographical and genetic variations on the shapes of the skulls. The FMI obtained from this study was higher than the 83.42 obtained in Local Mizoram Pig (Choudhary et al., 2019). It was, however, similar (below 100) to that of the African Giant Rat (81.42; Olude *et al*., 2009), dog (93.51; Onar, *et al*., 1997) and rabbit (74.78; Kahvecioglu *et al*., 2000), but lower than that of the West African Dwarf goat (102.5; Olopade and 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 a variability in the foramen magnum due to the age and species of the animals (Uddin *et al*., 2013). An 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 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).

CONCLUSION

In conclusion, the craniometric values of the neurocranium and skull of domestic pigs provide an important baseline for further research in this field. The results obtained, therefore, provide added information that can be used to aid the regional surgery around the head, and in comparative skull typology and craniometric research in pigs.

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