



Original Research Paper

Multivariate analysis of body weight, morphometric and thermo-physiological traits of indigenous pigs under tropical conditions

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Abstract

The study aimed at describing objectively the interdependence among the morphological and heat tolerance traits of Nigerian indigenous pigs and to predict body weight from conformation traits. Data on body weight, eight linear body measurements (BL, CG, CD, WH, RH, EL, SL and TL) and three thermo-physiological parameters were measured on 150 randomly selected pigs of three growth stages (piglets, growers and finishers) from February to December, 2020. The animals were managed in an extensive system in Plateau State, north central Nigeria. General linear model was used to study growth stage and sex effects including their interaction. Multivariate principal component analysis was used for the size, shape and heat tolerance determination while the animals were classified using canonical discriminant analysis. The stepwise regression was used for body weight prediction. The results showed that finishers had significantly higher ($P<0.05$) body weight, body length, chest girth, chest depth, withers height, rump height, ear length, snout length and tail length, followed by growers while the least values were recorded in piglets. Pulse rate was not significantly different ($P>0.05$) between piglets and finishers, although the latter had higher respiratory rate (39.48 ± 0.53 vs. 39.90 ± 0.53 vs. 36.77 ± 0.75). However, rectal temperature was similar ($P>0.05$) among the three pig categories. With the exception of tail length, sexual dimorphism was observed in all the morphometric traits with higher values recorded for males. However, the three thermo-physiological traits were not affected by sex ($P>0.05$). BW was highly and positively correlated with most biometric traits ($r = 0.80-0.93, 0.66-0.80$ and $0.83-0.93$; $P<0.01$ for piglets, growers and finishers, respectively). Three principal components (PC1, PC2 and PC3) were extracted for optimal balance of the animals. Withers height, ear length and body weight were found to be the most discriminating variables to separate the pig categories. Classification results showed that 100% of piglets, 96.7% of growers and 96.7% of finishers were correctly assigned to their distinct populations. The present information could be exploited in devising appropriate management and breeding programs for tropically adapted pigs in Nigeria.

Keywords: Nigerian indigenous pigs, conformation, measurements, heat tolerance, multivariate analysis

Introduction

Pigs are one of the most prolific and fast growing livestock that can convert feed and food waste to valuable products. The value of a pig carcass for meat production depends primarily on carcass weight and the relation proportions of fat and lean meat (Brown-Brandi *et al.*, 2004). Indigenous breeds are usually owned by rural farmers, although they may not yield as much in production as the exotic breeds. They produce a wider range of products, thrive on low forage and require lower levels of health care. Their management is ecologically more sustainable, especially in marginal environments (Kohler-Rollefson, 2000; Rege *et al.*, 2011). According to the 2011 National Agricultural Sample Survey, the population of pigs in Nigeria was put at 7.1 million compared to an estimated 19.5 million goats and 41.3 million sheep (NBS, 2011). Despite decreasing trends in population size, the existing indigenous pigs still represent a valuable component of local animal genetic resources. Evaluating and assessing the phenotypic variation among native pig populations are important to identify the uniqueness of populations and possible gene flow between indigenous pigs.

External appearance (morphology) is still commonly used by researchers and practitioners in the identification, characterization and selection of farm animals (Yakubu, 2013; Shi *et al.*, 2020; Siewe *et al.*, 2021; Zhang *et al.*, 2021). Alternative body measurements and indices estimated from different combinations of different body traits produced a superior guide to weight and were also used as an indicator of type and function in domestic animals (Schwabe and Hall, 1989; Fernandes *et al.*, 2019). Morenikeji *et al.* (2019) have used linear body measurements such as body length, trunk length, height at withers, chest girth, tail length and shoulder to tail length to characterize pigs. In a related study, Al Ard Khanji *et al.* (2018) used flank-to-flank distance, heart girth, length and loin depth to predict body weight. Also, Panda *et al.* (2021) reported that body length, heart girth, paunch girth, height at wither, height at back, rump width, thigh circumference, neck circumference, and body depth had high correlation coefficients (0.8–0.97) with body weight (BW) at both weaning and post-weaning stages; thereby permitting the estimation of BW from the former.

Changes in thermo-physiological traits such as rectal temperature, respiratory rate and pulse rate can be used to evaluate the capacity of adaptation of pigs to hot-dry conditions. The understanding of the animal responses to thermal challenge is paramount to successful implementation of breeding strategies to increase production and productivity of pigs under cold and warm climates (Sipos *et al.*, 2013).

A considerable number of techniques describing pig morphometric have been utilized in the past (Muta *et al.*, 2011; Adeola *et al.*, 2013; Walugembe *et al.*, 2014). However, multivariate principal component and discriminant analyses, which have been successfully used in other livestock species (Yakubu *et al.*, 2010; Fraga *et al.*, 2016; Belkhadem *et al.*, 2019; Mediouni *et al.*, 2020; Meka *et al.*, 2021; Abed *et al.*, 2021) could be invaluable refined techniques for obtaining very useful information related to several characteristics of pigs (Ventura *et al.*, 2012) including body measurements (Silva Filha *et al.*, 2010) and thermo physiological traits. Evaluating and assessing the body weight, morphometric and heat-tolerance traits of animals are important to identify the uniqueness of populations, adaptive capacity and possible gene flow between the indigenous populations. In north central Nigeria, there is dearth of information on body size, conformation and heat stress parameters to inform decisions on breeding and management of pigs especially under the low-input, smallholder production systems. The present study, therefore, aimed at determining the body weight, morphometric characteristics and thermo-physiological traits of indigenous pigs in Nigeria using multivariate techniques.

Materials and Methods

Study Area

The study was conducted in Plateau State, north central Nigeria. Plateau State is located between latitude 8° 24' North and longitude 8° 32' and 10° 38' east. The altitude ranges from 1,200 meters (400 feet) to a peak of 1,829 meters above sea level in the Shere Hills range near Jos.

Sampling of animals

A total number of one hundred and fifty (150) indigenous pigs of different physiological ages were randomly sampled from the 3 agricultural zones (Plateau North, Plateau Central and Plateau South) of Plateau State, Nigeria. In each of the 3 agricultural zones, 50 pigs (of both sexes) were considered (20 adults, 20 growers and 10 piglets, respectively). They were further classified as 0-6 weeks (piglets), 7-13 weeks (growers) and 14-24 weeks (Finishers). The study was carried out from February to December, 2020.

Morphometric Data

- Body weight (kg) (measured with a digital scale) and the following eight linear body measurements (cm) were taken using the anatomical measurements described by ESGPIP (2009) and AU-IBAR (2015):
- Body length (BL): This is the length from the base of the tail to the middle of the shoulder blade along the back on the middle line or the distance from the base of the ear to the base of the tail. A graduated meter rule was used
- Chest girth (CG): The chest girth was measured around the chest just behind the front legs and withers.
- Withers height (WH): This is the distance from the surface of a platform on which the animal stands to the withers, or midpoint of the shoulder blade to the floor in the perpendicular plane. A graduated metre rule was used in the measurement.
- Rump height (RH): Rump height is the distance from the surface of a platform to the rump, using a meter rule.
- Ear length (EL): The distance between the tip of the ear and the base was taken using a measuring tape.
- Snout length (SL): The distance between the frontal nasal suture and upper part of the snout.
- Chest depth (CD): The distance from the back bone at the shoulder (standardized on one of the vertical processes of the thoracic vertebrae) to the brisket between the front leg.
- Tail length (TL): The length of the tail from the base of its attachment to the tip.

Thermo-physiological data

Pulse rate (PR): This was examined at the coccygeal artery, or at the femoral artery by counting the pulse waves per minute (bpm) using a stethoscope of normal range value of 90-110 bpm.

Respiratory rate (RR): This was determined by counting respiratory movement of the thorax per minute (bpm) using the finger tip.

Rectal temperature (RT): This was determined by the use of a clean digital thermometer (38.5-40°C).

Statistical analysis

Data were analyzed using the general linear model (GLM) procedure of SPSS (2017) software to test the fixed effects of growth stage and sex as well as their interaction on BW, BL, CG, CD, WH, RH, EL, SL, TL, RR, PR and RT. Means were separated using the least significant difference (LSD) method at 95% confidence interval. The following linear model was employed:

$$Y_{ijk} = \mu + G_i + S_j + (GS)_{ij} + e_{ijk}$$

Y_{ijk} = individual observation

μ = overall mean

G_i = fixed effect of i^{th} growth stage (i = piglets, growers and finishers).

S_j = fixed effect of j^{th} sex (j = male, female)

$(GS)_{ij}$ = interaction effect of i^{th} growth stage and j^{th} sex

e_{ijk} = random error associated with each record (normally, independently and identically distributed with zero mean and constant variance)

Pearson's coefficients of correlations were computed for all the traits. The multivariate principal component (PC) and discriminant analyses were also employed. Among the many multivariate analysis methods, principal component analysis is a simple powerful one that has been advocated for analysis of population genetic relationship (Vohra *et al.*, 2015). The objective of PC analysis is to account for the maximum numbers of composite variables. The criterion of eigenvalues greater than 1 (one) was used to retain the main components. The reliability of the PC analysis was tested using anti-image correlations, The Kaiser Meyer Olkin measure of sampling adequacy and Bartlett Test of Sphericity.

In order to identify the combination of variables that best separate the three growth stages, canonical discriminant analysis was used (Tabachnick and Fidel, 2001). The ability of this discriminant model to identify piglets, growers and finishers was indicated as the percentage of individuals correctly assigned to its a priori group. Split-sample validation (cross-validation) was used to evaluate the accuracy of the classification.

A multiple regression procedure using a stepwise variable selection was used to obtain models of estimation of BW from biometric measurements. SPSS (2017) was used in all analyses.

Results

The body weight, linear body measurements and heat tolerance characteristics of piglets, growers and finishers are presented in Table 1. The results revealed that finishers had significantly higher ($P < 0.05$) body weight, body length, Chest girth, Chest depth, withers height, rump height, ear length, snout length and tail length, followed by growers while the least values were recorded in piglets. Pulse rate was not significantly different ($P > 0.05$) between piglets and finishers, although the latter had higher respiratory rate (39.48 ± 0.53 vs. 39.90 ± 0.53 vs. 36.77 ± 0.75). However, rectal temperature was similar ($P > 0.05$) among the three pig categories.

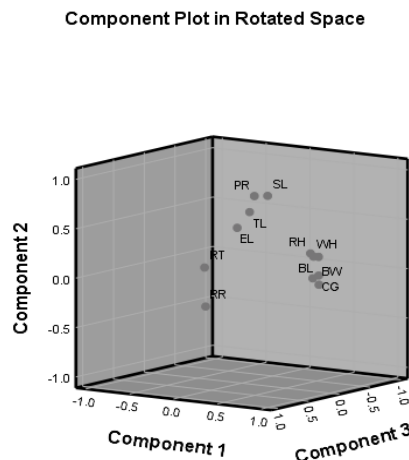


Figure 1. The three principal components plot in rotated space.

With the exception of tail length ($P > 0.05$), body weight and linear body measurements were significantly higher ($P < 0.05$) in males compared to their female counterparts (Table 2). However, rectal temperature, pulse rate and respiratory rate were not significantly influenced ($P > 0.05$) by sex.

There was significant ($P < 0.05$) growth stage and sex interaction effect on BW, BL, CG, CD, WH, RH and RR. Male finishers had significantly higher BW (29.83 vs. 22.17 ; $P < 0.05$) compared to females, whereas BW in both sexes was statistically similar ($P > 0.05$) among piglets and growers (Table 3). Male finishers also had higher BL (47.63 vs. 38.90), CG (51.37 vs. 41.43), WH (43.37 vs. 39.50) and RH (45.13 vs.

41.18; $P < 0.05$). The CD also favoured ($P < 0.05$) male growers (16.39 vs. 14.75) and finishers (26.63 vs. 22.63), respectively. With respect to RR, however, significantly higher $P < 0.05$ value was found in females (39.13 vs. 34.40).

Table 1. Body weight, conformation and heat tolerance traits (Means \pm SE) of different categories of pigs in Plateau State

Parameters	Growth Stage		
	Piglets	Growers	Finishers
Body weight	6.60 \pm 0.78 ^c	12.35 \pm 0.54 ^b	26.00 \pm 0.54 ^a
Body length	22.45 \pm 0.91 ^c	29.77 \pm 0.64 ^b	43.27 \pm 0.64 ^a
Chest girth	17.88 \pm 1.03 ^c	26.88 \pm 0.73 ^b	46.40 \pm 0.73 ^a
Chest depth	8.02 \pm 0.53 ^c	15.57 \pm 0.37 ^b	24.63 \pm 0.37 ^a
Withers height	19.98 \pm 0.47 ^c	29.02 \pm 0.33 ^b	41.43 \pm 0.33 ^a
Rump height	20.64 \pm 0.51 ^c	30.07 \pm 0.36 ^b	43.16 \pm 0.36 ^a
Ear length	2.87 \pm 0.20 ^c	7.59 \pm 0.14 ^b	10.82 \pm 0.14 ^a
Snout length	3.81 \pm 0.32 ^c	8.6 \pm 0.23 ^b	12.12 \pm 0.23 ^a
Tail length	3.74 \pm 0.34 ^c	8.14 \pm 0.24 ^b	10.70 \pm 0.24 ^a
Rectal temperature	39.32 \pm 0.53 ^a	38.47 \pm 0.37 ^a	37.93 \pm 0.37 ^a
Pulse rate	78.73 \pm 1.67 ^{ab}	75.32 \pm 1.18 ^b	79.93 \pm 1.18 ^a
Respiratory rate	36.77 \pm 0.75 ^b	39.90 \pm 0.53 ^a	39.48 \pm 0.53 ^a

S.E. = Standard error of means

^{abc} Means within rows carrying different superscripts are significantly different ($P < 0.05$)

Table 2. Effect of sex on body weight, conformation and heat tolerance traits (Means \pm SE) of pigs

Parameters	Sex	
	Female	Male
Body weight	13.11 \pm 0.51 ^b	16.84 \pm 0.51 ^a
Body length	30.01 \pm 0.60 ^b	33.65 \pm 0.60 ^a
Chest girth	28.21 \pm 0.69 ^b	32.56 \pm 0.69 ^a
Chest depth	14.93 \pm 0.35 ^b	17.21 \pm 0.35 ^a
Withers height	29.07 \pm 0.31 ^b	31.22 \pm 0.31 ^a
Rump height	30.30 \pm 0.34 ^b	32.27 \pm 0.34 ^a
Ear length	6.81 \pm 0.14 ^b	7.37 \pm 0.14 ^a
Snout length	7.78 \pm 0.21 ^b	8.58 \pm 0.21 ^a
Tail length	7.44 \pm 0.23 ^a	7.61 \pm 0.23 ^a
Rectal temperature	38.80 \pm 0.35 ^a	38.34 \pm 0.35 ^a
Pulse rate	77.51 \pm 1.12 ^a	78.48 \pm 1.12 ^a
Respiratory rate	39.30 \pm 0.50 ^a	38.13 \pm 0.50 ^a

In piglets, while BW was highly and positively correlated with WH, CG, CD, SL, RH, TL, EL and BL ($r = 0.93, 0.92, 0.91, 0.89, 0.88, 0.88, 0.85, 0.80$; $P < 0.01$), it was negatively associated with RT (-0.66) (Table 4). Incidentally, RT was positively and negatively correlated with all the body conformation traits ($r = -0.66-0.95$; $P < 0.01$) while PR was related to BL and CG ($R = -0.68$ and -0.67 ; $P < 0.01$). However, the highest correlation coefficient was found between WH and RH ($r = 0.98$; $P < 0.01$) while the lowest was between CG and RR ($r = 0.02$; $P > 0.05$). Among growers, BW was also highly and significantly ($P < 0.01$) related to WH (0.80), BL (0.77), CG (0.72), EL (0.68) and RH (0.66). In this group, statistically significant positive correlation was observed between BW and RT (0.26), the latter was also positively correlated with CG (0.41) and BL (0.34). PR was negatively related to CD (-0.65), TL (-0.58), SL (-0.48) and EL (-0.41) while RR had positive relationship with CD (0.33). However, the highest correlation was

between CG and BL ($r = 0.91$; $P < 0.01$) while the lowest was between CG and PR, SL and RT as well as TL and RT ($r = -0.01$; $P > 0.05$, respectively). At the finishing stage, strong relationship was observed between BW and body parameters such as CD (0.93), CG (0.92), BL (0.88), WH (0.86) and RH (0.83). RT and TL ($r = 0.28$; $P < 0.05$), PR and SL ($r = 0.42$; $P < 0.01$) and PR and TL ($r = 0.32$; $P < 0.05$) were positively and significantly correlated. However, the relationship between WH and RH was strongest ($r = 0.95$; $P < 0.01$) while the weakest was between WH and PR ($r = 0.03$; $P > 0.05$).

Table 3. Growth stage and sex interaction effect on body weight, conformation and heat tolerance traits of pigs

Parameters	Piglets		Growers		Finishers		P-value
	Female	Male	Female	Male	Female	Male	
BW	5.80±1.09 ^a	7.39±1.09 ^a	11.39±0.77 ^a	13.30±0.77 ^a	22.17±0.77 ^b	29.83±0.77 ^a	0.001
BL	22.20±1.28 ^a	22.70±1.28 ^a	28.93±0.91 ^a	30.60±0.91 ^a	38.90±0.91 ^b	47.63±0.91 ^a	0.001
CG	17.00±1.46 ^a	18.76±1.46 ^a	26.20±1.03 ^a	27.57±1.03 ^a	41.43±1.03 ^b	51.37±1.03 ^a	0.001
CD	7.40±0.75 ^a	8.63±0.75 ^a	14.75±0.53 ^b	16.39±0.53 ^a	22.63±0.53 ^b	26.63±0.53 ^a	0.036
WH	19.20±0.66 ^a	20.76±0.66 ^a	28.50±0.47 ^a	29.53±0.47 ^a	39.50±0.47 ^b	43.37±0.47 ^a	0.008
RH	20.20±0.72 ^a	21.10±0.72 ^a	29.53±0.51 ^a	30.60±0.51 ^a	41.18±0.51 ^b	45.13±0.51 ^a	0.007
EL	2.63±0.29 ^a	3.10±0.29 ^a	7.29±0.20 ^a	7.90±0.20 ^a	10.53±0.20 ^a	11.10±0.20 ^a	0.956
SL	3.40±0.45 ^a	4.23±0.45 ^a	8.33±0.32 ^a	8.87±0.32 ^a	11.60±0.32 ^a	12.64±0.32 ^a	0.725
TL	3.54±0.48 ^a	3.94±0.48 ^a	8.10±0.34 ^a	8.18±0.34 ^a	10.67±0.34 ^a	10.73±0.34 ^a	0.915
RT	39.61±0.75 ^a	39.02±0.75 ^a	38.88±0.53 ^a	38.06±0.53 ^a	37.92±0.53 ^a	37.93±0.53 ^a	0.718
PR	77.47±2.36 ^a	80.00±2.36 ^a	75.80±1.67 ^a	74.83±1.67 ^a	79.27±1.67 ^a	80.60±1.67 ^a	0.649
RR	39.13±1.06 ^a	34.40±1.06 ^b	39.13±0.75 ^a	40.67±0.75 ^a	39.63±0.75 ^a	39.33±0.75 ^a	0.004

BW=body weight; BL =body length; CG= chest girth; CD= chest depth; WH= withers height; RH= rump height; EL=ear length; SL= snout length, TL=tail length, RT=rectal temperature; PR= pulse rate; RR= respiratory rate ^{ab} Means within rows carrying the same superscripts do not differ significantly ($P > 0.05$) for all interactions

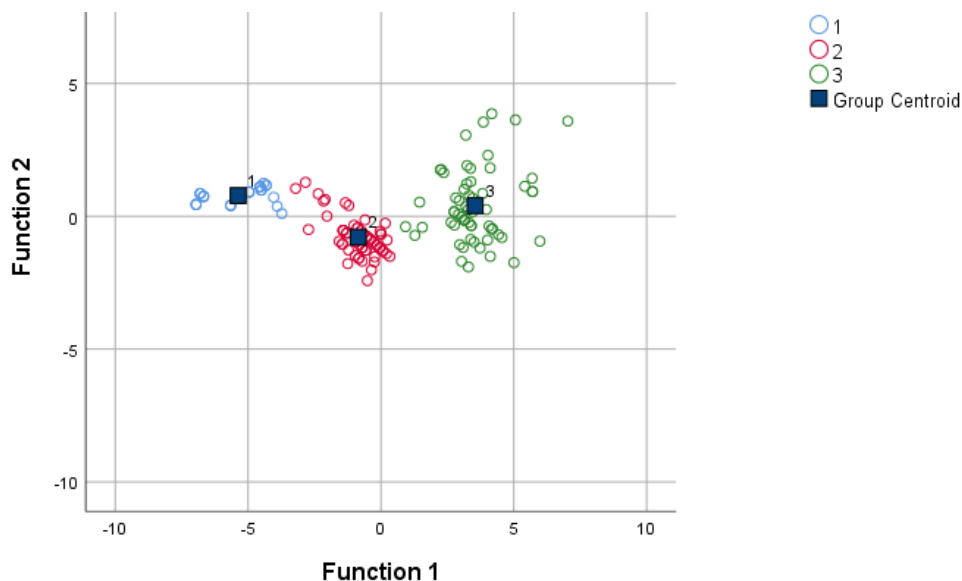


Figure 2. Canonical discriminant function showing the distribution among the three pig categories. 1=piglets; 2= growers; 3= finishers

Considering the low Anti-image correlations (partial correlations) obtained, there existed true factors in the data sets. This was strengthened by the high value (0.82) of Kaiser-Meyer- Olkin (KMO) measure of sampling adequacy, which revealed the proportion of the variance in BW, conformation traits and heat

Table 4. Phenotypic correlations of body weight, conformation and heat tolerance traits of pigs

Traits	BW	BL	CG	CD	WH	RH	EL	SL	TL	RT	PR	RR	
BW		0.80**	0.92**	0.91**	0.93**	0.88**	0.85**	0.89**	0.88**	-0.66**	0.07	-0.11	
BL	0.77**		0.83**	0.90**	0.93**	0.94**	0.84**	0.84**	0.89**	0.90**	-0.68**	-0.16	.157
CG	0.72**	0.91**		0.95**	0.96**	0.94**	0.91**	0.85**	0.95**	0.95**	-0.67**	0.02	.080
CD	0.58**	0.42**	0.44**		0.96**	0.94**	0.88**	0.92**	0.94**	-0.67**	-0.07	0.05	
WH	0.80**	0.71**	0.74**	0.62**		0.98**	0.89**	0.88**	0.93**	-0.72**	-0.07	0.17	
RH	0.66**	0.61**	0.62**	0.53**	0.82**		0.83**	0.80**	0.90**	-0.67**	-0.14	0.26	
EL	0.68**	0.53**	0.58**	0.70**	0.74**	0.69**		0.91**	0.98**	-0.71**	0.04	-0.11	
SL	0.37**	0.40**	0.37**	0.57**	0.46**	0.52**	0.75**		0.92**	-0.70**	-0.02	-0.17	
TL	0.26*	0.32*	0.26**	0.60**	0.35**	0.42**	0.60**	0.88**		-0.66**	0.02	-0.05	
RT	0.26*	0.34**	0.41**	0.13	0.24	0.13	0.09	-0.01	-0.01		0.42*	0.03	
PR	-0.05	0.05	-0.01	-0.65**	-0.19	-0.19	-0.41**	-0.48**	-0.58**	0.05		-0.36	
RR	0.14	-0.003	0.10	0.33**	0.16	0.03	0.09	-0.06	0.04	-0.02	-0.16		
BW													
BL	0.88**												
CG	0.92**	0.88											
CD	0.93**	0.87**	0.85										
WH	0.86**	0.80**	0.76**	0.83**									
RH	0.83**	0.79**	0.76**	0.80**	0.95**								
EL	0.35**	0.36**	0.29*	0.41**	0.47**	0.49**							
SL	0.34**	0.52**	0.33**	0.40**	0.50**	0.47**	0.55**						
TL	0.42**	0.50**	0.40**	0.44**	0.55**	0.59	0.62**	0.67**					
RT	0.09	0.16	0.12	0.17	0.15	0.14	0.18	0.15	0.28*				
PR	-0.11	0.16	0.10	-0.11	0.03	0.10	0.10	0.42**	0.32*	-0.05			
RR	0.25	0.09	0.21	0.19	0.06	0.10	0.23	-0.11	0.20	0.19	-0.18		

BW=body weight; BL =body length; CG= chest girth; CD= chest depth; WH= withers height; RH=rump height; EL=ear length; SL= sn out length, TL=tail length, RT=rectal temperature; PR= pulse rate; RR= respiratory rate

* **Significant at $P < 0.05$ and $P < 0.01$, respectively

1st Upper diagonal= piglets; 2nd Upper diagonal= growers; Lower diagonal= finishers

tolerance traits caused by the underlying factor. The overall significance of the correlation matrices tested with Bartlett's Test of Sphericity for the body parameters (chi-square =704.657; $P < 0.01$) supported the validity of the principal component analysis of the data sets. Principal components, eigenvalues and percentage of variance explained by components are shown in Table 5 and Figure 1, respectively. Based on the criterion of the eigenvalues-greater-than-one rule proposed by Kaiser, three principal components (PC1, PC2 and PC3) were retained. The three components had eigenvalues of 5.340, 2.353 and 1.565, respectively and explained about 77% of the generalized variance.

Based on Wilks' Lambda (0.056-0.105) and F statistics (155.375-625.864) (Table 6), withers height, ear length and body weight were the significant ($P < 0.001$) parameters of importance to separate piglets, growers and finishers (Figure 2).

The prediction of group membership of piglets, growers and finishers is shown in Table 7. The classification results showed that 100% of piglets, 96.7% of growers and 96.7% of finishers were correctly assigned to their distinct groups. The three respective percentage values were 97.3% cross-validated.

The stepwise models predicting BW from linear body measurements are shown in Table 8. For piglets, withers height solely accounted for about 86% of the variation in body weight. The inclusion of body length in the model increased the proportion of the explained variance to about 88%. The accuracy of the model was further improved ($R^2 = 90.8\%$) when snout length was added to the equation. In growers, withers height alone contributed to 63.2% of the variation in body weight. The best prediction equation ($R^2 = 0.722$) was obtained when it was combined with body length. However, the highest single contributor ($R^2 = 0.869$) to the variation in body weight of finishers was chest depth. However, the proportion of the explained variance progressively increased to 94.2% when chest girth, withers height and snout length were added to the model.

Table 5. Principal components, eigenvalues and percentage of variance explained by components (% VCP) and communalities

	PC1	PC2	PC3	Communality
Body weight	0.976	0.004	0.139	0.971
Body length	0.896	0.262	0.031	0.872
Chest girth	0.918	0.080	0.062	0.853
Chest depth	0.933	0.071	0.180	0.908
Withers height	0.886	0.274	0.098	0.869
Rump height	0.863	0.307	0.116	0.851
Ear length	0.289	0.561	0.488	0.636
Snout length	0.326	0.824	0.046	0.788
Tail length	0.363	0.714	0.392	0.796
Rectal temperature	0.027	0.155	0.644	0.440
Pulse rate	-0.083	0.728	-0.322	0.641
Respiratory rate	0.117	-0.214	0.757	0.632
Eigenvalues	5.340	2.353	1.565	
Percentage VCP	44.498	19.606	13.038	
Percentage VCP Cumulative	44.498	64.104	77.141	

Table 6. Variables of importance in separating piglets, growers and finishers

Parameters	Wilks' Lambda	df1	df2	df3	F-value	Significance
Withers height	0.105	1	2	147.000	625.864	0.001
Ear length	0.066	2	2	147.000	211.327	0.001
Body weight	0.056	3	2	147.000	155.375	0.001

Table 7. Assignment of the three pig populations into groups

	Predicted group membership
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	Growth stage	Piglets	Growers	Finishers	Total
Original count	Piglets	30	0	0	30
	Growers	2	58	0	60
	Finishers	0	2	58	60
%	Piglets	100.0	0.0	0.0	100.0
	Growers	3.3	96.7	.0	100.0
	Finishers	0.0	3.3	96.7	100.0
Cross-validated count	Piglets	30	0	0	30
	Growers	2	58	0	60
	Adults	0	2	58	60
%	Piglets	100.0	0.0	0.0	100.0
	Growers	3.3	96.7	.0	100.0
	Finishers	0.0	3.3	96.7	100.0

97.3% of original grouped cases correctly classified.

97.3% of cross-validated grouped cases correctly classified.

Table 8. Stepwise multiple regression of body weight on body measurements of pigs

Model	Significance	R ²	Adjusted R ²	RMSE
Piglets				
1. BW = -3.407 + 0.501WH	P<0.01	0.855	0.850	0.52
2. BW = -1.656 + 0.728WH - 0.280BL	P<0.01	0.883	0.875	0.48
3. BW = -0.237 + 0.571WH - 0.319BL + 0.675SL	P<0.01	0.917	0.908	0.41
Growers				
1. BW = -20.160 + 1.120WH	P<0.01	0.632	0.626	1.40
2. BW = -18.559 + 0.698WH + 0.358BL	P<0.01	0.722	0.713	1.23
Finishers				
1. BW = -20.384 + 1.883CD	P<0.01	0.869	0.867	2.66
2. BW = -16.877 + 1.108CD + 0.336CG	P<0.01	0.924	0.922	2.04
3. BW = -24.656 + 0.853CD + 0.305CG + 0.374WH	P<0.01	0.936	0.933	1.89
4. BW = -24.683 + 0.865CD + 0.295CG + 0.469WH + 0.309SL	P<0.01	0.942	0.938	1.82

R² = coefficient of determination; RMSE = root mean square error

Discussion

The higher values of finishers are consistent with the normal growth trajectories where adults are bigger in size than the young ones. This is consistent with the earlier submission that age greatly influence body weight and conformation traits of animals, and that growth follows a general pattern till maturity stage (Yakubu *et al.*, 2011). The body weight values of the three pig categories of the present study are comparable to the range of 9 - 32 kg (female) and 8 - 37 kg (male) in Nigerian indigenous pigs (NIP) and crossbred pigs (CBP) reported by Adeola *et al.* (2013) in a humid tropical zone of Nigeria. The body weight range (5.80 - 7.39 kg) of the Nigerian indigenous piglets is also comparable to the 6.8 kg of low performing population, but less than the 12.2 kg of high performing population 6-week-old Hypor Libra' piglets in Netherlands (Paredes *et al.*, 2014). The average body weight of the Nigerian indigenous piglets appeared lower than the 8.40 ± 2.04 kg found in purebred Berkshire pigs reared in a hoop structure (Park and Oh, 2018). The variation may be attributed to genotype and environmental factors. However, the small body size of the Nigerian indigenous piglets may be an adaptive strategy to withstand the prevailing harsh environmental conditions.

Sexual dimorphism is a widespread phenomenon among animal groups (Yakubu, 2011; Bozkurt and Can, 2021). The most likely traits to exhibit sexual dimorphism are body size and shape. At inter-population level especially with size and most conformation traits, sexual dimorphism in the present study favoured male animals. The differential rate and duration of growth may be responsible for the present observations. This is in

consonance with the report of Baeza *et al.* (2001) that between-sex differential hormonal action may invariably lead to differential growth rates in males and females. The present differences may also be attributed to strong sexual selection favouring large males whereas the females were subjected to weak fecundity selection. According to Salogni *et al.* (2018), high male-biased dimorphism in body size is as a result of the physical competition among males in order to have access to breeding females; hence the possession of large size can assist greatly in winning contests or allow the extension of a male's breeding tenure. It has been postulated that genes for important economic traits may be differently expressed in males and females (van der Heide *et al.*, 2016; Fairbairn, 2016). This was buttressed by the submission of Raidan *et al.* (2019) that in the presence of genotype-by-sex interactions, selection for traits in each sex may result in high rates of genetic improvement. However, if animals are to be identified based on highest breeding value, the data for females and males may be considered a single trait (Raidan *et al.*, 2019). The varying growth stage by sex interaction effect permits the different ranking of piglets, growers and finishers under the two sexes. The respiratory rate and rectal temperature of the present study were lower than the values of 43.75-72.12 breaths/min. and 39.05 °C-39.57 °C obtained in pigs reared in India (Pathak *et al.*, 2018). The differential values could be as a result of varying genetic groups, weather conditions and management practices.

The high correlation of rectal temperature with body weight and conformation traits in piglets is an indication that this parameter could be a good indicator of welfare and comfort (Zaake, 2018). According to Zaake (2018), rectal temperature is one of the key heat stress parameters, which was found to be associated with chest girth in pigs. Achieving optimal development of thermoregulation is a challenge that piglets must confront to successfully adapt to extrauterine life (Villanueva-García *et al.*, 2021), especially in the hot-dry season in a tropical guinea savannah of Nigeria (Zakari *et al.*, 2021). The high positive correlations observed in the present study suggest that selection for a trait may lead to a correlated response in the other trait. Strong association between body weight and other parameters could lead to its prediction from linear body measurements. The present correlation values are comparable to the values reported by Adeola *et al.* (2013) in indigenous pigs of southwestern Nigeria. In another study on pigs under tropical conditions, Oluwole *et al.* (2014) found high correlations between body weight and morphometric traits.

The relevance of PC as a multivariate statistical tool was evidenced in the reduction of large number of explanatory variables into components that gave a better description of size and shape. In the present study, twelve explanatory variables have been reduced to three components. The three principal components (PC 1, PC 2 and PC 3) obtained could be useful in evaluating animals for breeding and selection purposes. Since correlation between principal components is zero, the selection of animals for any principal component will not cause a correlated response in terms of other principal components (Pinto *et al.*, 2006; Yakubu and Ari, 2018). In this wise and across the three growth stages in this study, selecting for body weight will positively affect the selection of body length, chest girth, chest depth, withers height and rump height. Also, selecting for ear length, snout length, tail length (PC2) could invariably lead to pulse rate selection. The ability of the discriminant function to successfully classify the three growth stages can be useful in making general management decisions especially in smallholder farms.

Under the resource poor low-input setting, farms do not have complete restraint and handling systems, and few have animal scales to determine body weights. Therefore, equations to estimate body weight from other body measurements are needed (Heinrichs *et al.*, 1992). Withers height was found as a very good parameter to estimate body weight in the present study. This might not be unconnected with the fact that wither height is a skeletal parameter that is not influenced by body condition. It is important that growth recommendations be based on body weight within the parameters of desired skeletal growth (Heinrichs *et al.*, 1992). This is because large body weight during early life without corresponding skeletal growth may result in impaired mammary development and reduced milk production (Sejrsen *et al.*, 1982). The present findings on body weight and body dimensions of pigs could aid the design of modern housing structures and equipment as postulated by Smith and Ramirez (2021).

Conclusion

The indigenous pigs in Plateau State Nigeria were of small body weights and morphometric traits, which could be part of the animals' adaptation for survival under the low-inputs tropical environment. High correlations were observed between body weight and most linear body measurements. The resultant three principal components could aid in selection and breeding programmes of the pigs. Withers height, ear length and body weight were sufficient to assign the pigs into their appropriate growth stages. Withers height was the best single parameter to predict body weight. The phenotypic Information obtained in this study may be exploited in subsequent managerial decisions to improve pig production in the study area. There is need for future study on molecular characterization to better understand the genome of the pigs.

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Data availability

Availability of data will be based on request.

Authors' Contributions

AY and GLD designed the work. The field work was carried out by GLD. Data analysis was carried out by AY. The first draft was written by GLD and proofread by AY and JH. The final draft was approved by all authors.

Conflict of Interest

The authors declare that there is no conflict of interest.

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