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Relationship between Body Weight and Body Dimensions in Adult Domestic Cavy, using Principal Component Analysis

T. E. Zetang[1], O. M. Momoh[1], P. A. Addass[1] and M. E. Khan[2*]

[1]Department of Animal Breeding and Physiology, Federal University of Agriculture Makurdi Benue State, Nigeria.
[2]Department of Chemistry Federal University Lokoja, Kogi State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Authors TEZ and OMM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author PAA and MEK managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Body weight and eleven (11) morpho-structural traits of 300 adult cavies sampled from three States of Northern Nigeria were used to study relationship between body weight and body dimensions in adult domestic cavy. Data collected on bodyweight and body dimension was subjected to least squares analysis and principal components analysis procedure. Results obtained showed a mean body weight of 495.00±7.35g for adult cavies. The mean values of the body dimensions ranged from 2.57±0.02cm for femur radius (FR) to 27.17±0.16cm for body length (BL). Two principal components which accounted for 64.47% of the total variance in body dimensions were extracted. The first principal component (PC_1) loaded heavily on Belly girth (BG), neck circumference (NC), Heart girth (HG), Body length (BL), Shoulder length (SL), Head length (HL), and Trunk length (TL) and explained 49.25% of the total variance. The second principal component (PC_2) accounted for 15.214% of the generalized variance and loaded on Hind leg length (HLL), fore leg length (FLL) and

**Corresponding author: E-mail: khandora2000@gmail.com;*

Hip to kneel length (HKL). The Orthogonal body shape characters derived from the factor analysis accounted for 52.5% of the variation in body weight of the adult cavies. It was concluded that linear body measurements would be effectively used to predict live body weights of the adult cavies.

Keywords: Domestic cavy body weight; morpho-structural traits; body dimension; principal components.

1. INTRODUCTION

The domestic cavy (*Caviaporcellus*) also known as guinea pig is a species of rodents belonging to the family *Caviidae*and the genus *Cavia*. Cavy originated in the Andes Mountains [1]. Inadequate information on morphological characterization of the domestic cavy in the Tropics could have been responsible for little or no understanding of the genetic diversity and breed specification of this micro livestock [2].

Linear body measurements described an animal more completely than conventional methods of weighing and grading [3]. Evaluation of breed type by the use of body measurements is more objective than that obtained by visual examination although both are inferior to the notion of "function" as selection criteria of breeding animals [4-8]. High phenotypic correlations between body weight and other linear measurements indicate that animal selection through the use of body measurements is more interesting than live weight [4-8].

Ozoje and Mgbere [9] reported that the final body weight of an animal is a reflection of the sum total of the weight of all its component parts. Also, Lucrece and colleagues reported the morphometrices of *Cavia Porcellus* in Benin southern Nigeria [10]. Therefore a change in any one of the component parts could impart positively or negatively on the final body weight depending on the direction of the change. Olutogun et al. [11] stated that body dimension traits tend to increase as body weight increases. Therefore, the relationship between live body weight and body dimensions is useful in the prediction of live body weight of animals [12].

In Cameroon, [13] reported on 8 body metric traits using principal component analysis (PCA) as predictor of live body weight. Most researches / researchers conducted in Nigeria on relationships between body linear measurements and live body weight of cavies used univariate or and bivariate analyses such as in [14,15]. The drawback of uni or bivariate analysis is that, body traits are interrelated both phenotypically and genetically [16-18]. Multivariate analysis seems to be the way forward since it considers not only their linear relationship, but also their interdependence on each other. Many workers have used independent factor scores derived from multivariate techniques of factor analysis in body morphological data analysis [19,20], and as a selection criterion for the improvement of body size [21]. Although principal component analysis (PCA) is a common technique in numerical classification, few attempts have been taken to apply the technique on studies of linear body measurements in guinea pigs [13]. The objective of this study was to investigate the relationship between body weight and some morphological structures of the adult domestic caviesusing principal component analysis (PCA) with a view to predicting body weight from the morpho-structural traits.

2. MATERIALS AND METHODS

2.1 Experimental Site

The study area covers Makurdi, Jos and Zaria towns in Northern Nigeria. These areas fall within latitude $7^{o}30^{'}$N and longitudes $7^{o}30'$ and 10^{o}E [22]. The climatic conditions of northern Nigeria exhibits two distinct seasons: namely a short wet season (in most cases, June to October) and a prolonged dry season, from November to May. Temperature during the day remains constantly high while humidity is relatively low throughout the year with little or no cloud cover. There are however wide ranges in temperature (between nights and days) particularly in very hot months. Mean monthly temperatures during the day exceed 36^{0}C while the mean monthly temperatures at night fall most times to below 22^{0}C. Rainfall generally is below 508/524 mm per annum.

The high plateau of Jos experiences climatic conditions which are markedly different from the generalized dry and wet period in northern Nigeria. Temperatures are $5\text{-}10^{0}$C lower due to high altitude than the surrounding areas.

Similarly the annual rain fall figures are higher than in areas around other states [23].

2.2 Experimental Procedure

A total of 300 mature domestic cavies ages ranging from 12 to 13 weeks of both sexes were randomly sampled from domestic cavy keepers in three locations in northern Nigeria. In each location 100 adult cavies were randomly sampled. Body weight and eleven (11) linear body measurements was taken on each of the domestic cavy recruited for the study.

2.3 Parameters Measured

2.3.1 Live body weight

The weight of the guinea pig was taken by simply placing each guinea pig on a top sensitive scale and individual weight of the animal was read.

2.3.2 Linear body measurements

The following body parameters based on their more direct relationship to body weight than others were taken in centimeters using Tailor's tape as follows:

- Head Length (HL): This is the length from the tip of the nose to the base of the head.
- Neck Circumference (NC): This is the distant round the neck.
- Heart girth (HG): This is the circumference of the chest just behind the forelegs
- Shoulder length (SL): This is the length from one end of the shoulder to the other.
- Trunk length (TL): This is the length between the neck (Shoulder) and the rump (Tail Drop)
- Body length (BL): Body length will be the distance from the occipital protuberance to the base of the tail.
- Belly girth (BG): This is the circumference of the belly
- Hip to Knee Length (HKL): This is the length from the hip to the knee
- Fore Leg Circumference (FLC): This is the distance round the fore leg
- Fore leg length (FLL): This is the length from the point of attachment of the fore leg to the tip of the fore leg;
- Hind leg length (HLL): This is the length from the point of attachment of the hind leg to the tip of the hind leg;

2.4 Experimental Design and Data Analysis

The experimental design used for the study was completely randomized; a design in which the treatment (variables) was replicated three times, with each replicate having a least 100 animals. The data generated was subjected to both least squares analysis and Principal component analysis

The least squares analysis entertained the following linear model:

$$Y_{ijk} = \mu + s_i + l_j + e_{ijk}$$

Where:

Y_{ijk}= single observation
μ = overall mean
s_i= fixed effect of sexthei^{th}(i= 1,2)
l_j = fixed effect of the j^{th} location (j=1, 2, 3)
e_{ijk} = random residual error

Principal component analysis was applied separately to the 11 morphometric traits. The analytic tool was used to combine measurements (variables) into uncorrelated components (PCs). Varimax rotation was applied to enhance the interpretability of the principal components. The Kaiser Rule criterion [22] was used to determine the number of factors extracted and factors that had Eigen values greater than 1was retained. Bartlett's test of Spherity, Anti-image correlations and Kaiser's measure of sampling adequacy was conducted to determine the appropriateness of the common factor model in analyzing the data sets. A measure of sampling adequacy below 0.5 was not accepted. Cumulative proportion of variance criterion was employed in determining the number of principal components extracted. The factor program of SPSS 2011 version statistical package was used for the principal component analysis.

3. RESULTS AND DISCUSSION

Body weight and linear body measurements Table1, shows the descriptive statistics of body weight and body linear measurements of domestic cavies. The mean body weight 495±0.00 g obtained for cavies in this study, falls within the range of 350-500g for cavies at 15 and 20 weeks of age respectively, same as reported by Lukefahr [24]. National Research Council [25] had stated that an average sized cavy is about 0.5 kg. This is similar to the mean of this study. The body weight with a mean value of 495g showed a great deal of variability (CV= 25.70%)

in the population. The variability in the body linear measurements showed coefficients of variation ranging from 6.46% in FLC to 28.41% in SL. Apart from SL and BW other variables with CV of 14% and above were NL, FR, BG and HKL. Shoulder length is the most variable linear body parameter in the population under study with a minimum value of 2.5cm and a maximum value of 11cm and CV of 28.41%. This is followed by body weight (CV=25.70%) in that order. On the whole, variability within the body parameters was very low as revealed by low standard error of means (SEM).

3.1 Relationship of Body Weight and Linear Body Measurements

Pearson correlation coefficient of body weight and linear body measurements of adult cavy is presented in Table 2. The body weight correlated positively and significantly (P<0.01) with all linear body measurements except HG which has lower correlation coefficient and not significant. All linear body measurements are positively correlated among themselves except for NC, TL, BL, BG, HKL, HLL, and FLL which showed negative and non –significant correlation with HG. More so, HG is negatively and non-significantly correlated with SL.

Egena et al. [14], reported that body weight correlated positively and significantly (P<0.05) with all the linear body measurements in male guinea pigs. More so, the same result was observed in females except that fore leg length was negatively correlated with body weight [14]. This does not agree with this study, because in the present study, FLL was significantly (P<0.01) and positively correlated with body weight. The differences could be due to the distinction made between the male and female cavy in the [14] study. The present study does not distinguish between the male and female in the correlation analysis. The high and significant (P>0.01) correlation between body weight (BW) and NC, HG, TL, BL, and BG indicated that they could be good predictors of body weight in cavy. Egena *et al.,* [14] similarly suggested that body length, heart girth, trunk length and length of ear could be very useful in predicting live body weight in male guinea pigs. This is also portrayed in the work of Ologbose, Ajayi and Agaviezor [26]. [27] reported similar findings in broiler chickens. The high positive correlation values indicated that as live body weight increases, the linear body measurement could also increase, the implication is that, the traits could be selected for at the same time [28] The high correlations also indicated that the total size of the animal is a function of both the length and body circumference as reported by Raymond [29].

3.2 Principal Component Analysis

Table 3 reveals Eigen values and percentages of total variance along with the rotated component matrix and communalities of body measurements of domestic cavy. The communalities ranged from 0.532 to 0.846, implying that each variable's variance was well represented in the extracted components and hence PCA adequate. Only two principal components with Eigen values greater than 1 were extracted after PCA. The two components were rotated and all the variables loaded strongly on the two components showing high correlation. The first principal component (PC_1) loaded seven of the original variables with highest loading on BG. The second principal component (PC_2) loaded three variables with the highest loading on HLL.

The principal component analysis allowed better understanding of the complex correlation among the traits and reduced the number of traits studied in the cavy, using only the first two principal components, without loss of information. The first two principal components (PC) explained together a high percentage of the total variance (64.468) in the traits. According to [29] R^2 values less than 30% does not show a large effect on the predictor variable. The first principal component (BF, NC, HG, SL, HL and TL) strongly correlated with BW and could be used as good predictors of live weight in adult cavies. The first principal component could be referred to as general body measurement. This is similar to the findings of [13] who reported two principal components on 8 body metric traits of cavies at all ages and pointed out that the general body size (PC_1), showed much contribution to live weight. In addition, [20] pointed out that, two principal components were extracted which explained 90.27% of the total variance in domestic Rabbits. PC_1 was highly correlated with body length, heart girth and thigh circumference, while PC_2 was associated with ear length. The authors concluded that PC_1 was good estimator of general size. A similar finding was reported by Cohen [30] in New Zealand wide rabbits.

Table1. Descriptive statistics of body weight (g) and morpho-structural characteristics (cm) of adult cavy from three locations in northern Nigeria

Variable	N	Min.	Max.	Range	Mean	Variance	St.Dev.	SEM	CV
HL	300	5.00	9.20	4.20	7.05	0.62	0.79	0.05	11.13
NC	300	6.00	17.00	11.00	11.62	2.33	1.53	0.09	13.13
HG	300	9.50	20.00	10.50	14.36	2.90	1.70	0.10	11.84
SL	300	2.50	11.00	8.50	3.95	1.26	1.12	0.07	28.41
TL	300	11.00	23.00	12.00	17.38	4.55	2.13	0.12	12.28
BL	300	19.00	34.00	15.00	27.17	7.28	2.70	0.16	9.93
BG	300	12.00	27.00	15.00	17.77	7.45	2.73	0.16	15.36
HKL	300	3.00	7.50	4.50	5.39	0.59	0.77	0.04	14.27
HLL	300	6.50	16.00	9.50	9.12	1.13	1.06	0.06	11.66
FLL	300	5.50	9.50	4.00	7.63	0.69	0.83	0.05	10.86
BW	300	300.00	960.00	660.00	495.00	16187.63	127.23	7.35	25.70

HL: head length, NC: neck circumference, HG: heart girth, SL: shoulder length, TL: truck length, BL: body length, BG: belly girth, HKL: hip to kneel, HLL: hind leg length, FLL: fore leg length, BW: body weight, CV: coefficient of variation, Min: minimum, Max: maximum, St. Dev.: standard deviation, SEM: standard error of mean, and N sample size.

Table 2. Pearson correlation coefficients of body weight and linear body measurements of adult cavy in northern Nigeria

	HL	NC	HG	SL	TL	BL	BG	HKL	HLL	FLL	BW
HL											
NC	.513**										
HG	.555**	.640**									
SL	.531**	.462**	.498**								
TL	.497**	.585**	.599**	.321**							
BL	.665**	.653**	.668**	.437**	.895**						
BG	.513**	.542**	.501**	.518**	.549**	.603**					
HKL	.459**	.329**	.391**	.077	.442**	.502**	.300**				
HLL	.284**	.171**	.239**	.075	.295**	.356**	.062	.407			
FLL	.280**	.192**	.216**	.053	.368**	.417**	.140*	.342	.480**		
BW	.450**	.565**	.555**	.373**	.584**	.619**	.644**	.324	.166**	.278**	

**(P< 0.05) ** (P<0.01) N=300*

HL: head length, NC: neck circumference, HG: heart girth, SL: shoulder length, TL: truck length, BL: body length, BG: belly girth, HKL: hip to kneel, HLL: hind leg length, FLL: fore leg length, BW: body weight

The second principal component accounted for 23.537% of the total variance and loaded for HLL, FLL and HKL. The low phenotypic correlation between these traits and BW (Table 2) indicated that they are poor predictors of BW in adult cavies. The second principal component could be referred to as appendages measurement. [12] reported that the appendage factors (PC_2) also had significant contributions to live weight at birth in cavies. However, this assertion is not supported by this present study as the appendage traits had no significant contribution to live weight in the adult cavies.

The two PCs could be used to select cavy based on a group variable rather than isolated traits. This was supported by the findings of [31,32], who predicted the effect of the breeding program using a reduced data set on morphological traits that are sensitive to correlated response to selection. The principal components can also be used in development of selection index to simplify them, because such an index would have few PCs in the place of the original traits [33].

Table 4 presents the predictive equations generated from data of principal component taken at mature body weight and the coefficient of determination (R^2). The coefficient of determination ranged from 41.3% to 52.6%. The highest coefficient of determination was obtained by combining the following variables to predict body weight (BW): BG, HG, SL, HL, TL, BL, HLL HKL, NC and FLL. The PC_1 yielded 52.0% efficiency in body weight prediction as compared to 12.7% efficiency using PC_2.

All the predicted equations were significant (P<0.05) as group variables. PC_1 was the most reliable predictors of body weight because of its low coefficient of determination (R^2< 30%). Hence the most reliable predictors of body weight are the variables of PC_1 while the poor predictors of body weight are the variables of PC_2.

Table 3. Eigen values and percentage of total variance along with the rotated component matrix and communalities of body measurements of domestic cavy

Traits	Rotated component matrix		Communalities
	PC_1	PC_2	
BG	0.795	0.039	0.634
NC	0.782	0.171	0.641
BL	0.775	0.496	0.846
HG	0.771	0.246	0.655
SL	0.755	-0.144	0.592
HL	0.710	0.322	0.608
TL	0.692	0.463	0.693
HLL	0.032	0.797	0.636
FLL	0.074	0.777	0.609
HKL	0.306	0.662	0.532
Eigen values	4.925	1.521	
% of total variance	49.253	15.214	
Cumulative %	49.253	64.468	
Rotation sum of squared loadings			
% of total variance	40.931	23.537	
Cumulative %	40.931	64..468	

HL: head length, NC: neck circumference, HG: heart girth, SL: shoulder length, TL: truck length, BL: body length, BG: belly girth, HKL: hip to kneel, HLL: hind leg length, FLL: fore leg length,

Table 4. Stepwise multiple regression of body weight on the extracted linear body measurements and their principal components

Components	Regression equation	Coefficient of determination (R^2)
BG	BW= -38.8 +30.0BG	41.3
NC	BW= -198 +22.3BG +25.5NC	47.8
HG	BW= -281 +20.1BG +16.2NC +16.1HG	50.2
SL	BW= -297 +21.2BG +16.9NC+17.5HG -8.15SL	50.4
HL	BW=-314+20.9BG+16.5NC+16.8HG-9.18SL+6.02HL	50.3
TL	BW=-343+18.5BG+12.7NC+12.4HG-5.65SL+1.37HL+ 11.4TL	52.0
BL	BW=-361+18.2BG+11.9NC+11.8HG-5.84SL-3.38HL +6.32TL +5.93BL	52.0
HLL	BW=-371+18.4BG+12.0NC+11.7HG-5.72SL-3.76HL +6.37TL +5.54BL+2.08HLL	51.9
FLL	BW=-416+18.8BG+12.6NC+12.1HG-4.45SL-4.71HL +6.63TL +3.12BL-3.19HLL+17.8FLL	52.6
HKL	BW=-416+18.9BG +12.6NC +12.2HG – 4.72SL – 4.3HL +6.64TL +3.18BL -2.98HLL +17.8FLL -1.28HKL	52.5
PC_1	BW=-361+6.42(PC_1)	52.0
PC_2	BW= 68.9+23.46(PC_2)	12.7

HL: head length, NC: neck circumference, HG: heart girth, SL: shoulder length, TL: truck length, BL: body length, BG: belly girth, HKL: hip to kneel, HLL: hind leg length, FLL: fore leg length, BW: body weight, PC_1: principal component 1 and PC_2: principal component 2

4. CONCLUSION

Prediction of body weight of cavy from linear body measurement was more effective by using group variables or several linear parameters (multiple linear regressions) than single or isolated parameters (single linear regression). The principal component analysis grouped the body variables into two viz; general body measurements (HL, SL, NC, HG, BG, TL and BL) and appendages body measurements (FLL, HLL and HKL). The general body measurements as a group variable was more effective in predicting body weight in the cavy than the appendages body measurements. Hence linear body measurements could be used to predict live body weights of guinea pigs for selection purpose especially those from northern Nigeria, where the study was conducted.

5. RECOMMENDATIONS

We recommend that linear body parameters be carried out in cavies in other localities with same and / or different weather conditions, to find out whether the same prediction will be valid. This could also be extended to other rodents for accurate body measurements.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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