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Fixing Collinearity Instability in Body Weight Estimation Based on Morpho-biometrical Traits of Rabbits Bucks

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Abstract

Morpho-biometric studies were conducted on 32 growing rabbit bucks comprising Chinchilla, New Zealand white and Dutch breeds to identify the estimation of body weight collinearity. The body weight and biometric traits taken were analyzed using statistical package for the Social Sciences (SPSS) version 16. Body weight and zoometrical factors had positive and highly significant bivariate relationships. The body weight and height at the withers showed the best relationship (0.826; $p<0.01$), whilst the foreleg and ear length showed the lowest correlation (0.542; $p<0.05$). Since none of the body measurements were greater than 10.00, the variance inflation factors (VIFs) displayed non-collinearity issues in all of the measurements. Tolerance (T) values greater than 0.10 in all of the same measurements served as confirmation of this. No collinearity was also evident in the eigenvalues of the correlation matrix, condition indices, or variance proportions. Body length was kept as the most crucial attribute for prediction among the variables. This study showed that there is no collinearity among selected morphometric traits. Stepwise multi-regression models showed that the best predictor of body weight was based on a combination of wither height, chest circumference, waist circumference, waist length, hind limb length, and head circumference (R^2 and adjusted R^2 =0.84). This research has the practical application that morphological indices can be utilized in the field to estimate body weight for selection and to estimate market values for rabbit bucks.

Keywords: Body weight, Bucks, Collinearity, Morpho-biometrical, Rabbit

1.0 Introduction

Rabbits (*Oryctolagus cuniculus*) are among the most valuable and widely bred small livestock animals, playing a vital role in the agricultural and biomedical research sectors. The accurate prediction of body weight in growing rabbits is of significant importance as it facilitates informed decision-making in rabbit husbandry, nutrition, and breeding programmes (Sam *et al.*, 2020[a]). Morphometric traits, like body length, chest girth, height at the wither, and ear length, have been extensively used as predictors for body weight estimation in rabbits due to their relative simplicity and non-invasive nature (Gupta and Garg, 2020; Sam *et al*., 2020b).

However, the prediction accuracy of body weight from morphometric traits can be influenced by a statistical phenomenon known as multicollinearity. When there is a high degree of correlation in the regression between two or more variable models, this causes the estimates of the variables' coefficients to be unstable. This instability can lead to unreliable predictions and inflated standard errors, affecting the model's overall predictive performance (Smith and Johnson, 2018). To address the potential impact of multicollinearity instability on body weight prediction in growing rabbit bucks, rigorous statistical analysis is required (Sanchez and Bartell, 2019). It involves examining the correlation matrix of the predictor variables and employing appropriate diagnostic tools to identify and handle multicollinearity (Sanchez and Bartell, 2019). Failure to address multicollinearity can result in biased coefficient estimates and hinder the accurate prediction of body weight, compromising the effectiveness of breeding programmes and growth monitoring in rabbit farming.

Studies have investigated the relationship between morphometric traits and body weight prediction in rabbits (Shruthi *et al*., 2022). Studies in Animal Science have highlighted the significance of accounting for collinearity when developing regression models for estimating body weight from morphometric traits in various species, including cattle, goats, poultry, and sheep (Yakubu, 2009). However, research specifically focusing on the influence of multicollinearity on body weight prediction in growing rabbit bucks remains scarce, underscoring the need for more comprehensive investigations in this field. The study aimed to bridge this gap by investigating the presence of collinearity among selected morphometric traits.

2.0 Materials and Methods

2.1 Experimental Site

The experiment was carried out in the Rabbit Unit at the Teaching and Research Farm of Kaduna State University, Kafanchan Campus, Kaduna State Nigeria. Kafanchan is located at latitude 9^{o} 34’ 59.99’’N and longitude 8^{o} 16’ 60.00’’ E (Ovimaps, 2022).

2.2 Experimental Animals and Management

A total of 32 growing rabbit bucks comprising Chinchilla, New Zealand white, and Dutch breeds between the ages of 6 and 7 weeks old were used for this study, which lasted for 8 weeks. Before the commencement of the experiment, Ivermectin injection (the broad-spectrum anti-parasitic drug was administered to the rabbits to treat endo- and ecto-parasites, and embazin was also administered during the experiment. The experimental diet consisted of 16.00% CP, energy (2501.15 Kcal/kg) and crude fibre (11.20%). All animals were weighed prior to the start of the experiment and the mean initial body weight was 762.24±52.66 g. The rabbits were housed in individual pens and each pen had a feeder and drinker. During the 56-day study, routine management operations such as cleaning pens, feeders and drinkers were performed.

2.3 Body Weight and Morphometric Traits

A sensitive scale (Samurai weighing scale) was used in weighing the animals while a tape rule (tailor’s tape) was used in measuring body linear traits on a weekly basis. Both body weight and biometric traits measured were recorded weekly early in the morning before feeding. The body weight (BW) and the following morphometric traits measured were; body length (BL), chest girth (CG), ear length (EL), fore leg (FL), head length (HDL), hind leg (HL), height at wither (HW) and tail length (TL).

The morphometric traits were taken by the standard zoometrical procedures according to the method of Teguia *et al.* (2008), Obasi *et al*. (2019). The description of the measured traits is as stated below:

- **Body length (BL):** Is the distance between the shoulder (the first thoracic vertebrae) and the base of the tail (cm).
- **Chest girth:** Refers to the circumference of the chest just behind the forelimbs using a measuring tape (cm).
- **The length of the foreleg (FL):** Distance from where it begins at the shoulder to where it ends at the foot (cm).
- **Ear length (EL):** Distance from ear base to zygomatic arch (cm).
- **Head length (HDL):** Head length is the distance from the Glabella landmark (smooth part of the forehead) between the brow ridges to the Opisthocranion (posterior most point) (cm)
- **Hind leg (HL**): This is the distance from the hind leg's base to the hind leg's tip or feet (cm).
- **Height at withers (HW):** Height at withers is the vertical distance from the ground up to the point where the withers are located. This distance is measured from the ridge between shoulder bones to forefeet using a graduated measuring ruler (cm)
- **Tail length (TL):** Distance from base of the tail to end of tail tip (cm).

2.4 Statistical Analysis

Data collected were analysed for pre-descriptive statistics (Mean± SE and coefficient of variation). First, correlation coefficients were calculated between all independent body measurements. Due to the inadequacy of correlation as a method of detecting collinearity, the method of variance inflation factor (Rook *et al*., 1990) was adopted.

$$VIF = \frac{1}{1-R^2} \quad \text{.......Equation 1}$$

Where: R^2 = coefficient of determination.

Another way to measure tolerance is to calculate tolerance (T). To do this, each independent variable was treated as an dependent variable and then regressed on the remaining independent variables. The resulting R^2 was used to calculate tolerance T.

$$T = 1-R^2 \quad \text{.......Equation 2}$$

Where:
R^2 = coefficient of determination
T = Tolerance

The Eigenvalues of the X'X correlation matrix, condition indexes, and the variance proportions were also calculated to validate collinearity or non-collinearity according to the methods of Weisberg (1987); Pimentel *et al.* (2007)

3.0 Result and Discussion

3.1 Descriptive statistics of body weight (g) and body dimensions (cm) for growing rabbit bucks

Descriptive statistics of body weight (g) and body dimensions (cm) of growing rabbit bucks are presented in Table 3.1. Morpho-biometric measurements can be used to find correlations with animal size. The present results had higher values compared with 942.50g, 27.15cm, and 17.73cm reported for body weight, body length, and chest girth, respectively reported by Mallam *et al.* (2018) for New Zealand white rabbits at 14 weeks of age. The body weight obtained in this study was lower than the 1905.00 g final body weight obtained by Onoja and Mallam (2022) on a mixed breed of rabbit bucks at age 16 weeks. The differences obtained for body weight and other linear body measurements could be due to differences in age and other environmental factors.

Table 3.1: Descriptive statistics of body weight and body dimensions of growing rabbit bucks

Traits	Mean±SE	Std. Deviation	CV	Minimum	Maximum
BW (g)	1114.54±13.14	201.49	18.08	440	1550
BL (cm)	30.36±0.16	2.42	7.97	21	34
HL(cm)	25.66±0.14	2.21	8. 61	17.2	30.5
FL(cm)	18.07±0.14	2.09	11. 57	12	22.7
EL(cm)	10.44±0.14	0.89	8. 52	7.5	13.3
CG(cm)	19.55±0.06	2.05	10.49	8.4	23.8
TL(cm)	9.99±0.13	1.33	13.31	5	14
HDL(cm)	12.04±0.01	0.92	7. 64	9	14
HW(cm)	16.96±0.10	1.54	9.08	12	20

CV= Coefficient of variation, SE= Standard error, BW=Body weight, BL= Body length, HL=Hind leg, FL= Fore leg, EL= Ear length, CG= Chest girth, TL= Tail length, HDL= Head length, HW= Height at wither

3.2. Phenotypic correlation of body weight and biometric traits of growing rabbit bucks

The phenotypic correlation of body weight and biometric traits of growing rabbit bucks are presented in Table 3.2. The relationship of body weight with height at the withers was the highest (0.826; $p < 0.01$) followed by body weight and chest girth (0.824; $p<0.01$). The lowest correlated relationship was observed between fore leg and ear length ($r=0.542$; $p<0.05$).

The positive correlation between body weight and linear body measurements are similar to the report of Akanno and Ibe (2006) who observed the highest correlation between body weight and shoulder-to-tail length. Similarly, Yakubu (2009); Sam (2012) observed that body weight to withers height correlation was (0.95; $p<0.01$) in West African Dwarf goat. Mallam *et al.* (2018) obtained highest correlation between body weight and head-to-shoulder in New Zealand white rabbits and highest correlation between body weight and body length in chinchilla rabbits.

Table 3.2: Phenotypic correlation of body weight and biometric traits of rabbit bucks

Characters	BL	HL	FL	EL	CG	TL	HDL	HW
BW (g)	0.820**	0.810**	0.752**	0.658*	0.824**	0.644*	0.750**	0.826**
BL (cm)		0.780**	0.741**	0.637*	0.706**	0.625*	0.725**	0.777**
HL (cm)			0.816**	0.760**	0.703**	0.697*	0.815**	0.759**
FL (cm)				0.542*	0.640*	0.565*	0.723**	0.781**
EL (cm)					0.600*	0.653*	0.799**	0.640*
CG (cm)						0.637*	0.631*	0.742**
TL (cm)							0.658*	0.630*
HDL (cm)								0.689*

BW=Body weight, BL= Body length, HL=Hind leg, FL= Foreleg, EL= Ear length, CG= Chest girth, TL= Tail length, HDL= Head length, HW= Height at wither. **p<0.01

Table 3.3: Coefficient of determination (R^2), variance inflation factors (VIFs) and tolerance (T) values for body measurements of growing rabbit bucks

Traits	R^2	VIF	T	Remarks
BL	0.714	3.496	0.286	Non-collinearity
HL	0.835	6.065	0.165	Non-collinearity
FL	0.777	4.476	0.223	Non-collinearity
EL	0.733	3.740	0.267	Non-collinearity
CG	0.629	2.694	0.371	Non-collinearity
TL	0.564	2.292	0.436	Non-collinearity
HDL	0.774	4.432	0.226	Non-collinearity
HW	0.752	4.040	0.248	Non-collinearity

R^2 =Coefficient of determination, VIFs = variance inflation factors, T= tolerance**,** BL= Body length, HL=Hind leg, FL= Fore leg, EL= Ear length, CG= Chest girth, TL= Tail length, HDL= Head length, HW= Height at wither.

3.3 Coefficient of Determination (R^2), Variance Inflation Factors (VIFs) and Tolerance (T) Values for the Body Measurements of Growing Rabbit Bucks

The coefficient of determination (R^2), variance inflation factors (VIFs) and tolerance (T) values for the body measurements of growing rabbit bucks are presented in Table 3.3. The results showed non-collinearity in all the traits and this is evident because the VIF values were all less than 10.00 and the least R^2 value was 0.564. Collinearity problems may not be resolved by applying a pairwise correlation matrix to the explanatory variables, as there may be near-linear dependencies among more complicated combinations of regression (Pimentel *et al.*, 2007). This means that the VIF need to be used. The VIF is the amount of variation that happens because the predictors are so close together. This study showed that the predictors were not collinear in all the traits with the highest VIF of 6.065 in the hind leg. Although, there is no one-size-fits-all approach to measuring the size of a VIF, here is a rough guide, according to Gill (1986), if the VIF is more than 10.00, it is to be considered collinear. Rook *et al.* (1990) also reported similar results in their study. The tolerance (T) values confirmed the non-collinearity problem as T values were all greater than 0.10. There is no specific critical value that defines small tolerance. However, when the tolerance value for any X variable is less than 0.10, collinearity can have more than a marginal effect on the parameter estimates (Gill, 1986). Multicollinearity refers to a situation in which more than two explanatory variables in a multiple regression model are highly linearly related. The implication of non-collinearity means no linear relationship exists between the independent variables.

3.4 Eigenvalues, condition indexes (CI), and variance proportions of body measurements for predicting the body weight of growing rabbit bucks

The Eigenvalues, condition indexes (CI), and variance proportions of body measurements for predicting the body weight of growing rabbit bucks are shown in Table 3.4. The results of this study revealed that there were two relatively small eigenvalues of 0.002, 0.002, 0.001, and 0.001 for components 6, 7, 8, and 9 respectively, showing how much the correlation matrix approached singularity. Those components with small Eigenvalues had large variance proportions of 83%, 53%, 60%, and 59% for body length, hind leg, ear length, and head length, in that order. The corresponding condition indexes were: 75.494 (body length), 91.349 (hind leg), 104.005 (ear length), and 91.349 (head length). Eigenvalues are computed by a multivariate statistical technique called principal component analysis and these principal components are obtained by computing the eigenvalues and eigenvectors of the correlation or covariance matrix (Jeseshim and Kucc, 2002). The low eigenvalues are an indicator that the correlation matrix approached singularity (Shafey *et al*., 2014). Conversely, zero or nearly zero eigenvalues imply perfect collinearity among independent variables. When attempting to understand the cause of non-consistency, the emphasis is on the main components with very high Eigenvalues, as variables in no-consistency are identified by their relatively low variance proportions with high Eigenvalues (Malau-Aduli *et al*., 2004). The larger the condition index, the more the tendency towards collinearity, and the smaller the condition index, the more tendency toward no-collinearity. Moderate to strong relations are associated with condition numbers 30 to 100 (Belsley *et al*., 1980). Multicollinearity can be due to insufficient sample data or interactions between variables that are specific to the process being studied (Chatterje and Hadi, 2006). In these situations, not all combinations of predictor variables are represented by the data and, without data collected under all possible conditions, the effects of individual variables cannot be determined.

3.5 Regression models for the estimation of body weights from morphometric characters of growing rabbit bucks

The regression models for the estimation of body weights from morphometric characters of growing rabbit bucks are presented in Table 3.5. About 68% of the variation in body weight is attributed to height at withers alone. The models constructed with height at withers, chest girth, body length, hind length, and head length improved the efficiency of the prediction equations with R^2 84 %. The advantage of height at the withers compared to other linear-type characteristics is in line with the findings of Aziz and Sharaby (1993).This was buttressed by the submission of Boggs and Merkel (1984) that height at withers is the most accurate and repeatable measurement for frame size. However, the study by Akanno and Ibe (2006) reported that body length accounts for 93.70% in New Zealand White rabbit at three weeks of age. According to Nosike *et al.* (2017), breast length in the Marshall Broiler chicken strain accounted for (R^2=99.5%) of the variation in body weight

Table 3.4. Eigenvalues, condition indices and variance proportions of body measurements for predicting body weight in rabbit bucks

				Variance proportion							
Dimension	Eigenvalues	CI	(Constant)	BL	HL	FL	EL	CG	TL	HDL	HW
1	8.972	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.009	31.239	0.170	0.000	0.000	0.000	0.000	0.000	0.490	0.000	0.000
3	0.007	36.343	0.100	0.000	0.000	0.210	0.03	0.010	0.180	0.000	0.020
4	0.004	46.64	0.000	0.000	0.010	0.080	0.02	0.650	0.020	0.020	0.020
5	0.003	54.758	0.430	0.010	0.010	0.030	0.27	0.06	0.280	0.030	0.000
6	0.002	68.528	0.080	0.090	0.030	0.110	0.020	0.260	0.000	0.020	0.600
7	0.002	75.494	0.130	0.830	0.010	0.060	0.030	0.000	0.000	0.000	0.200
8	0.001	91.349	0.030	0.000	0.530	0.020	0.030	0.010	0.000	0.590	0.000
9	0.001	104.005	0.060	0.070	0.400	0.490	0.600	0.010	0.010	0.330	0.160

CI= Condition indices, BL= Body length, HL=Hind leg length, FL= Fore leg length, EL= Ear length, CG= Chest girth, TL= Tail length, HDL= Head length, HW= Height at wither.

Table 3.5: Regression models for estimating body weight from morphometric characteristics of growing rabbit bucks

No.	Equation	R^2	Adjusted R^2
1.	BW= -723.226 + 108.348HW	0.68	0.68
2.	BW= -866.905 + 62.603HW + 47.037CG	0.78	0.78
3.	BW= -1099.438 + 38.496HW + 37.615CG + 27.194BL	0.82	0.82
4.	BW= -1155.156 + 30.249HW +33.497CG +19.689BL +19.640HL	0.84	0.83
5.	BW= -1214.486+ 29.253HW +33.200CG +18.091BL +13.887HL +23.104HDL	0.84	0.84

BW=Body weight, BL= Body length, HL=Hind leg, CG= Chest girth, HDL= Head length, HW= Height at wither, R^2 = Coefficient of Determination

4.0 Conclusion

Body weight and linear body measurements all showed positive and highly significant phenotypic correlations. All linear body measurements were not collinear with each other.

The height at withers, chest girth, body length, hind length, and head length combination produced the best model, according to the stepwise multiple regression analysis, with an R^2 of 0.84 (84%).

The practical application of this study is that morphological indices can be used in the field to estimate body weight for selection purposes and to estimate market values for the price of rabbit bucks.

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