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Original Contribution

FIXING COLLINEARITY INSTABILITY IN THE ESTIMATION OF BODY WEIGHT FROM MORPHO-BIOMETRICAL TRAITS OF WEST AFRICAN DWARF GOATS

A. Yakubu

Department of Animal Science, Nasarawa State University, Keffi, Shabu-Lafia Campus, P.M.B. 135, Lafia, Nigeria

ABSTRACT

Morphobiometric studies were conducted on 58 West African dwarf kid goats of both sexes in order to determine the problem of collinearity in body weight estimation. There were no gender-associated differences in the estimated morphological indices. The bivariate correlations between body weight and zoometrical variables were positive and highly significant. The highest correlation was observed between withers height and rump height while the lowest was recorded for withers height and rump width. Variance inflation factors (VIFs) showed severe collinearity problems in three body measurements as these were higher than 10.00 (VIF= 24.992, 22.377 and 12.074 for withers height, rump height and body length respectively). This was confirmed by tolerance (T) values lower than 0.1 in the same measurements. Eigenvalues of the correlation matrix, condition indexes and variance proportions showed also collinearity. Among the collinear variables, withers height was retained as the most single important trait for prediction. The eventual stepwise multiple regression models revealed that body weight was best predicted from a combination of withers height, heart girth and rump width [R^2, Adjusted R^2 and RMSE (Root mean squares error) = 0.951, 0.949 and 0.698 respectively].

Key Words: body weight, body dimensions, collinearity, goats, prediction.

INTRODUCTION

A problem for livestock researchers is the interrelatedness or lack of orthogonality of the independent variables (collinearity). In any regression analysis, the partial regression coefficients and partial sums of squares for any independent variable are dependent on which other independent variables are in the model. Inferences based on ordinary least-squares regression can be influenced strongly by collinearity, and the fitted model hence, may reflect unusual features because of the overall relationship among the variable (1). Indications of collinearity problem include substantial coefficient of determination (R^2) but statistically insignificant coefficients; unstable regression coefficients (i.e., weight that change dramatically when variables are added or drop from equation); unexpected size of coefficients (much or smaller than expected); and signs (+/-) that are unexpected (2,3).

Body measurements have been used in animals to contrast variation in size and shape (4, 5), and to estimate body weight (6,7). Weight is a very important factor in selection and production of goats. These small ruminants play a major role in the maintenance of rural populations in Nigeria in conditions of extreme poverty and also have a major cultural significance. Genetic improvement is currently being centred on indigenous breeds because they have long adapted to extreme harsh environmental conditions and might be more productive in their own environment than the exotic breeds. Morphological characters provide useful information to detect genetic structure and individual breed's potentiality due to the intrinsic relationship among all biological characters (8).

Although interrelationships among body dimensions (conformation) and body weight of goats have been investigated to an extent, information on the problem of collinearity is

*** Correspondence to**: *A. Yakubu, Department of Animal Science, Nasarawa State University, Keffi, Shabu-Lafia Campus, P.M.B. 135, Lafia, Nigeria; E-mail: abdul_mojeedy@yahoo.com*

still scanty. The first objective of this study therefore, was to ascertain the existence or otherwise of collinearity in the estimation of body weight from morphological indices of West African Dwarf kid goats (potential store of unique genes) . The second objective was to fix the problem if detected using stepwise multiple regression analysis.

MATERIALS AND METHODS

Experimental animals and their management

Data were obtained from 58 West African Dwarf (WAD) kid goats of both sexes which were randomly sampled in Nasarawa State, North Central Nigeria. The kid goats were less than 1.5 years old (milk- tooth age) as revealed by non-eruption of permanent incisors. The environmental setting of the study location and extensive management practices have been previously described (9).

Parameters measured

Body weight (BW) and five exterior traits were taken on each animal. The measured parts were withers height (WH), measured as the distance between the most dorsal point of the withers and the ground; rump height (RH), distance from *Spina illiaca* to the ground; body length (BL), measured from distance between the occipital protuberance and tail-drop; heart girth (HG), circumference of the chest just behind the forelimbs and rump width (RW), distance between the hip bones (*Tuber coxae*).Body weight estimation was done using a hanging scale. The length and circumference measurements were effected using a measuring tape while the width measurement was done using a calibrated wooden calliper. In order to avoid between-individual variations, measurements were carried out by the same person.

Statistical analysis

Data collected were analysed for preliminary descriptive statistics (Mean± SE and coefficient of variation). General Linear Model (GLM) was used to determine sex effect. As a first indication of severity of collinearity, correlation coefficients among all the five independent body measurements were estimated. Due to the inadequacy of correlation as a method of detecting collinearity, the method of variance inflation factor (10) was employed as follows:

$$VIF = \frac{1}{1-R^2}$$

where,
R^2 = coefficient of determination.

A further step for testing collinearity was to calculate the tolerance (T) value. To obtain measures of tolerance, each independent variable was treated as a dependent variable and regressed on the other independent variables. The R^2 so obtained was used to calculate T.

$$T = 1-R^2$$

where,
R^2 = coefficient of determination.

Eigenvalues of the correlation matrix (X'X), condition indexes and variance proportions were also computed to confirm the existence or otherwise of collinearity following the procedures adopted by (11) and (12).

In order to delete redundant variables arising from multicollinearity, the following model as described by (13) was employed:

$$RV = \frac{|B_j|}{á}$$

where,
RV = redundant variable.
B_j = regression coefficient of X_j variable.

á = square root of residual mean square of the full regression model.

The full regression model (all the five morphometric indices inclusive) was defined as:

$$Y= B_o + [B_iX_i].$$

The eventual regression models were fitted using stepwise multiple regression analysis. Each model was assessed using R^2, Adjusted R^2 and RMSE (Root mean squares error).SPSS Statistical package was employed in the analysis (14).

RESULTS AND DISCUSSION

Mean (± SE) and coefficient of variation estimates associated with each body weight and linear body measurement of WAD kid goats are presented on **Table 1**. There were no gender- associated differences in the body parameters estimated. Similar findings have been reported (15). Measurements of morpho-biometrical traits can provide evidence of breed relationships and size. The present results are comparable to the values of 10.08kg, 47.08, 37.09, 42.04 and 9.74cm reported for body weight, heart girth, withers height, rump height and sacral pelvic width in over a year-old kids in a derived savanna agro-ecological zone of southern Nigeria (16). The high variability in body weight and rump width could be a reflection of great environmental influence such as temperature and nutrition on these parameters. They are polygenic in nature, hence their environmental sensitivity. The variations provide a basis for their genetic manipulation and improvement. The goats' body stature kinetics deserve consideration because their body parts contribute to the local goat characterisation by assessing the animal size during young age when the essentials of meat production might have been realised (17).

Table 1: *Descriptive statistics of body weight (kg) and zoometrical traits (cm) of West African Dwarf kid goats*

Variable	Male animals (n=27)		Female animals(n=31)	
	Mean(±SE)	CV	Mean(±SE)	CV
BW	10.01±0.67[a]	35.26	8.82±0.50[a]	31.52
WH	38.36±0.89[a]	11.99	38.23±0.84[a]	12.27
RH	41.71±0.88[a]	11.08	41.24±0.96[a]	13.00
HG	53.03±1.51[a]	14.80	52.16±1.14[a]	12.21
BL	62.53±1.24[a]	10.28	63.54±1.27[a]	11.11
RW	6.81±0.41[a]	33.92	7.31±0.46[a]	35.29

Means in the same row bearing the same superscript do not differ significantly (p>0.05). SE: Standard error of mean.
CV: Coefficient of variation.

Table 2*: Correlation coefficients of body weights and morphological indices of West African Dwarf kid goats*.*

Trait	BW	WH	RH	HG	BL	RW
BW	-	0.95	0.94	0.92	0.93	0.84
WH	-	-	0.97	0.88	0.93	0.77
RH	-	-	-	0.87	0.93	0.80
HG	-	-	-	-	0.87	0.80
BL	-	-	-	-	-	0.86

**Significant at p< 0.01.*

Phenotypic correlations between body weight and morphometric characters of WAD kid goats are shown on **Table 2**. Body weight was best associated with withers height (r=0.95; p< 0.01), chronologically followed by rump height, body length and heart girth (r=0.94, 0.93 and 0.92 respectively). Among the linear type traits, the highest correlation was observed between withers height and rump height (r=0.97), while the lowest value of r=0.77 was recorded for withers height and rump width. The correlation coefficients are comparable to values recorded for kid goats (15) and lambs (18) respectively.

Table 3*: Variance inflation factors (VIFs) and tolerance (T) values for the body measurements of West African Dwarf kid goats*

Traits	VIF	T	Remarks
WH	24.992	0.040	Collinearity
RH	22.377	0.045	Collinearity
HG	5.251	0.190	Non-collinearity
BL	12.074	0.083	Collinearity
RW	4.517	0.221	Non-collinearity

The strong relationship existing between body weight and body measurements suggest that either or combination of these morphological traits could be used to estimate live weight in goats fairly well in the situation where weighbridges or scales are not available. It also implies that frame size and absolute height are complementary and that the total size of the animal is a function of length, height and circumference measurements (19). The association may also be useful as selection criterion, since positive correlations of traits suggest that the traits are under the same gene action (Pleiotropy). Consequently, selection for improvement in one trait would result in the concomitant improvement of the other traits.

The variance inflation factors (VIFs) and tolerance (T) values for the relationships between body measurements of WAD kid goats are presented on **Table 3**. A pairwise correlation matrix of explanatory variables might be insufficient to identify collinearity problems because near linear dependencies may exist among more complex combinations of regressors (12). This therefore calls for the use of the VIF, which represents the increase in variance due to high correlation between the predictors. In the present study, the VIFs gave the first indication of the existence of severe collinearity in withers height, rump height and body length (VIF =24.992, 22.377 and 12.074 respectively). Although no absolute standard exists for judging the magnitude of the VIF, a crude rule of the thumb, according to (20), is to be suspicious of collinearity if VIF is greater than 10.00. Similar report has been documented in (10). The tolerance values confirmed collinearity problem (T = 0.040, 0.045 and 0.083 for withers height, rump height and body length respectively). There is no well defined critical value that characterises small tolerance values. However, if the tolerance value is smaller than 0.10 for any X-variable, then collinearity may have more than a trivial impact on the estimates of the parameters (20). The presence of collinearity was also clearly evident as revealed by the eigenvalues of the correlation matrix, condition indexes and variance proportions of the estimates (**Table 4**). A close examination of this Table revealed that there were two relatively small eigenvalues of 0.001 and 0.000 for components 5 and 6 respectively, showing how much the correlation matrix approached singularity. These components with small eigenvalues had large variance proportions of 0.89 for body length, 0.78 for rump height and 0.96 for withers height respectively. The corresponding condition indexes were 88.027 (body length) and 131.375 (rump height and withers height). When trying to diagnose the reason for collinearity, the focus is on the principal components with very small eigenvalues because variables in multicollinearity are identifiable by their relatively large variance proportions with small eigenvalues (11). The variance proportions indicate the relative contribution from each principal component to the variance of each regression coefficient. The larger the condition index, the more the tendency towards collinearity. Moderate to strong relations are associated with condition numbers of 30 to 100 (21).

Table 4: *Eigenvalues, condition indexes and variance proportions of body measurements for the prediction of body weights of West African Dwarf kid goats*

Component	**Eigenvalue**	**Condition index**	**Variance Proportion**					
			C	**WH**	**RH**	**HG**	**BL**	**RW**
1	5.934	1.000	0.00	0.00	0.00	0.00	0.00	0.00
2	0.057	10.213	0.02	0.00	0.00	0.00	0.00	0.29
3	0.005	33.230	0.50	0.02	0.02	0.04	0.00	0.36
4	0.003	47.689	0.00	0.01	0.04	0.93	0.01	0.01
5	0.001	88.027	0.45	0.01	0.17	0.00	0.89	0.18
6	0.000	131.375	0.02	0.96	0.78	0.03	0.10	0.16

C: Constant

The deletion of one or more collinear variables improves the accuracy and robustness of the prediction models. According to (13), the deletion of variables with small $|B_j|/$ á would be desirable. In the present study, values obtained for withers height, rump height and body length were 0.70, -0.15 and 0.02 respectively. Thus, withers height was retained for the subsequent analysis.

The four regression models for estimating body weight from body measurements of WAD kids are presented on **Table 5**. Withers height singly accounted for about 91% of the variation in body weight, although with higher root mean squares error (RMSE = 0.938). The models constructed with withers height and rump width, and withers height and heart girth improved the efficiency of the prediction equations (R^2, Adjusted R^2 and RMSE= 0.940, 0.938 and 0.765; 0.937, 0.935 and 0.785 respectively). However, the best model involved the combination of withers height, rump width and heart girth (R^2, Adjusted R^2 and RMSE = 0.951, 0.949 and 0.689 respectively). The superiority of withers height over other linear type traits is consistent with the report of (22). This was buttressed by the submission of (23) that height at withers is the most accurate and repeatable measurement for frame size. However, in a study on Kanni Adu goat kids, chest girth alone accounted for maximum of 80.4 to 93.6% of total variation in body weight, and the best fitted multiple regression model included chest girth, body length and height at withers (15).

***Table 5**: Regression models for the estimation of body weights from morphometric characters of West African Dwarf kid goats*

No	Equation	R^2	Adjusted R^2	RMSE
1	BW= -14.995 + 0.636WH	0.909	0.907	0.938
2	BW= -15.335 + 0.431WH + 0.156HG	0.937	0.935	0.785
3	BW= -12.122 + 0.495WH + 0.358RW	0.940	0.938	0.765
4	BW= -13.119 + 0.393WH + 0.263RW + 0.106HG	0.951	0.949	0.698

CONCLUSION AND RECOMMENDATIONS

The study revealed that there were no significant sex- differences in the morphostructural traits of West African Dwarf kid goats. Phenotypic correlations between body weight and body dimensions were positive and highly significant. The problems of collinearity were evident in withers height, rump height and body length as revealed by variance inflation factors, tolerance values, eigenvalues of the correlation matrix, condition indexes and variance proportions. Withers height was retained among the collinear variables and singly accounted for about 91% of the variation in body weight of kids. The stepwise multiple regression analysis revealed that the best prediction model was obtained from the combination of withers height, rump width and heart girth. The practical implications of this study are that body weight can be estimated in the field using morphological indices for selection purposes and as a way of estimating market values in terms of cost of animals.

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