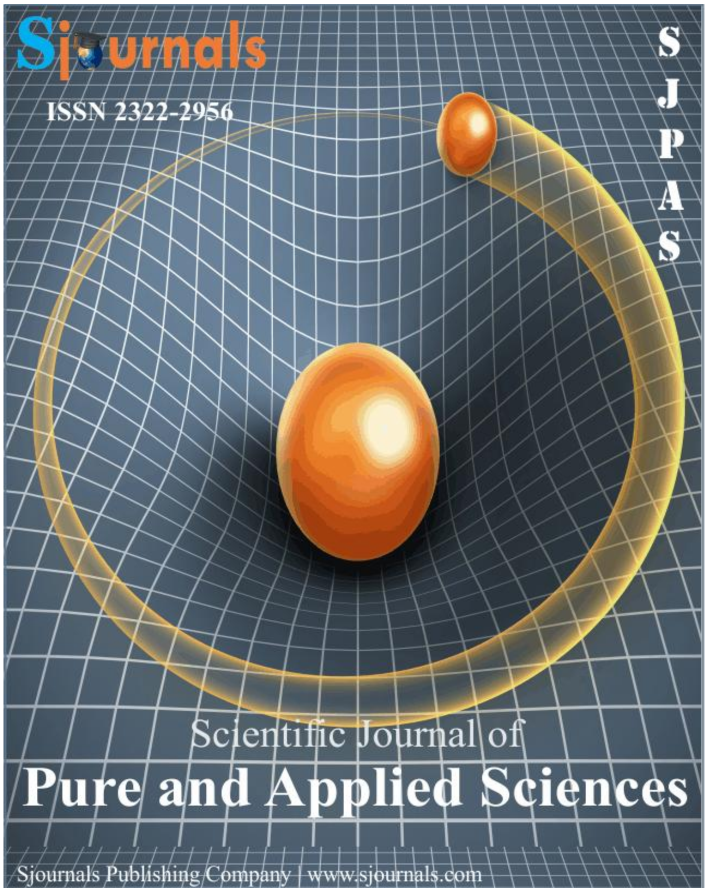

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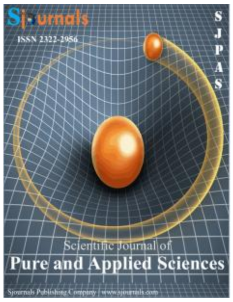

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Original article

Path coefficient analysis of body weight and morphometric measurements in indigenous Matabele goat of Zimbabwe

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ABSTRACT

Direct and indirect effects of seven predictor variables (withers height, body length, heart girth, shoulder width, head width, rump width and rump length) on body weight of 109 Matabele goats, 47 females and 62 males, were investigated using path analysis. Sex-associated difference was significant ($P<0.05$) only for withers height, with higher value recorded for female goats. Pairwise correlations between body weight and zoometrical traits ranged from 0.420-0.966 and 0.507-0.959 for male and female goats, respectively. The direct effect of heart girth on body weight was the strongest in both sexes (path coefficient of 0.81 and 0.87 in males and females, respectively). Head width (males) and body length (females) also positively ($P<0.05$) influenced body weight. The direct effects of other linear type traits on body weight in both sexes were non-significant as revealed by the t-test. These traits were indirectly realized mostly via heart girth. Thus, they were expunged from the final regression equations to obtain much more simplified prediction models. The optimum multiple regression equation included heart girth with a determination coefficient (R^2) of 0.939. Forecast indices obtained in this study could aid in weight estimation, selection and breeding programmes.

1. Introduction

The weight of an animal’s body is a primary characteristic in livestock production. Growth assessment and feed efficiency evaluation can be done using body weight, which assist in the overall economic and management decisions (Nwosu et al., 1985). Knowledge of body weight has a bearing on enhancing production and profitability in any livestock or poultry production venture (Assan, 2013). Different authors have reported the significance of the relationship between morphometric measurements with body weight in estimating body weight (Milla et al., 2012; Bozkurt, 2006), in goats (Mahieu et al., 2011; Otoikhain et al., 2008), in sheep (Sowande and Sobola, 2008; Baffour-Awuah et al., 2000) in pigs (Brannaman, 1984), in rabbits (Chineke, 2005; Pinna et al., 2004), in poultry (Ogah, 2011; Ige et al., 2006) and in fish (Yakubu et al., 2012). Morphometric measurements have been used to estimate an animal’s body weight in case where weighing scales are unavailable. The association between body weight and morphometric measurements are not only merited for estimating body weight but can also be applied in genetic evaluation (Momoh and Kershima, 2008). This implies that morphometric attributes are a verifiable tool for depicting and ascertaining of body weight than visual assessment. However, the application of a simple correlation coefficient of an animal weight and linear body measurements may be limiting in explaining the causative influence among these biologically associated variables. Hence, the current study was conducted to evaluate the appropriateness of path coefficient and analysis in modelling body weight in indigenous Matebele goat.

2. Materials and methods

2.1. Study location and animal management

The study was conducted at Matopos Research Station ($20^{0} 23^{'}$ S, $31^{0} 30^{'}$ E) which is situated in semi arid areas of Zimbabwe. The nearest town in Bulawayo which is 30 km away. The research station sits on low altitude of 800 m above sea level and characterised by low rainfall of less than 450 mm (Homann et al., 2007). The temperatures are high in summer, with minimum and maximum mean temperatures of hottest months being 21.6 and 11.4 ^{0}C, respectively. Day et al. (2003) reported an elaborate specification of the climate and vegetation type of the study location.

Extensively managed bucks (62)and does (47) totalling 109 goats were randomly selected for the present study. The does age ranged from 4.0 to 25.4 months, and the bucks age ranged from 5.5 to 29.4 months. The goats were grazed during the day on range. Supplementation of cowpea husk and wheat bran was provided. The animals grazed during the day on natural pasture containing forages and grass. Appropriate health and sanitary measures were strictly practiced.

2.2. Morphometric measurements

Animals weights (body weight) and the following morphometric measurements were taken: wither height (WH), body length (BL), heart girth (HG), shoulder width (SW), head width (HW), rump width (RW), and rum length (RL). Body weights were taken in the morning before grazing and watering. Heart girth measurements were taken around the chest just behind the front legs and withers using a tape measure (Fig. 1). Wither height was measured using a measuring stick while an animal stood on a platform (Fig. 2).

Fig. 1. Measuring heart girth.

Fig. 2. Measuring withers height.

BL was measured using a tape measure, while RW, SW and HW were measured using a calliper. In order to avoid individual variation, same person took the measurements.

Fig. 3. Measuring body length.

2.3. Path analysis procedure

The path coefficient is derived from an explanatory variable (X) to a response variable (Y) and is given by:

$$Pyx_{i} = \frac{b_iSx_i}{Sy}$$

Where

$Py\mathrm{x}_i$ = Path coefficient from X_i to Y (i= WH, BL, HG, SW, HW, RW, RL);
b_i = Partial regression coefficient;
Sx_i = Standard deviation of X_i and;
S_Y = Standard deviation of Y.

The following multiple linear regression model was fitted:

$$Y = A+p_{01}X_1+p_{02}X_2+p_{03}X_3+p_{04}X_4+p_{05}X_5+p_{06}X_6+p_{07}X_7+\xi$$

Where Y = Body weight (endogenous variable);
A = Intercept;
Po_i = Path coefficient;
X_i = WH, BL, HG, SW, HW, RW, RL and;
ξ = error term, normally distributed with mean zero and variance, σ^2.

The following model was used to assess the importance of each path coefficient in the linear multiple regression model using a t-test.

$$t_i = \frac{\hat{\beta}_i - \varphi_i}{\sqrt{Var(\hat{\beta}_i)}} \sim t_{\alpha(n-p-1)}$$

For i = 1,2,3,..., p

Where:

$Var\ (B_i)$ = The diagonal member of matrix $S^2(X^TX)^{-1}$;
S^2 = Mean square of residual obtained from ANOVA;
The indirect effects of X_i , $IEyx_i$ on Y through X_i can be calculated as follows:

$$IEyx_i = rx_ix_j\,Pyx_j \quad (4)$$

Where $IEyx_i$ = The direct effect of X_i via X_j on Y
rx_ix_j = Correlation coefficient between i^{th} and j^{th} independent variables, and
Pyx_j = Path coefficient that indicates the direct effect of j^{th} independent variable X_j on the dependent variable.
R^2) is partitioned into its components using path analysis as follows:

$$R^2 = \sum_{i=1}^{7} P_{YX_i}^2 + 2\sum_{i=2}^{7} r_{X_1X_i} P_{YX_1} P_{YX_i} + 2\sum_{i=3}^{7} r_{X_2X_i} P_{YX_2} P_{YX_i} + 2\sum_{i=4}^{7} r_{X_3X_i} P_{YX_3} P_{YX_i} + 2\sum_{i=5}^{7} r_{X_4X_i} P_{YX_4} P_{YX_i}$$
$$+ 2\sum_{i=6}^{7} r_{X_5X_i} P_{YX_5} P_{YX_i} + 2r_{X_6X_7} P_{YX_6} P_{YX_7}$$

Where P^2_{yxi} = Direct effects of explanatory variables (WH, BL, HG, SW, HW, RW, RL) in contributing to the variation of *Y* (body weight) and $2rx_ix_j\, Pyx_i\, P_{yxj}$ = Combined effects of explanatory variables, WH, BL, HG, SW, HW, RW, in contributing to the variation of Y (body weight). Standardized partial regression coefficient called path coefficients (beta weights) are calculated as follows:

$$ryx_i = \sum_{j=1}^{7} r\, x_1x_j\, byx_j$$

For *i* = 1,2,..., 7

Where b_{yxi} = Coefficient of the standardized regression model.

3. Results and discussion

3.1. Morphometric measurements

Within sex means, standard deviation and coefficient of variation of body weight and morphometric measurements are presented in Table 1.

Table 1
Descriptive statistics of body weight and morphometric measurements in indigenous Matebele goats.

	Male (n = 62)			**Female (n = 47)**		
Trait	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**
BW(kg)	36.429032	22.704491	62.325264	31.402553	18.551743	59.077181
HG (cm)	74.703226	16.674649	22.32119	68.325532	16.289307	23.840731
WH (cm)	69.21355	14.92433	21.56274	64.85319	13.57111	20.9259
BL (cm)	66.22903	13.37615	20.19681	65.05745	14.81798	22.77676
RW (cm)	23.65161	6.26954	26.50787	17.22553	3.947342	22.91565
RL (cm)	21.05	4.632874	22.0089	18.1766	4.134332	22.74536
HW (cm)	22.27581	6.215177	27.90102	23.38298	5.991999	25.62547
SW (cm)	15.15806	3.805499	25.10544	15.45319	3.584681	23.19702

Males had higher means for all morphometric measurements (Table 1). There was a significant difference ($P<0.05$) in bucks and does in indigenous Matebele goat. Body weight and RW showed much variation in both sexes which implies that morphometric measurements are less influenced by the environment. The grouped data showed that body weight had a highest coefficient of variation (63%) (Table 2).

Table 2
Descriptive statistics of grouped data of morphometric traits of Matabele goats.

	Matabele goats (n = 109)		
Trait	**Mean**	**Standard deviation**	**CV%**
BW (kg)	34.261651	21.071366	61.501313
HG (cm)	71.953211	16.737016	23.260971
WH (cm)	67.33339	14.4553	21.46825
BL (cm)	65.72385	13.96133	21.24242
RW (cm)	20.88073	6.249777	29.93083
RL (cm)	19.81101	4.631081	23.3763
HW (cm)	22.75321	6.116683	26.88272
SW (cm)	15.28532	3.697868	24.19228

3.2. Bivariate model

Pairwise correlations from bivariate model are presented in Table 3, 4 and 5. Correlation matrices revealed that there was a very strong relationship between RW and RL in female goats (0.999) while the same cannot be said for male goats (0.471). The association between HG and RL in does (0.945) is higher than the association in bucks (0.696). The relationship between HG and WH is very high in both sexes (0.940 in bucks and 0.939 in does). RL in does relates very high to BW (0.909) than its association to BW in bucks (0.661). The relationships between body weight and morphometric measurements were observed to be strong in both sexes. However, a weak correlation was observed for BW and HW in both sexes, while BW and HG gave the highest correlation in both sexes (Table 3, 4 and 5).

Table 3
Correlation matrix-both sexes.

Variables	HG(cm)	WH(cm)	BL(cm)	RW(cm)	RL(cm)	HW(cm)	SW(cm)	BW(kg)
HG(cm)	1.000	0.940	0.910	0.771	0.799	0.539	0.648	0.958
WH(cm)	0.940	1.000	0.953	0.799	0.775	0.600	0.698	0.882
BL(cm)	0.910	0.953	1.000	0.755	0.795	0.590	0.663	0.849
RW(cm)	0.771	0.799	0.755	1.000	0.664	0.503	0.574	0.668
RL(cm)	0.799	0.775	0.795	0.664	1.000	0.438	0.452	0.742
HW(cm)	0.539	0.600	0.590	0.503	0.438	1.000	0.892	0.430
SW(cm)	0.648	0.698	0.663	0.574	0.452	0.892	1.000	0.559
BW(kg)	0.958	0.882	0.849	0.668	0.742	0.430	0.559	1.000

Table 4
Correlation matrix-bucks.

Variables	HG(cm)	WH(cm)	BL(cm)	RW(cm)	RL(cm)	HW(cm)	SW(cm)	BW(kg)
HG(cm)	1.000	0.940	0.908	0.752	0.696	0.561	0.702	0.966
WH(cm)	0.940	1.000	0.964	0.814	0.663	0.609	0.722	0.876
BL(cm)	0.908	0.964	1.000	0.828	0.702	0.634	0.717	0.828
RW(cm)	0.752	0.814	0.828	1.000	0.471	0.688	0.739	0.639
RL(cm)	0.696	0.663	0.702	0.471	1.000	0.447	0.406	0.661
HW(cm)	0.561	0.609	0.634	0.688	0.447	1.000	0.843	0.420
SW(cm)	0.702	0.722	0.717	0.739	0.406	0.843	1.000	0.586
BW(cm)	0.966	0.876	0.828	0.639	0.661	0.420	0.586	1.000

Table 5
Correlation matrix-does.

Variables	HG(cm)	WH(cm)	BL(cm)	RW(cm)	RL(cm)	HW(cm)	SW(cm)	BW(kg)
HG(cm)	1.000	0.939	0.940	0.947	0.945	0.595	0.648	0.959
WH(cm)	0.939	1.000	0.967	0.968	0.966	0.648	0.711	0.894
BL(cm)	0.940	0.967	1.000	0.999	0.998	0.579	0.646	0.910
RW(cm)	0.947	0.968	0.999	1.000	0.999	0.590	0.655	0.915
RL(cm)	0.945	0.966	0.998	0.999	1.000	0.590	0.654	0.909
HW(cm)	0.595	0.648	0.579	0.590	0.590	1.000	0.958	0.507
SW(cm)	0.648	0.711	0.646	0.655	0.654	0.958	1.000	0.573
BW(kg)	0.959	0.894	0.910	0.915	0.909	0.507	0.573	1.000

3.3. Variance Inflation Factors (VIF)

The variance inflation factors were calculated by forming a symmetric correlation matrix and finding its inverse which gave the major diagonal elements which also are the variance inflation factors for each independent variable (Table 6) The variance inflation factors are used as a test for mutli-collinearity problems in data. The VIF <

10 values signal that multi-collinearity is not present in data, otherwise, if VIF > 10 is found in any of the diagonal elements then multi-collinearity in data would need removing. The diagonal elements (Table 6) are all less than 10 which implies non multi-collinearity in relation to morphometric measurements.

Table 6
Variance Inflation Factors (VIF).

	HG(cm)	WH(cm)	BL(cm)	RW(cm)	RL(cm)	HW(cm)	SW(cm)
HG(cm)	**9.0791**	-6.76415	-0.84931	-0.36964	-1.849	1.464439	-1.50308
WH(cm)	-6.76415	**8.96449**	-9.86292	-1.98555	0.46987	0.563298	-1.89418
BL(cm)	-0.84931	-9.86292	**7.21643**	0.456958	-1.56254	-0.88472	0.570832
RW(cm)	-0.36964	-1.98555	0.456958	**2.839566**	-0.34169	0.009127	0.07144
RL(cm)	-1.849	0.46987	-1.56254	-0.34169	**3.351291**	-0.89721	1.38439
HWCM)	1.464439	0.563298	-0.88472	0.009127	-0.89721	**5.392453**	-5.10889
SW(CM)	-1.50308	-1.89418	0.570832	0.07144	1.38439	-5.10889	**6.892461**

3.4. Direct path coefficients

The direct path coefficient model was:
BW = 1.13HG+0.072WH-0.05BL-0.15RW-0.03RL-0.11HW+0.01SW.

Predicting body weight values using the above model and using a student's t-test to test for equality of means on predicted and observed values at alpha = 0.05, we get t-value = -0.005, t-critical = 1.971 and P-value = 0.996. Therefore, we conclude that the predicted values are not significantly different from the observed values, thus the above model can be used to predict body weight. The association of BW with WH was high (r= 89%), however, its direct effect on body weight was minimal (path coefficient= 7%) which was nonsignificant.

Table 7
Regression on standardised variables.

	Coefficient	Standard Error	t-Sta	P-value	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Intercept	0							
HG(cm)	1.1346532**	0.0779545	14.555	1.22E-3	0.980030	1.28927	0.98003	1.28927
WH(cm)	0.0719363	0.1069303	0.6727	0.50263	-0.140159	0.28403	-0.14015	0.28403
BL(cm)	-0.050351	0.0858227	-0.587	0.55870	-0.220580	0.11987	-0.22058	0.11987
RW(cm)	-0.153039	0.0413767	-3.699	0.00035	-0.23511	-0.0709	-0.23511	-0.0709
RL(cm)	-0.03310	0.0449506	-0.736	0.46319	-0.122259	0.05605	-0.12225	0.05605
HW(cm)	-0.114703	0.0570195	-2.012	0.04689	-0.227801	-0.0016	-0.22780	-0.0016
SW(cm)	0.0126984	0.0644640	0.1969	0.84423	-0.115166	0.14056	-0.11516	0.14056

3.5. Indirect path coefficients

The indirect contributions of HG to BW will include HG through WH, BL, RW, RL, HW and SW. The same applies to WH, BL, RW, RL, HW and SW.

Table 8
Indirect path coefficients.

Trait	Intercept	HG	WH	BL	RW	RL	HW	SW
Coefficient	0	-0.1765	0.8221	0.9604	0.9216	0.7767	0.5468	0.5481

3.6. Total path coefficients

The total path coefficients are obtained when we sum up the direct and indirect path coefficients. The results are as shown in Table 9 below.

Table 9
Coefficients of determination.

Trait	HG	WH	BL	RW	RL	HW	SW
Coefficient	0.968	0.893	0.858	0.676	0.718	0.493	0.559

The final path analysis body weight prediction equation therefore can now be written as follows:

$$BW = 0.968HG + 0.893WH + 0.858BL + 0.676RW + 0.718RL + 0.429HW + 0.559SW$$

In terms of direct influence to body weight variation HG had the highest contribution (R^2 = 0.91) and the coefficient of determination was 96.8% while the separate regression equation was:

$$BW = -52.537+1.206HG.$$

Height at withers had the next higher direct contribution to the variation in BW (R^2 = 0.77). When WH was considered with HG the coefficient of determination increased to 92.1%. BL also had a high correlation coefficient (0.85) with BW. Taking height at withers, BL and HG together, the coefficient of determination increased to 92.2%. HG had the highest beta coefficient of 1.135 implying that it is the most appropriate body measurement for estimating BW in Matabele goats. Thus HG is a good estimator of BW and better estimation values are obtained when it is used with WH and BL.

The does mean body weight (31.4 kg) obtained in the present study were higher than those reported by Chitra et al (2012) for Malabari does. This implies that prediction equation could be population specific in their use, for example, no one equation can be used across goat breeds. The higher means for morphometric measurements in bucks than in does is a results of inter-sex differential in hormonal response causing sexual dimorphism. The different hormones profiles in bucks and does invariably translate to differential growth rates. Testosterone is the most important male sex hormone, culpable of most of the male attributes. The variation in correlation coefficient of body weight and morphometric measurements in males and females advocates sexual differences in the genetic body configuration of goats. Sexual dimorphism have been observed in Awassi lambs (Al-Tarayrah and Tabbaa, 1999). However, in a similar study Yakubu (2010) reported a non significant sex difference for body weight and morphometric measurements. Furthermore, there was a weak association of body weight with rump width in ewes. The morphometric measurements correlations in the present study reflect active growth of body size and conformation in bucks. This is consistent with the fact that testosterone influence male characteristics. In contrary, Yakubu (2010) reported morphometric characters being positively and significantly correlated for males and females. This might not agree with the idea that majority of genes influencing the configuration of an animal's body are of common action and not local. In agreement with our results, Thiruvenkadan (2005) observed a significant association of body weight with linear body measurements in Kanni Adu kids. Working with Nadji sheep, Aziz and Sharaby (1993) also found positive correlation of body weight and morphometric measurements. Hasam and Cirom (1990) observed a correlation coefficient for body weight and hearth girth of two experimental groups of 0.95 and 0.84, respectively, which is consistent with our results.

4. Conclusion

From the study can conclude that path coefficient analysis is applicable in deriving equations for estimating body weight from morphometric measurements in indigenous Matebele goats. The appropriate model for estimating body weight using morphometric measurements in indigenous Matebele goat should include heart girth, wither height and body length. The relationship between body weight and morphometric measurements which seem to be positive and high can be useful as a selection tool for resource poor goat farmers. Gender is an important aspect of considering the association of body weight with linear body measurements. Goats of different sex might have the same heart girth measurements, but being of different body weights, hence there is a need for development of models for males and females separately. Males and females grow differently at various stages of development, therefore, body weight might differ at a given stage of growth.

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