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Research Article

Phenotypic Correlation Between Body Weight and Linear Body Measurements of Savanna Goats

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ABSTRACT

The study investigated the relationship between body weight and linear body measurements to develop a model Savannah goat farmers will use to improve the body weight. The study was conducted at Bosveld Game Breeders using 60 goats of both sexes (7 bucks and 53 does). A total of six variables, including body weight (BW), heart girth (HG), rump height (RH), sternum height (SH), body length (BL), and withers height (WH), were measured. Pearson's correlation and Stepwise regression analysis were performed for data analysis. Correlation findings revealed that BW had a significantly positive correlation ($p < 0.01$) with HG ($r = 0.88$), WH ($r = 0.80$), RH ($r = 0.75$), BL ($r = 0.72$), and SH ($r = 0.57$) in does. While in bucks, BW had a positively high correlation ($p < 0.01$) with RH ($r = 0.99$), BL ($r = 0.98$), SH ($r = 0.97$), HG ($r = 0.97$), and WH ($r = 0.83$). Correlation outcome suggests that HG, WH, RH, BL, and SH might be used to improve the BW of Savanna goats. According to the regression analysis, both bucks and does have a significant contribution ($p < 0.05$) of BL to BW. Regression results suggest that BL might be used as a single linear body measurement to estimate BW without a weighing scale. The current study might be used to predict the live body weight of animals to support marketing, breeding, feeding, and health services in rural areas.

Keywords: cross-sectional design, regression, relationship, weighing scales

INTRODUCTION

Goats are important producers of meat, milk, fibre, and other products (Isa et al., 2019). Goats are produced or kept for various purposes, including brush management, livestock exhibitions, packing, and entertaining company (Akkina, 2010). Savanna goats were bred by various farmers with what was known as white Boer Goats for several years in Southern Africa (Epstein, 1983). They are valued for meat production, leather, and as liquid capital in case of financial need (Snyman, 2014). White goats are popular for religious or celebratory events (Visser & van Marle-Köster, 2017). The problem is that communal farmers lack knowledge of significant body weight, which prevents them from maximizing their goat farming yield, due to unavailable weighing scales, which are way too costly for smallholder farmers (Sam et al., 2016). Consequently, it led to difficulty in selection during the breeding programs, feeding, health care, and live animal marketing regarding price setting (Tudu et al., 2015; Sam et al., 2016). The study will help communal farmers understand how body weight and linear body weight measurement traits are related. Weighing the animals is critical in any farm; accurate weighing helps check the health of animals at different stages of their growth (Hill, 2018). Thus, communal farmers will no longer

predict the price of their live animals but get the accurate marketing price and more income, understanding medication doses and adjusting feeding (Tsegaye et al., 2013; Chitra et al., 2012). However, the relationship between body weight and linear body measurement traits of Savanna goats is not yet known. Hence, the study aimed to investigate the relationship between body weight and linear body measurement traits and develop a model to predict the body weight of Savanna goats.

MATERIAL AND METHODS

Ethical Approval

The study complied with the guidelines of the University of Limpopo Animal Research Ethics Committee (AREC/17/2022:UG).

Study Area

The study was conducted at Bosveld Game Breeders in Limpopo province, South Africa. Bosveld Game Breeders is situated in the Polokwane Local Municipality. Temperature in winter ranges between 18°C and 32°C, and in summer, temperature ranges from 30°C to 34°C, with annual rainfall of more than 600mm (Mokoena et al., 2022). The latitude coordinates are -23°28'54" and the longitude coordinates are 29°11'1" east

Experimental Animal and Management

A total of 60 Savannah goats (53 females and seven males) aged 2- 3 years were used in the study. The goats were reared under an extensive production system, allowing them to graze outside their camps in the morning and return by late noon. The kraal had different housing for goats; bucks were kept in their housing, as well as does. When Savanna goats were released in the morning, does were released first to their camps, followed by bucks, which were kept in separate camps. The non-breeding and breeding bucks had different camps. Savanna goats go through a footbath when they are released for grazing and return to their camps. Every Wednesday, all goats were dipped for external parasites. Clean water was provided ad libitum. Supplemental feed was provided for the goats when required.

Research Design

A cross-sectional design was used as an experimental design, where all 50 Savannah goats were used during data collection. A cross-sectional study is a research design that gathers information from many individuals simultaneously (Setia, 2016). In cross-sectional research, variables are observed without being changed (Wang & Cheng, 2020). These investigations are quick, inexpensive, and simple to carry out because there is little possibility for error and no follow-up with the subjects (Setia, 2016).

Data Collection

Body weight and five linear body measurements traits were measured following the procedure stated by Selala and Tyasi (2022). Body weight (BW) was measured using a weighing scale calibrated in kilograms (kg), and linear body measurements were measured using a tape measure calibrated in centimeters (cm). The linear body measurements were measured as follows: Body length (BL) was measured as a distance from the base of the ear to the base of the tail (where it joins the body). Heart girth (HG) was measured around the chest just behind the front legs. Withers height (WH) was measured starting from the base of the forelegs to the highest

mark of the shoulder. Rump height (RH) was measured from the pelvic girdle to the ground surface of the hind legs. Sternum height (SH) was measured as a vertical position from the lower tip of the sternum to the ground as the animal was standing. One person took the measurements to avoid errors in individual measurement readings.

Statistical Analysis

The data was analyzed using the Statistical Package for the Social Sciences (IBM SPSS, 2020) version 27.0 software. Descriptive statistics (average, mean, standard deviation, standard error, and coefficient of variance) were calculated. Pearson's correlation coefficients between body weight and linear body measurement traits were computed within each sex and age group. Stepwise regression was used to estimate body weight and linear body measurement traits. The following regression model was used:

$$Y = a + b_1X_1 + \dots + b_nX_n$$

Where:

Y = dependent variable (BW)

a = intercept

b = regression coefficients

X = independent variables (BL, HG, WH, SH, RH)

The goodness-of-fit model in this study was selected based on the coefficient of determination (R^2) and mean root squared error (RMSE), Akaike's information criterion (AIC), and Bayesian information criterion (BIC) using the mathematical formula as follows:

$$R^2 = 1 - \left(\frac{SST}{SSE} \right)$$

$$RMSE = \sqrt{\frac{SSE}{N - p - 1}}$$

$$AIC = N \ln \left(\frac{SSE}{N} \right) + 2p$$

$$BIC = N \ln \left(\frac{SSE}{N} \right) + p \ln N$$

Where R^2 is the coefficient of determination, RMSE is the root mean square error, SST is the total sum of squares, AIC is Akaike's information criterion, BIC is the Bayesian information criterion, N is the number of observations (data points), and p is the number of parameters.

RESULTS AND DISCUSSION

Descriptive Statistics of Measured Traits

Table 1 shows a descriptive summary of the estimated variables of does and bucks. The average body weight (BW) was calculated to be 42.45kg, while the bucks were calculated to be 56.03kg. Both bucks and does have the most significant average mean heart girth (HG), 90.00 cm and 83.36 cm, followed by body length (BL), with 80.00 cm and 74.51 cm, and finally, sternum height (SH) had the least average value, which was calculated to be 48.00 cm and 44.36 cm, respectively. The coefficient of variation of does ranges from 0.07% to 0.25%, while in bucks it ranges from 8.14% to 31.14%.

Table 1. Descriptive Statistics of Body Weight and Linear Body Measurement Traits of Does and Bucks

Does Traits	Mean $\pm$ SE	SD	CV (%)	Bucks Mean $\pm$ SE	SD	CV (%)
Body weight	42.45 $\pm$ 1.47	10.67	25	56.03 $\pm$ 11.77	31.14	56
Withers height	65.70 $\pm$ 0.73	5.29	8	72.43 $\pm$ 3.93	10.39	14
Rump height	68.47 $\pm$ 0.70	5.04	7	74.26 $\pm$ 3.75	9.93	13
Sternum height	44.36 $\pm$ 0.44	3.23	7	48.00 $\pm$ 1.48	3.92	08
Body length	74.51 $\pm$ 1.07	7.81	10	80.00 $\pm$ 3.08	8.14	10
Heart girth	83.36 $\pm$ 1.35	9.84	12	90.00 $\pm$ 6.09	16.10	18

SD: Standard deviation, SE: Standard error, CV: coefficient of variation, BW: Body weight, WH: Withers height, RH: Rump height, SH: Sternum height, BL: Body length, HG: Heart Girth

Phenotypic Correlation of Measured Traits in Does

Pearson correlation was used to determine the relationship between body weight and linear body measurement traits in Savanna goat does. Table 2 shows that body weight is highly significantly correlated with linear body measurement in does. The correlation coefficient ranged from 0.57 to 0.88. Body weight and heart girth ($r = 0.88$), body weight and withers height ($r = 0.80$), body weight and rump height ($r = 0.75$), body weight and body length ($r = 0.72$), and body weight and sternum height ($r = 0.57$) were highly positively significant ($p < 0.01$). The correlation coefficient among linear body measurements ranged from 0.46 to 0.86, with rump height and withers height ($r = 0.86$) at $p < 0.01$, body length and sternum height ($r = 0.46$) at $p < 0.05$.

Table 2. Phenotypic Correlation of Body Weight and Linear Body Measurements Traits of Savanna Goat Does

Traits	BW	WH	RH	SH	BL	HG
BW						
WH	0.80**					
RH	0.75**	0.86**				
SH	0.57**	0.69**	0.67**			
BL	0.72**	0.71**	0.61**	0.46*		
HG	0.88**	0.72**	0.69**	0.54**	0.65**	

** . Correlation is significant at the 0.01 level and * 0.05 level. BW: Body weight, WH: Withers height, RH: Rump height, SH: Sternum height, BL: Body length, HG: Heart Girth

Phenotypic Correlation of Measured Traits in Bucks

Table 3 shows the results of the Pearson correlation between body weight and linear body measurement traits in Savanna goat bucks. The results indicated a positive correlation between body weight and linear body measurements analysed. The correlation coefficient ranged from 0.83 to 0.99. Body weight and rump height ($r = 0.99$), body weight and body length ($r = 0.98$), body weight and sternum height ($r = 0.97$), body weight and heart girth ($r = 0.97$), body weight and withers height ($r = 0.83$) were highly positively significant ($p < 0.01$). The correlation coefficient among linear body measurements ranged from 0.75 to 0.99, with rump height highly correlated to sternum height and body length ($r = 0.99$); meanwhile, withers height and sternum height recorded the lowest correlation coefficient ($r = 0.75$) ($p < 0.01$).

Table 3. Phenotypic Correlation of Body Weight and Linear Body Measurements Traits of Savanna Goat Bucks

Traits	BW	WH	RH	SH	BL	HG
BW						
WH	0.83**					
RH	0.99**	0.80**				
SH	0.97**	0.75**	0.99**			
BL	0.98**	0.82**	0.99**	0.99**		
HG	0.97**	0.82**	0.97**	0.94**	0.95**	

** Correlation is significant at the 0.01 and * 0.05 level. BW: Body weight, WH: Withers height, RH: Rump height, SH: Sternum height, BL: Body length, HG: Heart Girth

Simple Linear Regression Analysis for Does

Table 4 presents the prediction model used to estimate body weight from linear body measurements of Savanna bucks. In bucks, the results of the stepwise regression analysis showed that all the traits were significant in predicting the body weight, rump height, $R^2 = 0.98$, $p < 0.01$. The regression model was established as $BW = -174.65 + 3.11RH$. When body length and rump height were added, $R^2 = 0.98$, $p < 0.01$, the model changed to, $BW = -175.79 + 3.06RH + 0.57BL$. Sternum height was added to the model, $R^2 = 0.99$, $p < 0.01$, which resulted in the model changing to $BW = -103.62 + 3.91RH + 1.64BL - 5.45SH$. Heart girth was added to the model, $R^2 = 0.99$, $p < 0.01$, and gave the new model as $BW = -47.63 + 6.34RH + 2.32BL - 10.15SH - 0.72HG$. When all traits were added to the model, $R^2 = 0.99$, $p < 0.01$, the model changed to $BW = -122.97 + 4.92RH + 3.49SH - 0.43HG + 0.28WH$.

Table 4. Stepwise Regression Analysis for Different Linear Body Measurements Traits in Savanna Bucks

Model	AIC	BIC	R^2	RM Se	p-value
$BW = -174.65 + 3.11RH$	21.64	21.59	0.98	4.81	0.001
$BW = -175.79 + 3.06RH + 0.57BL$	23.64	23.53	0.98	5.38	0.001
$BW = -103.62 + 3.91RH + 1.64BL - 5.45SH$	23.72	23.56	0.99	5.42	0.003
$BW = -47.63 + 6.34RH + 2.32BL - 10.15SH - 0.72HG$	24.21	24.00	0.99	5.96	0.024
$BW = -122.97 + 4.92RH + 3.49SH - 0.43HG + 0.28WH$	27.16	26.89	0.99	9.01	0.028

Significant $p < 0.01$, R^2 coefficient of determination, RMSe: root mean square, BW: Body weight, BL: Body length, HG: Heart girth, RM: Rump height, WH: Withers height, SH: Sternum height.

Simple Linear Regression Analysis for Bucks

Table 5 presents the prediction model used to estimate body weight from linear body measurements of Savanna does. In this study, the results of stepwise regression showed that some traits were significant in predicting body weight. The heart girth, $R^2 = 0.78$, $p < 0.01$, the regression model was established as, $BW = -37.42 + 0.96HG$. When withers height and heart girth were added, $R^2 = 0.84$, $p < 0.01$, the model changed to $BW = -61.17 + 0.69HG + 0.71WH$. Body length was added to the model, $R^2 = 0.85$, $p < 0.01$, resulting in a change to $BW = -62.32 + 0.64HG + 0.57WH + 0.19BL$. Rump height was added to the model, $R^2 = 0.85$, $p < 0.01$ and gave the new model as $BW = -59.96$

+ 0.66HG + 0.69WH + 0.18BL - 0.16RH. When sternum height was added, $R^2 = 0.85$, $p < 0.01$ and the model changed to, $BW = -59.23 + 0.66HG + 0.70WH + 0.18BL - 0.15RH - 0.05SH$.

Table 5. Stepwise Regression Analysis for Different Linear Body Measurements Traits in Savanna Does

Model	AIC	BIC	R^2	RM SE	p-value
$BW = -37.42 + 0.96HG$	171.73	173.70	0.78	5.06	0.001
$BW = -61.17 + 0.69HG + 0.71WH$	156.94	160.88	0.84	4.36	0.001
$BW = -62.32 + 0.64HG + 0.57WH + 0.19BL$	156.14	162.05	0.85	4.29	0.001
$BW = -59.96 + 0.66HG + 0.69WH + 0.18BL - 0.16RH$	157.66	165.54	0.85	4.31	0.001
$BW = -59.23 + 0.66HG + 0.70WH + 0.18BL - 0.15RH - 0.05SH$	159.62	169.47	0.85	4.36	0.001

Significant $p < 0.01$, R^2 coefficient of determination, RMSE: root mean square, BW: Body weight, BL: Body length, HG: Heart girth, RM: Rump height, WH: Withers height, SH: Sternum height.

Body weight is a crucial economic characteristic that requires exact estimation to increase goat breeding and output through selection (Sam et al., 2016). The first objective of the current study was to determine the relationship between body weight and linear body measurement traits in Savannah goats. The results show a relationship between some linear body measurements and body weight. The relationship was found between heart girth and body weight, rump height and body weight. Similar studies (Khargharia et al., 2015) reported a relationship between heart girth and body weight, rump height and body weight in Assam hill goats. However, Iqbal et al. (2013) reported no relationship between rump height and body weight in Beetal goats. The results might differ because breeding and management differed from those used in the present study. In bucks, the results show that the traits correlated to body weight include heart girth, body length, rump height, and sternum height. Similar studies (Sam et al, 2016) reported that heart girth was highly correlated to body weight in West African Dwarf goats. However, Rashijane et al. (2021) reported no relationship between heart girth and body weight in Boer goats. Breed and environmental factors could be the causes of the variations. According to Mathapo et al. (2022), the relationship between the growth features shows that the same genes control the qualities. Please add the limitation of the correlation.

Hence, this study's second objective was to develop a model that can be used to predict body weight using a stepwise regression. The results show that the body weight of Savanna goats can be predicted from rump height, body length, and sternum height in bucks with the highest R^2 and lowest RMSE, AIC, and BIC, while rump height and heart girth can be used in the body weight prediction of does. The best-fitted regression models were chosen using the coefficient of determination (R^2) value. Similar studies (Idorenyin et al., 2016) show that body weight can be predicted from heart girth in West African Dwarf goats. However, Norris et al. (2015) reported that heart girth alone cannot predict body weight in indigenous goats. The difference might be due to the goats' diets and climatic conditions. The findings show that rump heart girth, withers height, and body length can be used in the body weight prediction in does, with the highest R^2 , lowest RMSE, AIC, and BIC. Similar studies (Norris et al., 2015) reported that heart girth was valuable.

Able to estimate the body weight of female indigenous goats. However, Dakhlan et al. (2020) reported that body weight can be predicted from chest girth (CG) and body length (BL) in the

Ettawa Grade goat. According to the present study's findings, linear body measurement traits can be used to estimate body weight, which will be helpful for farmers who do not have weighing scales. Although correlation data show a relationship between the variables, they do not show the different effect sizes of the predictor and response (Loftus, 2022). The findings of this study demonstrate that body weight may be predicted using linear body measures, which will be extremely helpful for farmers who lack weighing scales. Using linear body measures has the advantages of being inexpensive and straightforward to undertake. However, more research on Savanna goats is required to ascertain the connection between body weight and linear body measures. The quantity of Savanna goats utilized may be increased.

CONCLUSIONS

The current research results correlate body weight and linear body measurements. Because they are correlated, choosing animals with good linear body measures can help with body weight. A model developed in the current study can be used to predict the body weight of the Savanna goats. According to the regression analysis, both the bucks and does of Savanna goats significantly contribute to body length and body weight.

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