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ORIGINAL RESEARCH ARTICLE

Species dependent correlation analysis and regression models of body weight on linear body measures in indigenous sheep and goats of Zimbabwe

Never Assan[1,2,*], Michael Musasira[3], Maphios Mpofu[3], Nicholas Mwareya[4]

[1] *Department of Agriculture Management, Bulawayo Regional Campus, Faculty of Agriculture, Zimbabwe Open University, Bulawayo ZW102102, Zimbabwe*

[2] *Department of Agriculture and Animal Health, College of Agriculture and Environmental Sciences, University of South Africa, Pretoria 0001, South Africa*

[3] *Matopos Research Station, Department of Research and Extension, Ministry of Lands and Agriculture, Bulawayo Private Bag 5137, Zimbabwe*

[4] *Department of Mathematics, Mutare Regional Campus, Faculty of Agriculture, Zimbabwe Open University, Mutare ZW110501, Zimbabwe*

*** Corresponding author:** Never Assan, neverassan@gmail.com

ABSTRACT

Measurements of live weight in goats and sheep are an important source of information for a range of scientific fields and applications in animal husbandry activities. The study was conducted to investigate the relationship between body weight and body measurements and to predict live body weight from body measurements in indigenous Matabele goats and indigenous Sabi sheep at Matopos Research Station in Zimbabwe. For this purpose, data on body weight (BWT) and linear body measurements (LBM) such as heart girth (HG), body length (BL), wither height (WTH), and rump height (RH) were collected from randomly selected females of each species at the age of 4 years. The corresponding means, standard deviations (SD), and coefficients of variation (CV) were determined for body weight and linear body measurements. Bivariate correlations between bodyweight and linear body measure characteristics were also determined. Simple and multiple regression were used to develop a model to predict BWT using linear body measures. Indigenous Matabele goat females' CV ranged from 15.77% to 22.68%, while indigenous Sabi sheep females' CV ranged from 19.16% to 19.37%. The CV was calculated by dividing the mean by the standard deviation. At 4 years of age, the mean BWT of the indigenous Sabi sheep and female Matabele goat were 35.96 ± 0.83 kg and 27.90 ± 0.66 kg, respectively. In indigenous Matabele goat females, the average linear body measures were HW (74.20 ± 0.53 cm), WTH (48.55 ± 0.53 cm), BL (47.53 ± 0.61 cm), and RH (57.50 ± 0.88 cm). The mean values for native Sabi sheep were 63.33 ± 0.70 cm, WTH (52.00 ± 0.80 cm), BL (51.26 ± 0.78 cm), and HW (85.56 ± 1.04 cm). The results showed a strong and positive correlation between BWT and linear body measures in female indigenous Matabele goats. The phenotypic correlation values were HG (r = 0.79), BL (r = 0.70), WTH (r = 0.68), and RH (r = 0.56), in decreasing order. In indigenous Sabi sheep, the phenotypic correlation for BWT and linear body measurement was high and positive for HG (r = 0.73), and positive and moderate to low with WTH (r = 0.41), BL (r = 0.32), and RH (r = 0.36). Again, the results also indicated that HG had a high and positive phenotypic correlation with BL (r = 0.53), while modest correlation was observed with

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HG and WTH (r = 0.41) and HG and RH (0.32). The optimal regression models for easily measuring body weight using HHG are BWT = −46.711 + 1.006 HG (R^2 = 60%) and BWT = −15.209 + 0.586 HG (R^2 = 53%) for indigenous Matabele goats and indigenous Sabi sheep, respectively. It is recommended that smallholder farmers use HG measurements to estimate body weight in both indigenous Sabi sheep and indigenous Matabele goat females at the age of 4 years.

Keywords: body weight; linear body measurements; correlation analysis; regression models; indigenous Sabi sheep; indigenous Matabele goats

1. Introduction

The indigenous Matabele goat is descended from numerous breeds introduced by northern Bantu tribes[1]. The breed is primarily found in Matabeleland North province (Nkayi, Lupane, Umguza, Bubi, Hwange, and Tsholotsho districts); Matabeleland South province (Matobo, Mzingwane, Insiza Gwanda, and Beitbridge districts); and some parts of Midlands province (Mberengwa district)[2]. They are a medium-to-large breed with a height at withers of around 65 cm. Matabele goat mature weights range from 35 kg to 55 kg. The typical birth weight of kids is around 2.5 kg, with weaning weights ranging from 12 kg to 16 kg[3]. Both males and females should have powerful legs for browsing higher up the trees (bi-pedal posture). Short and moderate neck that is proportional to body length. The face of the head may have different color markings/patterns that indicate a certain ecotype. Colors include white, black, brown, and cream, as well as mixed/pied (speckled) patterns. An ecotype might be represented by some of the colors[4].

Indigenous Sabi sheep are the most prevalent indigenous breed in Zimbabwe[5]. Zimbabwe has roughly 350,000 sheep, with the smallholder sector making up about 80% of the population and reared for meat[6]. Exotic, indigenous, and hybrid sheep breeds are the three categories into which the sheep raised in Zimbabwe may be separated. According to Donkin[7], lamb output varies greatly depending on the environment and the breed. It is possible to select the breeds that are most suited to different production objectives, conditions, and management techniques since Zimbabwean sheep breeds exhibit such large variability in performance. The breed is small and grows slowly, yet it is resilient and fertile in challenging environments[5]. The Blackhead Persian breed has been steadily introducing itself into Zimbabwe's sheep flocks since the turn of the century, while the majority of flocks in that country have their roots in the native Sabi ewe[7]. The indigenous Sabi sheep breed was referred to as the fat-tailed type, distinguished by a non-wooled, hairy coat in a variety of colors[8]. While black, pure white, and mixed colors are also frequently seen, the coat of short, stiff hair is typically fawn, brown, and/or red in color. Mason[9] reported that the indigenous sheep have the same characteristics as the Red Maasai and Tswana sheep from Eastern and Southern Africa. The breed has a broad distribution throughout the nation thanks to the resilience of their hairy coat against penetration by awned seeds. The Sabi is renowned for its toughness, fertility, and resistance to a number of regional maladies and pests. Devendra and Burns[1] noted that indigenous Sabi sheep mature at adult weights of 35 kg for ewes and 45 kg for rams.

Body measurements are important data sources in terms of reflecting breed standards and are also important in giving information about the morphological structure and development ability of the animals[10]. Body measurements differ according to factors such as breed, gender, yield type, and age. Establishing the live weight of a goat is essential for optimal management, including monitoring growth and selecting replacement females[11]. The interrelationship between body weight and linear body measures is influenced by an animal's gender and age[12]. Dakhlan et al.[13] in Saburai goats likewise found a favorable phenotypic correlation between body weight and many biometric parameters at various ages. The age of the animal should be taken into consideration while selecting goats, along with other variables that include growth rate, chest circumference, and body length. This is consistent with the fact that, in general, livestock farmers prioritize morphological selection criteria (subjective selection) above productivity selection criteria (objective selection)[14].

Regression models and simple phenotypic correlation between bodyweight and morphological variation factors can be used to estimate bodyweight[15–17]. A number of researchers have used external body measurements for determining goat body weight[18,19]. Several authors have found a strong relationship between animals' LW and their linear measurements and then developed LW prediction models using body measurements[20,21]. Since linear body measurements may be influenced by an animal's age and sex, regression models that take into account these variables can be developed[22]. It is logical to propose that distinct prediction models based on age, sex, management, and localities should be created for various livestock species or breeds[23]. Hence, these variables were used in BWT prediction by various authors[24,25]. The purpose of the study was to use correlation analysis and regression models to predict body weight using morphometric traits in adult sheep and goats at Matopos Research Station in Zimbabwe.

2. Materials and methods

2.1. Study location

The study was carried out at the small stock section of Matopos Research Institute, Bulawayo, Zimbabwe. The research institute is located at (20°23′ S, 31°30′ E), which is situated approximately thirty kilometers south-western of Bulawayo, Zimbabwe. The setting is 800 m above sea level and receives irregular rainfall of only 450 mm annually[26]. The temperatures during the summer are quite high, with the average maximum and the lowest temperature of the warmest months being 21.6 and 11.4 °C, respectively. According to Hagreveas et al.[27], there is a chance of severe droughts in the area. The most prevalent form of flora is called sweet veld, and its browsing and annual grass species have relatively excellent nutritional values. Van Rooyen et al.[28] noted that if rangelands are properly managed, they should be able to provide goats and other animals with the nourishment they need. Nevertheless, a sizable percentage of the rangeland has been degraded, resulting in low biomass and, consequently, a restricted supply of poor-quality feed resources, especially during the dry season[29]. Day et al.[30] and Gambiza and Nyama[31] provided in-depth descriptions of the research area's climate and plant types, respectively.

2.2. Experimental flocks

Four-year-old females of indigenous Matabele goats and indigenous Sabi sheep were used for the study.

2.3. Management of experimental flock

Feeding, watering, and medication of the flock were described by Assan et al.[32].

2.4. Data collection

Data were collected from thirty (N = 30) randomly selected females for each species (indigenous Sabi sheep females and indigenous Matabele goat females). Body weight (BWT) and linear body measurements (LBM), namely heart girth (HG), wither height (WTH), body length (BL), and rump height, were collected using a graduated measuring tape. Only adult female animals at the age of four years of age (having completed their growth) were used.

- Live body weight (BWT): The experimental animals were weighed using an electronic weighing scale.
- Heart girth (HG): chest circumference, behind the posterior edge of the shoulders at the point of least perimeter.
- Withers height (WTH): distance from the top of the withers to the ground.
- Body length (BL): body length, from the anterior edge of the shoulder to the posterior edge of the ischium.

- Rump height (RH): the distance from the surface of a platform to the rump using a measuring stick as described for height at withers.

2.5. Statistical data analysis

The collected data was entered into an Excel worksheet in Microsoft Excel 2016. Means, standard deviations (SD), and coefficients of variation (CV) for bodyweight (BWT), heart girth (HG), wither height (WTH), body length (BL), and rump height were obtained. Bivariate correlations among bodyweight and linear body measurement traits were also obtained. Simple and multiple regression were used to establish a formula to predict the BWT using linear body measurements[33].

The below simple linear regression of body weight on linear body parameters was performed:

$$\text{Model: } Y = \alpha + \beta X$$

where, Y = dependent variable (BWT), X= independent variable (HG, WTH, BL, RH), α = the intercept, β = regression coefficient.

The below multiple linear regression was adopted:

$$\text{Model: } Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4$$

where, Y = dependent variable (BWT), a = intercept, $b_1 - b_4$ = coefficient of regression, and $X_1 - X_4$ = independent variables (HG, WTH, BL, RH).

3. Results and discussion

The summary of BWT and linear body measurements (HG, WTH, BL, and RH) is presented in **Table 1**. The BWT mean numerical values of female indigenous Matabele goats and indigenous Sabi sheep at the age of 4 years were 27.90 ± 0.66 kg and 35.96 ± 0.83 kg, respectively. Descriptive statistics of linear body measurement traits indicated that the indigenous Sabi female had higher mean numerical values in all the linear body measurements. The average values for linear body measurements in indigenous Matabele goat females were HW (74.20 ± 0.53 cm), WTH (48.55 ± 0.53 cm), BL (47.53 ± 0.61 cm) and RH (57.50 ± 0.88 cm). For indigenous Sabi sheep, the mean values were HW (85.56 ± 1.04 cm), WTH (52.00 ± 0.80 cm), BL (51.26 ± 0.78 cm), and RH (63.33 ± 0.70 cm). The CV was computed by dividing the mean with the standard deviation, and the results showed a range of 15.77%–22.68% in indigenous Matabele goat females and 19.16%–19.37% in indigenous Sabi sheep females.

Table 1. Descriptive statistics for BWT (kg) and LBMs (cm) for females in indigenous Matabele goat and indigenous Sabi sheep of Zimbabwe.

Animal species	Trait	Mean	SE	SD	CV%
Indigenous Matabele goat females (N = 30)	BWT	27.90	0.66	4.19	15.75
	HG	74.20	0.53	3.33	15.91
	WTH	48.55	0.53	3.33	15.91
	BL	47.53	0.61	3.83	22.68
	RH	57.50	0.88	5.58	15.77
Indigenous Sabi sheep females (N = 30)	BWT	35.96	0.83	4.32	19.21
	HG	85.56	1.04	5.39	19.29
	WTH	52.00	0.80	4.13	19.37
	BL	51.26	0.78	4.07	19.16
	RH	63.33	0.70	3.65	19.17

(LBM): HG = heart girth, WTH = wither height, BL = body length, RH = rump height, SE = standard error, SD = standard deviation, CV = coefficient of variation.

The results presented in **Table 2** and below the diagonal line show the correlation results of female indigenous Matabele goats and female indigenous Sabi sheep, respectively. The findings indicated that in indigenous Matabele goat females, BWT had a high and positive correlation with linear body measurements. In descending order, the phenotypic correlation values were HG (r = 0.79), BL (r = 0.70), WTH (r = 0.68), and RH (r = 0.56). The result of the present study is in conformity with reports of a high phenotypic correlation between HG and BWT[34–38]. There is a strong correlation between body measurements and production traits; traits such as body weight, body length, and height are used as proxy indicators of production traits[39]. This high and positive value entails the importance of the relationship between HG and BWT as body weight predictors. The strong positive and significant correlation between BW and HG in indigenous Matabele goats (r = 0.79) suggested that HG could provide a good estimate for predicting the live BW of indigenous Matabele goat females.

Table 2. Bivariate Pearson correlation coefficients between BWT (kg) and LMBs (cm) in females of indigenous Sabi sheep and indigenous Matabele goat of Zimbabwe.

Species/class	**Indigenous Matabele goat females**					
	Trait	**BWT**	**HG**	**WTH**	**BL**	**RH**
Indigenous Sabi sheep females	BWT	1	0.79	0.68	0.70	0.56
	HG	0.73	1	0.66	0.74	0.46
	WTH	0.41	0.41	1	0.84	0.76
	BL	0.32	0.53	0.51	1	0.65
	RH	0.36	0.32	0.66	0.43	1

(LBM): HG = heart girth, WTH = wither height, BL = body length, RH = rump height; phenotypic correlation coefficient (r): r = significant at ($r < 0.50$); r = non-significant at ($r > 0.50$).

Khargharia et al.[40] reported the same range of correlation of BW with BL (r = 0.86) and HG (r = 0.79) for Indian Assam Hill goats, which is comparable to those observed for indigenous Matabele goat females. With high correlation estimates, our results are comparable to earlier reports for Hararghe highland goats[41], Woyto-Guli goats[42], Ethiopian indigenous goats[43], Karya sheep[44], Afar goats[45] and indigenous sheep population[46]. HG is the only optimal parameter for body weight estimation[25]. This might suggest that the greater correlation between BWT and HG is caused by the comparatively greater contribution of bones, muscles, and viscera to HG[35].

The strong positive correlation of BW with HG, BL, and WTH suggested that either or the combination of these morphometric traits could be used to estimate the BW of goats in the fields in the absence of a weighing scale. The same LBMs showed that there was a higher intercorrelation between HG and WTH (r = 0.66), HG and BL (r = 0.74) and WTH and BL (r = 0.84) amongst themselves in indigenous Matabele goats than in indigenous Sabi sheep. Our results of high correlation amongst (HG and WTH), HG and BL, and WTH and BL in indigenous Matabele goats are within the range reported by Ambel and Bayou[47]. These results further showed that HG in indigenous Matabele goat females had a moderate and positive phenotypic correlation with RH (r = 0.46) while maintaining a high and positive phenotypic correlation with BL and WTH of r = 0.70 and r = 0.66, respectively. WTH in indigenous Matabele goat females showed a high and positive phenotypic correlation with BL (r = 0.84) and RH (r = 0.76). However, phenotypic correlation results of female indigenous Sabi sheep below the diagonal line revealed that in indigenous Sabi sheep, the phenotypic correlation for BWT and linear body measurement was high and positive for HG (r = 0.73), and positive and moderate to low with WTH (r = 0.41), BL (r = 0.32), and RH (r = 0.36).

Ayalew et al.[48] have also indicated that HG is correlated with the weight of the animals, as the thoracic cavity houses most of the vital organs responsible for the wellbeing of the animals. The weights of the animals are also correlated with their skeletal dimensions, as the weight of the bones comprises the bulk of their weight of the animals[36]. Thus, the wider and longer the bones, the higher the weight of the animal[34]. Again, the results also indicated that HG had a high and positive phenotypic correlation with BL ($r = 0.53$), while modest correlation was observed with HG and WTH ($r = 0.41$) and HG and RH (0.32). On the same note, WTH maintained a positive and high phenotypic correlation in indigenous Sabi sheep females of $r = 0.51$ and $r = 0.66$. The result of the current study shows that the live body weight and most linear body measurements of goats vary significantly with species. Hassan and Cirom[49] observed a correlation coefficient for BWT and HG of two experimental groups of $r = 0.95$ and $r = 0.84$, respectively, which was on the upper side as compared to our results in both indigenous Sabi Matabele goat females ($r = 0.73$ vs. 0.79).

For indigenous Matabele goats, using a simple regression equation where one LMB is fitted, the best prediction equation was given by HG ($R^2 = 63\%$) in **Table 3**. This was followed by BL ($R^2 = 0.50$). WTH gave a modest coefficient of determination of R^2, while the poorest prediction equation was recorded by RH. The coefficient of determination (R^2) ranges from 32% to 63%. This implies that 32% to 63% of the variation in body weight in indigenous Matabele goats was accounted for by the linear body measurements. The outcome of using a simple regression equation where one LBM was fitted for indigenous Sabi sheep females-maintained HG has the best predictor of body weight with a coefficient of determination of $R^2 = 0.54$. It was reported that the most significant BWT predictor was HG in beetal goats[50]. Reported R^2 values ranged from 0.16 to 0.69 using different body measurements in beetal goats, with the maximum value reported for WH and HG. The rest of the LBMs were poor in body weight, WTH ($R^2 = 0.16$), RH ($R^2 = 0.13$), and BL ($R^2 = 0.10$) in indigenous Sabi sheep.

Table 3. The simple and multiple regression equation of BWT (kg) on LBM in indigenous Matabele goat and indigenous Sabi sheep of Zimbabwe.

Species	Model	Regression equation	R^2 (%)	SE
Indigenous Matabele goat females		Simple Regression Models (Single Factors)		
	1	BWT = –14.081 + 0.865WTH**	0.47	3.08
	2	BWT = –8.871 + 0.773BL**	0.50	3.00
	3	BWT = 3.358 + 0.427RH**	0.32	3.49
	4	BWT = –46.711 + 1.006HG**	0.63	2.50
		Multiple Regression Models (Two Factors)		
	5	BWT = –46.668 + 0.768 HG** + 0.361WTH*	0.69	2.42
	6	BWT = –42.278 + 0.764HG** + 0.284BL	0.67	2.48
	7	BWT = –46.847 + 0.858HG** + 0.193RH*	0.69	2.40
	8	BWT = –14.26 + 0.484BL + 0.395WTH	0.53	2.95
	9	BWT = –10.585 + 0.642BL* + 0.139RH	0.52	2.98
	10	BWT = –13.729 + 0.764WTH + 0.079RH	0.48	3.11
		Multiple Regression Model (Three Factors)		
	11	BWT = –45.489 + 0.741HG** + 0.308WTH + 0.073BL	0.69	2.45
	12	BWT = –46.748 + 0.785HG** + 0.128RH + 0.186WTH	0.70	2.40
	13	BWT = –13.938 + 0.481BL* + 0.072RH + 0.306WTH	0.53	2.98
		Multiple Regression Model (Four Factors)		
	14	BWT = –45.917 + 0.765HG** + 0.149WTH + 0.054BL + 0.126RH	0.70	2.44
		Simple Regression Models (Single Factors)		
Indigenous Sabi sheep females	1	BWT = 13.857 + 0.425WTH*	0.16	4.01
	2	BWT = 18.456 + 0.342BL	0.10	4.17
	3	BWT = 8.628 + 0.432RH	0.13	4.10
	4	BWT = –14.209 + 0.586HG**	0.54	3.00
		Multiple Regression Models (Two Factors)		
	5	BWT = –17.591 + 0.543HG** + 0.137WTH	0.55	3.01
	6	BWT = –12.595 + 0.624HG** –0.094BL	0.54	3.05
	7	BWT = –21.872 + 0.549HG** + 0.171RH	0.55	3.00
	8	BWT = 9.900 + 0.158BL + 0.345WTH	0.19	4.06
	9	BWT = 4.174 + 0.215BL + 0.328RH	0.17	4.11
	10	BWT = 7.421 + 0.313WTH + 0.194RH	0.18	4.06
		Multiple Regression Model (Three Factors)		
	11	BWT = –16.075 + 0.594HG** + 0.200WTH –0.180BL	0.57	3.02
	12	BWT = 4.736 + 0.257WTH + 0.140BL + 0.169RH	0.20	4.12
	13	BWT = –21.448 + 0.604HG** –0.168BL + 0.226RH	0.57	3.01
		Multiple Regression Model (Four Factors)		
	14	BWT = 20.694 + 0.593HG* + 0.120WTH –0.196BL + 0.153RH	0.58	3.06

LBMs: HG = heart girth, WTH = wither height, BL = body length, RH = rump height; *significant at ($p < 0.05$); **significant at ($p < 0.01$), all LBMs without superscript are non-significant.

Of interest is the predictive power of RH for body weight in both indigenous sheep (R^2 = 0.13) and goats (R^2 = 0.32). However, the behavior of BL, which only explains 10% of the variation in body weight in indigenous sheep as opposed to 50% in indigenous goats, cannot be scientifically explained. The results reveal LMBs behave differently in different animal species despite beginning under the same management systems and even the same sex. The indigenous Sabi and Matabele goats have been kept under the same management system over the decades. The data considered randomly selected females of the age of four years of both species. The likely result of the differentiated nature of LBMs is the adaptation of the experimental sheep and goat flocks to changes in climate over time. It is more likely that the species responded differently to changes in climate, which could have an influence on their morphological structures over the years. The two flocks were being exposed to the same selection procedures.

Step-wise linear regression analysis was made to identify the best predictor variable for estimating body weight from body measurements. Regression analysis was performed by including different body measurements individually and collectively as independent variables and body weight as a dependent variable. The coefficient of multiple determination (R^2) was used as a criterion to determine the best-fit regression equation. Multiple regression equations were developed in both indigenous sheep and goats, taking into account two factors (Model 5–10), three factors (Model 11–14), and all four factors (14) and their coefficients of determination. In the two-factor category, the highest fit was observed for a combination of BWT = −46.668 + 0.768HG + 0.361WTH (R^2 = 69%) (for goat) in Model 5, which had the same value as Model 7: BWT = −46.847 + 0.858HG + 0.193RH (R^2 = 69%) (for goat). All the factors were significant in the models. The same models (5 and 7) with the same combination of factors (HG and WTH; HG and RH) maintained their best fit in indigenous Model 5: BWT = −17.591 + 0.543HG + 0.137WTH (55%) (indigenous sheep) and Model 7: BWT = −21.872 + 0.549HG + 0.171RH (55%) (indigenous sheep). However, in indigenous Sabi sheep, only HG was significant, while WTH and RH were non-significant in the models. The two factor models had a higher predictive value in indigenous Matabele goats (69%) as opposed to only 55 percent in indigenous Sabi sheep. For indigenous Matabele goat females, a combination of HG, WTH, and RH gave the best fit in the three-factor multiple regression model: Model 12: BWT = −46.748 + 0.785HG + 0.128RH + 0.186WTH (R^2 = 70%); however, by replacing RH with BL, the model lost 1% predictive power. Model 11: BWT = −45.489 + 0.741HG + 0.308WTH + 0.073BL (R^2 = 69%). In the three factor models of indigenous Matabele goat females, only HG was significant. Model 12: BWT = 4.736 + 0.257WTH + 0.140BL + 0.169RH (R^2 = 20%) gave the poorest fit in indigenous Sabi sheep. RH seemed to influence poor fit in the models; this is probably due to its poor correlation with body weight.

Considering a full multiple equation of all factors in indigenous Matabele goat Model 14: BWT = −45.917 + 0.765HG + 0.149WTH + 0.054BL + 0.126RH (70%) and BWT = 20.694 + 0.593HG + 0.120WTH − 0.196BL + 0.153RH (58%). Our coefficients of determination (R^2) results for y yrs. old females in indigenous Matabele goats for HG are in the same range reported in nondescript Kashmiri (Kashir) goat[51]. However, using HG as a sole predictor, our results are on the lower side of the coefficient of determination (59% to 81% accuracy) for predicting the body weight reported in Nigerian red Sokoto goats[52]. However, our results confirm the observation by Mavule et al.[53] in Zulu sheep and also report heart girth as an indicator in live weight estimation[13]. Salako et al.[54] reported that CG was the best predictor of BW in small ruminants.

The development of preliminary and optimum regression equations for prediction of BW in both indigenous Matabele goat females and indigenous Sabi sheep of Zimbabwe is presented in **Tables 3** and **4**, respectively. The most pertinent issue in predicting body weight using linear body measurements is that it is difficult to measure many LBMs in the field; hence, the use of fewer variables with a slightly compromised coefficient of determination might be considered. In the present study, using HG as a sole predictor could give an optimal regression equation for predicting body weight in field conditions for both indigenous Matabele goat females and indigenous Sabi sheep females. The optimal regression models for easily measuring body weight using HG are BWT = −46.711 + 1.006 HG (R^2 = 60%) and BWT = −15.209 + 0.586 HG (R^2 = 53%) for indigenous Matabele goats and indigenous Sabi sheep, respectively. Smallholder farmers can use HG measurements to estimate body weight in both indigenous Sabi sheep and indigenous Matabele goat females at the age of 4 years.

Table 4. Developing optimal regression equations from preliminary regression model.

Species	Type	Model	R^2	SE
Indigenous Matabele goat females	Preliminary	BWT = −45.917 + 0.765HG** + 0.149WTH + 0.054BL + 0.126RH	0.70	2.44
	Optimal	BWT = −46.711 + 1.006HG	0.60	2.50
Indigenous Sabi sheep females	Preliminary	BWT = 20.694 + 0.593HG* + 0.120WTH − 0.196BL + 0.153RH	0.58	3.06
	Optimal	BWT = −15.209 + 0.586HG	0.53	3.00

LBMs: HG = heart girth, WTH = wither height, BL = body length, RH = rump height; *significant at ($p < 0.05$); **significant at ($p < 0.01$), all LBMs without superscript are non-significant.

Our results confirm the notion that considering more parameters of linear body measurements could provide better precision in predicting body weight using the established equation. However, HG is the easiest way to use for live weight prediction in field conditions, especially for smallholder farmers, as there are hardly any restraining mechanisms available[55]. On the contrary, elsewhere, the highest coefficients of determination were obtained from the models formed of BL or BL and HG together in Karya sheep (R^2 = 0.79, R^2 = 0.87)[56]. In the present study, models of BL or BL and HG together (R^2 = 0.50, R^2 = 0.67) and (R^2 = 0.10, R^2 = 0.54) in indigenous Matabele goats and indigenous Sabi sheep, respectively, BL on its own was a poor predictor of body weight in indigenous Sabi sheep females. Also, the highest relationship among body measurements may be used as the selection criterion[57].

Based on existing research, it has been determined that HG and BL were the most suitable parameters for predicting body weight in the regression equations (**Table 4**). The best estimating precisions were obtained in goats when HG and BL were taken into account in equations at the same time[58]. Combining WTH, HG, and BL explained the most difference in body weight compared to each of the age groups in both sexes when taken separately[35]. This pattern was also shown in the current investigation, whereby native Matabele goat and indigenous Sabi sheep females, respectively, had coefficients of determination (R^2 = 67% vs. 54%) when HG and BL were combined in a model. In the case of the indigenous Matabele goat and the indigenous Sabi sheep, the addition of WTH as a third variable increased the coefficient of determination by at least 2% and 3%, respectively.

4. Conclusion

In conclusion, female indigenous Matabele goats and Sabi sheep may have their body weight estimated using HG; optimal model (indigenous Matabele goat): BWT = −46.711 + 1.006 HG (R^2 = 60%); optimal model (indigenous Sabi sheep): BWT = −15.209 + 0.586 HG (R^2 = 53%). There was species influence on regression models, with indigenous Matabele goat females having better-fitting preliminary models and a stronger phenotypic correlation among body parameters than indigenous Sabi sheep. The current study used a randomly selected equal number (forty) of females of each of the same age (4 years old), and these animals have been under the same selection criteria and management method for decades. Hence, the comparison of the relationship between body weight and linear body measurements and the derivation of prediction models could offer a fair appraisal of these flocks. The substantial association between different measures and body weight means that linear body measurement can be used as a predictor of body weight or as an indirect selection criterion to improve living weight. It's likely that species influence in the two flocks' evolutionary responses to both natural and artificial selection contributed to the differences in the relationship between body weight and morphological measurements between them. Climate change and variability over time may probably also have had a significant effect on the population's condition with respect to the relationship between body weight and linear body measures, particularly the derived prediction regression equations, as these two populations attempted to adapt to environmental changes.

Author contributions

Conceptualization and writing—original draft preparation, NA; methodology, NA; formal analysis, NM; investigation, MUM and MPM provide resources—review and editing, NA and NM; supervision, NA. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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