

## Research Article



# The Effect of Age on Prediction of Body Weight from Body Linear Measurements of Female Indigenous Matebele Goat in Zimbabwe

NEVER ASSAN<sup>1,2</sup>, MACHEL MUSASIRA<sup>3</sup>, NICHOLAS MWAREYA<sup>4</sup>, KWENA MOKOENA<sup>5</sup>, THOBELA LOUIS TYASI<sup>5\*</sup>, ENOCK MUTEYO<sup>3</sup>

<sup>1</sup>Zimbabwe Open University, Faculty of Agriculture, Department of Agriculture Management, Bulawayo Regional Campus, Bulawayo, Zimbabwe; <sup>2</sup>Professor Extraordinaire, University of South Africa, College of Agriculture and Environmental Sciences, Department of Agriculture and Animal Health, South Africa; <sup>3</sup>Matopos Research Station, Ministry of Lands and Agriculture, Department of Research and Extension, Private Bag, Bulawayo, Zimbabwe; <sup>4</sup>Zimbabwe Open University, Faculty of Agriculture, Department of Mathematics, Mutare Regional Campus, Bulawayo, Zimbabwe; <sup>5</sup>School of Agricultural and Environmental Sciences, Department of Agricultural Economics and Animal Production, University of Limpopo, Private Bag X1106, Sovenga, Limpopo, South Africa.

**Abstract** | The primary goal of the study was to establish models for predicting body weight (BW) using linear body measurements (LBMs) in indigenous Matebele does. BW data were correlated and regressed to body measurements (withers height = WTH, heart girth = HG, body length = BL, and rump height = RH) using linear and multiple linear regression of Statistical Package SS. A total of 127 does of different ages of 2yrs (N=26), 3yrs (N=34), 4yrs (N=32), and 5yrs (N=35) were used in the study. The strongest association ( $r = 0.89$ ) was observed between HG and BW in 5-year-old females, and ( $r = 0.73$ ) between WTH and BW. In 2-year-old females, BL was associated with RH ( $r = 0.89$ ) and WTH ( $r = 0.88$ ). In does aged 4 years, the coefficients of correlation between BW and all LBMs were high and positive. The best fits were found for all different age groups when all four LBMs were included in the model, with 2yr ( $R^2 = 0.599$ ), 3yr ( $R^2 = 0.624$ ), 4yr ( $R^2 = 0.97$ ), and 5yr ( $R^2 = 0.845$ ). With increasing dam age, predictive power strengthens. In the 4yr age group, linear body measures ( $R^2 = 0.638$ ) and BL ( $R^2 = 0.501$ ) provided satisfactory predictors of body weight as single factors. The findings indicate that the body weight of does in native Matebele goats of different ages could be calculated in the field using linear body measures obtained with a tape measure if there was no available weighing equipment.

**Keywords** | Regression, Linear body measurements, Bivariate correlation, Heart girth

**Received** | July 09, 2024; **Accepted** | January 15, 2025; **Published** | March 27, 2025

**\*Correspondence** | Thobela Louis Tyasi, School of Agricultural and Environmental Sciences, Department of Agricultural Economics and Animal Production, University of Limpopo, Private Bag X1106, Sovenga, Limpopo, South Africa; **Email:** louis.tyasi@ul.ac.za

**Citation** | Assan N, Musasira M, Mwareya N, Mokoena K, Tyasi TL, Muteyo E (2025). The effect of age on prediction of body weight from body linear measurements of female indigenous matebele goat in Zimbabwe. J. Anim. Health Prod. 13(2): 265-274.

**DOI** | <https://dx.doi.org/10.17582/journal.jahp/2025/13.2.265.274>

**ISSN (Online)** | 2308-2801

**Copyright** © 2025 Kumar *et al.* This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



**Copyright:** 2025 by the authors. Licensee ResearchersLinks Ltd, England, UK.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

## INTRODUCTION

Goats in Africa made up 30% of the global population in 2005 after increasing by 75% between 1980 and

that year (Simela and Merkel, 2008). According to CSO (2000), there are 4.4 million goats in Zimbabwe and their number is continually growing. Small-scale producers possess 90% of the country's goat population (Homann *et al.*,

2007). The small-scale farmers rear a large proportion of goats in communally owned land for both personal use and resale in both formal and informal markets (Agrisystems, 2000). More than 90% of goats are native to Zimbabwe; they are either of the more robust Matebele goat breed, which is found in the country's south and west, or the smaller variety, the East African goat, which is found in the country's east and center (Van Rooyen and Homann, 2008). An experimental indigenous Matebele goat flock, on the other hand, has been preserved at Matopos Research Station from its inception ten decades ago (Ward *et al.*, 1979).

The phenotypic relationship between LBMs and BW can be used to regress models to estimate body weight (Yakubu, 2009; Kuzelove *et al.*, 2011). Numerous researchers such as Waheed *et al.* (2020) and Ouchene-Khelifi and Ouchene (2021) reported on using external LBMs to estimate BW. There are several studies which recorded a positive association among LBMs and BW, thus, developing the predictive model from the strongly associated traits to BW (Lesosky *et al.*, 2013; Lukuyu *et al.*, 2016). The age and sex of the animal has an influence on the growth traits, therefore, regression models can be developed taking into account these variables (Farhad and Bolghasem, 2013). It makes sense to suggest that different prediction models for different livestock species or breeds should be developed based on factors like age, sex, management, and regions (Assan, 2013). Hence, there are several studies incorporating these variables in their prediction of body weight (Tsegaye *et al.*, 2013; Rashid *et al.*, 2016).

BW is used as an essential tool by farmers in their daily management at the farm, such as selecting replacement animals, monitoring the growth and health of the animals (Singh *et al.*, 2020). The link between an animal's BW and LBMs is influenced by its age and gender (Ojedapo *et al.*, 2007). Dakhlan *et al.* (2021) revealed a relationship between BW and many LBMs (chest circumference, and body length) at different ages, concluding that age had an influence on the association. In general, livestock farmers prioritize morphological selection criteria above productivity selection criteria (Tabbaa and Al-Atiyat, 2009). Farmers are supposed to choose females on their overall physical and productive attributes. The age of the dam affects reproductive success in goats and it's critical to study the association between a females age, biometric features and body weight interact. The purpose of this study was to predict body weight using linear body measurements on indigenous Matebele does of varying ages.

## MATERIALS AND METHODS

### STUDY SITE

The Matopos Research Station (20° 0' 23" S, 31° 0' 30" E), which is located around thirty kilometres southwest of Bu-

lawayo, Zimbabwe, is the location of the research project. The region receives irregular rainfall of roughly 450 millimetres annually while being 800 meters above sea level (Homann *et al.*, 2007). The average maximum and lowest temperatures during the hottest months are 21.6 °C and 11.4 °C, respectively, making summertime temperature fairly high.

### EXPERIMENTAL DOE MANAGEMENT

The females and their offspring are allowed to graze on a well-tended arid veld from 8:00 a.m. to 5:00 p.m. They were housed at night. There was always water available. During the dry season, mineral licking is supplied. Plunge dip preventative care, deworming, and ticking were frequently performed with organophosphates. All animals received vaccinations against local diseases. On an annual basis, does are assigned for mating, however inbreeding in closely monitored. Does of differing ages were included in each buck-mating group. Single sire flocks of one buck to thirty does. The breeding season lasted from May to June. Rubber rings were used to castrate all unwanted males. Mature females were generally culled based on their reproductive effectiveness, because they failed to produce kids or weaned kids in two consecutive seasons. Age and dental status were also considered during the culling process.

The rainy season began in late October and early November, when the vast bulk of offspring are born. New-borns' ears were tagged and weighted using an electronic scale shortly after delivery. They were then let to suckle from their own mothers while grazing until they were weaned at roughly three months of age. When the lambs were weaned, they were separated into distinct weaned flocks by gender. Weaning weights of offspring were captured.

### TRAITS MEASURED

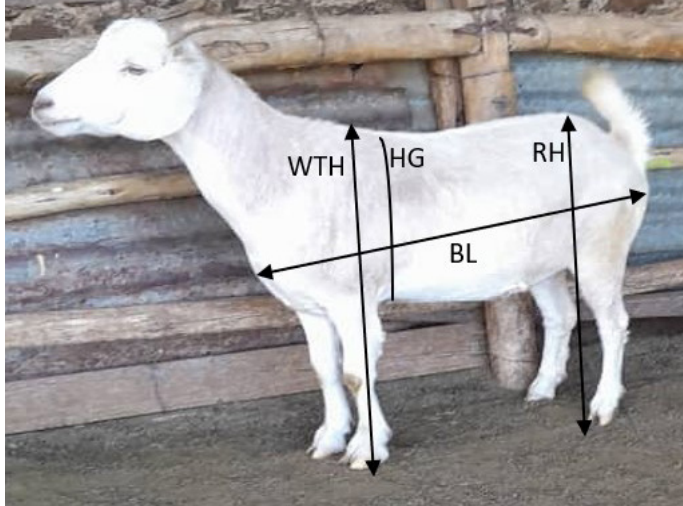
A total of 127 females of different ages of 2yrs (N = 26), 3yrs (N = 34), 4yrs (N = 32), and 5yrs (N = 35) on which body weight (BW) and linear body measurements (LBMs) namely heart girth (HG), rump height (RH), wither height (WTH) and body length (BL) were measured. A measuring tape calibrated in centimetres (cm) was used to measure the LBMs., whilst the BW (kg) was determined using a balance weighing scale. One person was taking the measurements for each trait to prevent discrepancies. The Figure 1 below shows the linear body parts in female Matebele goats. The four linear body measurements were taken for consideration in this study.

**WITHERS HEIGHT (WTH):** The difference between the ground and the top of the withers.

**BODY LENGTH (BL):** Body length, measured from the posterior margin of the ischium to the anterior edge of the shoulder.

**HEART GIRTH (HG):** Chest circumference, located at the point of least perimeter behind the rear margin of the shoulders.

**RUMP HEIGHT (RH):** The measurement, using a measuring stick as for height at withers, of the distance between the surface of a platform and the rump.



**Figure 1:** Linear body features measured in female Matebele goat.

## DATA ANALYSIS

The gathered data were input into a Microsoft Excel 2016 worksheet. For BW, HG, WTH, BL, and RH, standard deviations (SD), coefficients of variation (CV), and means were acquired. Additionally, bivariate associations between LBM features and BW traits were found. There was proven simple and multiple regression. Multiple regression analyses were done using **BM SPSS (2010)**. The regressions were used to establish a formula to predict the BW using LBMs. The below multiple linear regression was adopted:

$$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4$$

Where;

Y: dependent variable (BW).

A: intercept.

$b_1 - b_4$ : coefficient of regression.

$X_1 - X_4$ : independent variables (LBMs).

## RESULTS AND DISCUSSION

Descriptive statistics of LBMs and BW in indigenous Matebele does are shown on **Table 1**. The overall estimates of mean  $\pm$  SE of mature female (5yrs) for BW and respective linear body measurements were BW ( $31.13 \pm 1.60$  kg), HG ( $77.75 \pm 1.32$ ), WTH ( $50.75 \pm 0.94$ ), BL ( $53.38 \pm 1.52$ ) and RH ( $60.38 \pm 1.59$ ). Values for each of the LBMs and BW confirms the range observed across multiple goat breeds by different researchers. **Iqbal et al. (2013)** obtained

average for body length (inch), body weight (kg), heart girth and height at withers of 27.001.35 (inch), 27.001.35 (inch), and 27.163.94 (inch) in which in Beetle goats breed. In Crossbred (BeetalxTeddi) goats, (**Moaeen-ud-Din et al., 2006**) recorded 64.97 cm body length, 70.23 cm height at withers, and 61.29 cm hearth girth. Beetal goats had body lengths of 60.14 cm, withers heights of 63.14 cm, and heart girths of 61.29 cm, according to **Hamayun et al. (2006)**. **Shettar and Rudresh (2003)** found a mean body weight of 31.330.20 kg in Bidri goats, which is similar to the current study.

**Table 1:** Descriptive statistics of body weight and linear body measurements in females of varying ages of indigenous Matebele goat.

| Trait           | N  | Means | SE   | SD   | CV%   |
|-----------------|----|-------|------|------|-------|
| <b>BW (kg)</b>  |    |       |      |      |       |
| 2               | 26 | 23.30 | 0.52 | 2.34 | 10.04 |
| 3               | 34 | 31.28 | 0.72 | 3.86 | 12.34 |
| 4               | 32 | 27.90 | 0.66 | 4.19 | 15.02 |
| 5               | 35 | 31.13 | 1.60 | 4.52 | 14.52 |
| <b>HG (cm)</b>  |    |       |      |      |       |
| 2               | 26 | 69.30 | 1.20 | 5.38 | 7.76  |
| 3               | 34 | 77.55 | 0.72 | 3.88 | 5.00  |
| 4               | 32 | 74.20 | 0.53 | 3.33 | 4.49  |
| 5               | 35 | 77.75 | 1.33 | 3.77 | 4.86  |
| <b>WTH (cm)</b> |    |       |      |      |       |
| 2               | 26 | 48.75 | 0.42 | 1.86 | 3.82  |
| 3               | 34 | 51.00 | 0.69 | 3.70 | 7.25  |
| 4               | 32 | 48.55 | 0.53 | 3.34 | 6.88  |
| 5               | 35 | 50.75 | 0.94 | 2.66 | 5.24  |
| <b>BL (cm)</b>  |    |       |      |      |       |
| 2               | 26 | 46.40 | 0.77 | 3.42 | 7.37  |
| 3               | 34 | 52.07 | 0.69 | 3.69 | 7.09  |
| 4               | 32 | 47.53 | 0.61 | 3.84 | 8.08  |
| 5               | 35 | 53.38 | 1.52 | 4.31 | 8.07  |
| <b>RH (cm)</b>  |    |       |      |      |       |
| 2               | 26 | 58.70 | 0.58 | 2.58 | 4.40  |
| 3               | 34 | 60.86 | 0.86 | 4.62 | 7.59  |
| 4               | 32 | 57.50 | 0.88 | 5.58 | 9.70  |
| 5               | 35 | 60.38 | 1.59 | 4.50 | 7.45  |

**BW:** Body weight; **HG:** Heart girth; **WTH:** Wither Height; **BL:** Body length; **RH:** Rump Height; **SE:** Standard Error; **N:** number; **SD:** Standard deviation; **CV:** coefficient of variation; **cm:** centimeter; **kg:** kilogram.

The coefficient of variation for BW for different doe ages ranged from 10.04 to 15.02% while coefficient of variation for LBMs ranged from 3.82 to 9.70%. The coefficient of variation of BW was at least 1–2 times greater than LBMs; this was inline to the study by **Sabbioni et al. (2019)** in

sheep. Walstra (1980) reported similar results on BW and LBMs with reference to allometric coefficients and explained the three-dimensions of BW compared to LBMs. The findings revealed that goats BW variation was high within low and high age groups (10.04 vs 15.02 CV%) enough although their ages were close to each other (2, 3, 4 and 5 years old).

HG (69.30 to 77.75cm) of female in indigenous Matebele female goats of current study were within the same range reported for female Jawarandu goats of which the mean HG was 75.86 cm (Nurhayati *et al.* 2014). However, HG measurements were higher than those reported in female Sabura goat (Daklan *et al.*, 2021). This may be due to effect of breed, management and environment. The variation of BW and LBMs in goats of the same breed are greatly due to environmental factors (Devendra and Burns 1994).

### PHENOTYPIC CORRELATION BETWEEN LINEAR BODY MEASUREMENTS AND BODY WEIGHT

The correlation of BW at 2, 3, 4 and 5 years of age of does with different LBMs viz. HG, RH, BL and WH were presented in Table 2. The correlation values were low, moderate and high in the BW of indigenous Matebele does except between HG and WTH, BL and RH ( $r = -0.56, -0.56, -0.57$ ) where negative correlation, respectively. BW and HG were highly correlated in 3, 4 and 5 year female groups with an indication that correlation improved with increased age [ 3yr ( $r = 0.68$ ), 4yr ( $r = 0.80$ ), and 5 ( $r = 0.86$ )]. Several studies reported on the relationship of BW and LBMs and concluded that HG and BL are highly associated with BW in goats (Adeyinka and Mohammed 2006; Khan *et al.*, 2006; Alex *et al.*, 2010; Cam *et al.*, 2010a; Chitra *et al.*, 2012; Tsegaye *et al.*, 2013; Abdallah *et al.*, 2019; Abd-Allah *et al.*, 2019; Dakhlan *et al.*, 2020). BW was also highly correlated with WTH ( $r = 0.69$  vs  $0.73$ ) for 4 and 5 years, respectively. The correlations observed for WTH in relation to BL of 0.88, 0.84 and 0.75 in 2, 4, and 5 years' female groups and WTH.RH of 0.89, 0.76 and 0.63 in 3, 4 and 5 years female groups, respectively confirms the reports of Topal and Macit (2004). This finding, which is contradicted by other studies (Das *et al.*, 1990; Ulaganathan *et al.*, 1992), might be the result of the WTH being a function of bone growth rather than an increase in total body weight (Thiruvankadan, 2005).

The strongest associations were seen between BW and WTH ( $r = 0.69$  vs  $r = 0.73$ ) and BWT and BL ( $r = 0.71$  vs  $r = 0.73$ ) for females aged 4 and 5. Our findings contradict those of Idamokoro *et al.* (2018), who found no association between BW and LBMs (BL and WTH) in Boer and Non-descript goats. This was also corroborated by Bello and Adama (2012), who found no link between BW and BL in Nigerian Savannah Brown goats. The outcomes

gathered from multiple studies on the issue of association between LBMs and BW imply that using BL and other LBMs to estimate goat BW may depend on breed (Semakula *et al.*, 2010).

**Table 2:** The phenotypic correlation coefficients between body weight and body measurements in females of varying ages of indigenous Matebele goat.

|              | BW   | HG    | WTH  | BL   | RH |
|--------------|------|-------|------|------|----|
| <b>2 YRS</b> |      |       |      |      |    |
| BW           | 1    |       |      |      |    |
| HG           | 0.31 | 1     |      |      |    |
| WTH          | 0.20 | -0.56 | 1    |      |    |
| BL           | 0.39 | -0.56 | 0.88 | 1    |    |
| RH           | 0.18 | -0.57 | 0.89 | 0.82 | 1  |
| <b>3 YRS</b> |      |       |      |      |    |
| BW           | 1    |       |      |      |    |
| HG           | 0.68 | 1     |      |      |    |
| WTH          | 0.17 | 0.49  | 1    |      |    |
| BL           | 0.37 | 0.40  | 0.43 | 1    |    |
| RH           | 0.61 | 0.53  | 0.42 | 0.67 | 1  |
| <b>4 YRS</b> |      |       |      |      |    |
| BW           | 1    |       |      |      |    |
| HG           | 0.80 | 1     |      |      |    |
| WTH          | 0.69 | 0.66  | 1    |      |    |
| BL           | 0.71 | 0.74  | 0.84 | 1    |    |
| RH           | 0.57 | 0.46  | 0.76 | 0.65 | 1  |
| <b>5 YRS</b> |      |       |      |      |    |
| BW           | 1    |       |      |      |    |
| HG           | 0.86 | 1     |      |      |    |
| WTH          | 0.73 | 0.68  | 1    |      |    |
| BL           | 0.80 | 0.76  | 0.75 | 1    |    |
| RH           | 0.24 | 0.41  | 0.63 | 0.19 | 1  |

**BW:** Body weight; **HG:** Heart girth; **WTH:** Wither Height; **BL:** Body length; **RH:** Rump Height; **YRS:** years; Phenotypic correlation ( $r$ ):  $r$ : significant at ( $r < 0.50$ );  $r$ : non-significant at ( $r > 0.50$ ).

BW and RH recorded an  $r = 0.61$  vs  $r = 0.57$  in 3 and 4-year-old females, respectively. BW and HG ( $r = 0.31$ ) and BW and RH ( $r = 0.18$ ) recorded the lowest values in 2yr old females, while BW and RH gave a low value of  $r = 0.18$ . The interaction of HG and BL had the positive and high correlation to BW in 4 ( $r = 0.74$ ) and 5 years. ( $r = 0.76$ ) old does. This was within the same range reported by Dakhlan *et al.* (2020) of female Ettawa grade goat. The results of the current study are in harmony with the findings of Fahim *et al.* (2013) in Rohilkhand goats. Rather *et al.* (2020) further support the results of the study, where BL and CG were predictors of body weight of animals.

This is most likely due to the fact that the HG is directly correlated with the chest and abdominal region, where the goat's body weight is mostly distributed from the chest to the BL base of the tail. Therefore, the higher the HG and the longer the BL, the heavier the goat.

According to [Dakhlan \(2019\)](#), there was no multicollinearity across body measurements because the correlation was primarily positive and varied from 0.20 to 0.86. Given the strong association between live body weight and body measures, estimating live weight using any one of these factors alone or in combination may yield reliable results on indigenous Matebele goat females. Hence, can be used for selection of replacement females in the flock. According to [Khan et al. \(2006\)](#), there was a strong association between the live body weight and the body measurements, suggesting that this may be utilized as a criterion for selection. Since linear size attributes are favourably connected with animals' subjectively evaluated body conformation qualities, they are valuable on their own and can be used as indirect selection criterion to increase live weight ([Janssens et al., 2004](#)).

### PREDICTION OF BODY WEIGHT FROM LINEAR BODY MEASUREMENTS

Simple and multiple regression models (Equations 1-9) between BW and LBMs of female indigenous Matebele goat of different ages are presented in [Table 3](#). The best fitting model was found using the statistical method known as the coefficient of determination ( $R^2$ ). It indicates how near the data points are to the fitted regression line. Based on  $R^2$  criteria, the best regression model for predicting BW of female indigenous Matebele goat of different ages was obtained by simple regressing body weight on BW (BW. HG=  $R^2 = 0.638$  (4years);  $R^2 = 0.735$  (5years). There was a tendency of coefficients of determination ( $R^2$ ) increasing as the age of dam increased in indigenous Matebele goat females.

When weighing equipment is inaccessible, animal researchers often employ simple and multiple regression analysis to establish quantitative correlations between a response variable and one or more explanatory factors, such as BW and LBMs ([Cankaya et al., 2008](#)). BW was estimated using Simple and multiple regression equations were developed from LBMs. The result of the study shows that HG explained more variation on BW at the age of 5years in does ( $R^2 = 0.735$ ) ([Table 3](#)).

At 2 years, there was poor prediction of body weight using any LBMs, with R-squares ranging from 0.040 to 0.150. The model 6 under 2 years old, which contained HG and BL, predicted 56%, while the model combining HG, WTH, and BL had the greatest fit, with  $R^2 = 60\%$ . It was

reported that the most significant BW predictor was HG in Beetal goats ([Eyduan et al., 2017](#)). [Iqbal et al. \(2013\)](#) predicted body weight in in Beetal goats using body measurements and concluded that WH and HG can be used to predict BW with  $R^2$  values ranging from 0.16 to 0.69. the current study reported BL, WH and HG could be used to predict BW giving  $R^2$  of 0.85, the findings are similar to the study of by [Chitra et al. \(2012\)](#) on Malabari goats. Adding all four LBMs lowered predictive power by 1%. The current study suggests that HG in combination with other traits will give the best variables to predict BW under field condition. Thus, prediction of BW could be based on Model:  $BW + -26.152 + 0.336HG + 0.564BL$  ( $R^2 = 0.562$ ) for 2-year-old females. [Shirzeyli et al. \(2013\)](#) suggested linear body measurement, such as chest circumference and body length, as indirect selection criteria for the prediction of live weight in sheep, which is consistent with the findings of the current study.

HG had the greatest fit ( $R^2 = 47\%$ ) for single factor prediction of body weight, followed by BL ( $R^2 = 44\%$ ) at 3 years of age. When all four linear body measures were included in model 9 under three years of age, the greatest coefficient of determination ( $R^2 = 70\%$ ) was observed. The improvement in coefficient of determination in two factor combinations where HG had been paired with the other three traits was not significant. At 4 years of age, the single predictors were HG ( $R^2 = 64\%$ ), BL ( $R^2 = 50\%$ ), WTH ( $R^2 = 46\%$ ), and RH ( $R^2 = 32\%$ ). HG had the greatest fit in predicting body weight. However, there was a minor increase in prediction when additional characteristics (5-9) were added in the model for the female group aged 4 years. In contrary to other research According to [Rather et al. \(2021\)](#), WTH was the most significant and trustworthy indication for estimating the body weight of Kashmir Merino sheep.

Even though all biometric traits included in the present study may give together a better prediction of BW in indigenous Matebele goat owing to  $R^2$  values of 0.599, 0.624, 0.697 and 0.845, 2, 3, 4 and 5 years' female groups, single body measurement (HG) can be the best predictor of BW in indigenous Matebele goat. At 5 years of age, for single factor prediction of body weight, HG provided the greatest fit with  $R^2 = 74\%$ , followed by BL ( $R^2 = 65\%$ ), and WTH ( $R^2 = 53\%$ ). RH had an exceptionally low coefficient of determination ( $R^2 = 6\%$ ) in the 5 years. group.

A combination of HG and any characteristic produced a significant prediction value more than ( $R^2 = 70\%$ ), but the greatest was obtained when all four traits were included in the model 9 ( $R^2 = 85\%$ ). Our coefficients of determination ( $R^2$ ) results for 5 years old females for HG are with the same range reported by [Rather et al. \(2022\)](#) in nondescript

**Table 3:** Simple and multiple regression analysis of body weight and body measurements in females of varying ages of indigenous Matebele goat.

| Age, yrs. | Model | Trait | Model        | Parameter |      |       |       |       | R <sup>2</sup> | SE    |
|-----------|-------|-------|--------------|-----------|------|-------|-------|-------|----------------|-------|
|           |       |       |              | Intercept | β1   | β2    | β3    | β4    |                |       |
| 2         | 1     | BW    | WTH          | 11.07     | 0.25 |       |       |       | 0.040          | 2.357 |
|           | 2     |       | BL           | 10.89     | 0.27 |       |       |       | 0.153          | 2.214 |
|           | 3     |       | RH           | 13.63     | 0.16 |       |       |       | 0.033          | 2.366 |
|           | 4     |       | HG           | 13.95     | 0.14 |       |       |       | 0.096          | 2.288 |
|           | 5     |       | HG+WTH       | -28.55    | 0.27 | 0.68  |       |       | 0.299          | 2.074 |
|           | 6     |       | HG+BL        | -26.15    | 0.34 | 0.56  |       |       | 0.560          | 1.640 |
|           | 7     |       | HG+RH        | -23.45    | 0.27 | 0.48  |       |       | 0.290          | 2.090 |
|           | 8     |       | HG+WTH+BL    | -10.84    | 0.32 | -0.50 | 0.79  |       | 0.600          | 1.600 |
|           | 9     |       | HG+WTH+BL+RH | -10.13    | 0.32 | -0.43 | 0.80  | -0.08 | 0.599          | 1.669 |
| 3         | 1     | BW    | WTH          | 22.11     | 0.18 |       |       |       | 0.029          | 3.875 |
|           | 2     |       | BL           | 17.44     | 0.83 |       |       |       | 0.444          | 3.508 |
|           | 3     |       | RH           | 34.03     | 0.53 |       |       |       | 0.180          | 0.218 |
|           | 4     |       | HG           | -21.49    | 0.68 |       |       |       | 0.467          | 2.873 |
|           | 5     |       | HG+WTH       | -18.21    | 0.79 | -0.22 |       |       | 0.501          | 2.830 |
|           | 6     |       | HG+BL        | -24.15    | 0.64 | 0.12  |       |       | 0.480          | 2.900 |
|           | 7     |       | HG+RH        | -25.03    | 0.50 | 0.29  |       |       | 0.560          | 2.670 |
|           | 8     |       | HG+WTH+BL    | -21.75    | 0.74 | -0.28 | 0.20  |       | 0.528          | 2.808 |
|           | 9     |       | HG+WTH+BL+RH | -20.29    | 0.61 | -0.31 | -0.05 | 0.38  | 0.624          | 2.558 |
| 4         | 1     | BW    | WTH          | -14.08    | 0.86 |       |       |       | 0.459          | 3.083 |
|           | 2     |       | BL           | -8.87     | 0.77 |       |       |       | 0.501          | 2.999 |
|           | 3     |       | RH           | 3.358     | 0.42 |       |       |       | 0.323          | 3.495 |
|           | 4     |       | HG           | -46.71    | 1.01 |       |       |       | 0.638          | 2.557 |
|           | 5     |       | HG+WTH       | -46.61    | 0.77 | 0.36  |       |       | 0.685          | 2.418 |
|           | 6     |       | HG+BL        | -42.28    | 0.76 | 0.28  |       |       | 0.670          | 2.480 |
|           | 7     |       | HG+RH        | -46.85    | 0.86 | 0.19  |       |       | 0.690          | 2.400 |
|           | 8     |       | HG+WTH+BL    | -45.49    | 0.74 | 0.31  | 0.07  |       | 0.686          | 2.447 |
|           | 9     |       | HG+WTH+BL+RH | -45.917   | 0.77 | 0.15  | 0.05  | 0.13  | 0.697          | 2.435 |
| 5         | 1     | BW    | WTH          | -31.67    | 1.24 |       |       |       | 0.530          | 3.343 |
|           | 2     |       | BL           | -13.93    | 0.84 |       |       |       | 0.647          | 2.897 |
|           | 3     |       | RH           | 16.39     | 0.24 |       |       |       | 0.060          | 4.733 |
|           | 4     |       | HG           | -48.77    | 1.03 |       |       |       | 0.735          | 2.510 |
|           | 5     |       | HG+WTH       | -55.10    | 0.81 | 0.46  |       |       | 0.776          | 2.531 |
|           | 6     |       | HG+BL        | -43.33    | 0.70 | 0.38  |       |       | 0.790          | 2.450 |
|           | 7     |       | HG+RH        | -45.85    | 1.09 | -0.13 |       |       | 0.750          | 2.670 |
|           | 8     |       | HG+WTH+BL    | -48.28    | 0.65 | 0.27  | 0.29  |       | 0.800          | 2.674 |
|           | 9     |       | HG+WTH+BL+RH | -53.04    | 0.81 | 0.86  | -0.02 | -0.35 | 0.845          | 2.714 |

**BW:** Body weight; **HG:** Heart girth; **WTH:** Wither Height; **BL:** Body length; **RH:** Rump Height; **SE:** stand; **R<sup>2</sup>:** coefficient of determination; **yrs:** = years.

Kashmiri (Kashir) goat. HG alone and or in combinations other linear body measurements biometric traits gave 59% to 81% accuracy for predicting the body weight. Ravimurugan *et al.* (2013) in Kilakarsal sheep, Tadesse and Gebremariam (2010) in Highland, Adeyinka and Mohammed (2006) in Nigerian red Sokoto goats, Musa *et al.* (2012)

in Sudanese Shogur, Raja *et al.* (2013) in Attappady black goats, Berhe (2020) in Maefur goat, Kumar *et al.* (2018) in Harnali sheep, by Chitra *et al.* (2012) in Malabari goat, Habib *et al.* (2019) in black Bengal goats, and (Dakhlan *et al.*, 2021) in small ruminants also reported heart girth as indicator in live weight estimation.

Combining the two LBMs, HG and BL, for the multiple regression equations boosted the reliability of the coefficients of determination ( $R^2 = 0.560$  vs  $0.790$ ) in 2 and 5 years old females. While two factor combination of HG and RH improved prediction in 3 years ( $R^2 = 0.5600$ ) vs 4 years ( $R^2 = 0.690$ ). For instance, the inclusion of a third linear body measurement reduced the coefficient of determination ( $R^2$ ) of from 0.560 to 0.528, 0.690 to 0.686 and 0.790 to 0.686 in 3, 4, and 5-year female group. There was an increase of 4% in the predictive power ( $R^2 = 0.560$  to  $0.600$ ) of the model when three factors were included in the model in 2 years female group.

As shown in Table 3  $R^2$  increases significantly from 2 to 3 year (0.096 to 0.467) and remained constant at 3 and 4 years with highest experienced at 5 years. Then after 5 years there was a decline in 6 and 7 years old. Generally, the predictive power in terms of coefficient of determination ( $R^2$ ) for regression analysis improved by addition of all 4 linear body measurements traits in all ages, with the highest  $R^2$  observed at 2 years (0.096-0.599), 3 years (0.467-0.624), 4 years (0.467-0.697) and 5 years (0.735-0.845). The increase in accuracy of prediction were 50.3, 15.7, 23.0 and 11.0% at 2, 3, 4 and 5 years of does age.

Across ages, the predictive power of the models increased with the number of linear body measurements in the model, and the predictive power improved with all four traits as the age of the does increased ( $R^2 = 0.590$ ,  $R^2 = 0.624$ ,  $R^2 = 0.697$ , and  $0.845$ ) for models 9 of 2, 3, 4, and 5 years. According to Waheed *et al.* (2020), Beetal goats raised in farms and fields showed a similar pattern in the prediction of monthly body weight based on body measures. Their overall value of  $R^2$  increased with increasing age and its highest value was obtained for animals aged as 17 months.

It was observed that addition of new linear body traits in the model for 2, 3 and 4-year category there was a decrease in standard error which was unlike in 5 year does category actually the standard error increased. Since the goal of predicting BW from LBMs is to readily estimate BW from LBMs, it is not practical to use all liLBMs in a field setting. Therefore, the result of the current study suggests that HG is the best variable to predict BW at the ages of 4 years ( $R^2 = 64\%$ ) and 5 years ( $R^2 = 74\%$ ) in female indigenous Matebele goat under field condition. However, a combination of HG and BL will also improve the prediction value ( $R^2 = 79\%$ ).

Therefore, combining the heart circumference with one or two other measurements can lead to a more accurate estimate of body weight (Bhattacharya *et al.*, 1984). This is considering that both HG and BL are easy to measure in the field. For 2 years old females the optimal Model: BW =  $-26.152 + 0.336HG + 0.564BL$  ( $R^2 = 56\%$ ) For 3 years old females in indigenous Matebele goats the optimal re-

gression -Model: BW =  $-25.033 + 0.495HG + 0.294RH$  ( $R^2 = 56\%$ ) (SE = 2.671). For 4 and 5 years grouping sole predictor of HG could give the optimal prediction models. Model: BW =  $-46.71 + 1.01HG$  ( $R^2 = 64\%$ ) and BW =  $-48.77 + 1.03HG$  ( $R^2 = 74\%$ ), respectively. The inclusion of a new variable to the model in the current study resulted in a little drop in SE; however, this was not the case once linear body measures were included in the model.

It should be noted that while the SE often decreases when additional variables are introduced to the model, adding unnecessary variables may cause the error to grow. According to the multiple regression study results, adding linear body measurements to heart girth did not considerably boost  $R^2$ , but it greatly improved prediction accuracy by reducing error. However, since the primary goal of predicting BW from linear body measurements is to easily predict BW from LBMs, employing all LBMs under field conditions is not feasible.

## CONCLUSIONS AND RECOMMENDATIONS

Age of dam influenced the relationships between LBMs and BW in indigenous Matebele goat breed. The correlation coefficients were generally moderate to high. BW was both positively and negatively correlated with other measurements due to the effect of age of dam experiencing higher correlation in mature females (4-5 years). In conclusion, it was established that in the absence of weighing equipment for use, the BW of does in indigenous Matebele goats of varied ages could be estimated in the field using LBMs acquired with a tape measure. The results indicated that the age had important effect on the BWs of indigenous Matebele goats' females, however, the effect of age was most prominent in later ages of female goats (4 and 5 years' age group). Except for females under two years old, the measurement of HG only showed adequate for the calculation of BW in a simple regression model throughout dam ages. Moreover, anyone could measure it with ease and accuracy. As a result, farmers and researchers may utilize this model to effectively forecast and track BW and maximize the production of native Matebele goat flocks in smallholder farming settings.

## ACKNOWLEDGEMENTS

Authors would like to extend their deepest appreciation to the Matopos Research Station for allowing us to use their goat for data collection.

## NOVELTY STATEMENTS

The novelty of the study is that age is an important factor

to be considered when estimating the live body weight of goats.

## AUTHOR'S CONTRIBUTIONS

Nicholas Mwareya and Never Assan: Experimental design and data analysis.

Never Assan: Draft of manuscript.

Machel Musasira, Never Assan, and Nicholas Mwareya: Fieldwork.

Kwena Mokoena, Thobela Louis Tyasi and Enock Muteyo: Editing the manuscript and approved the final manuscript.

## CONFLICT OF INTEREST

The authors declares that there is no conflict of interests regarding the publication of this article.

## REFERENCES

- Abd-Allah S, Abd-El Rahman HH, Shoukry MM, Mohamed MI, Salman FM, Abedo AA (2019). Some body measurements as a management tool for Shami goats raised in subtropical areas in Egypt. *Bull. Natl. Res. Cent.*, 43: 0-5 <https://doi.org/10.1186/s42269-019-0153-3>.
- Abd-Allah S, Salman FM, Shoukry MM, El-Rahman HH, Mohamed MI, Abedo AA (2019). Study of some morphological characteristics of Boer goat raised in Egypt. *Adv. Anim. Vet.*, 7: 888-897. <https://doi.org/10.17582/journal.aavs/2019/7.10.888.897>
- Adeyinka IA, Mohammed ID (2006). Accuracy of body weight prediction in Nigerian Red Sokoto goats raised in North-Eastern Nigeria using linear body measurement, *Pak. J. Biol. Sci.*, 9: 2828-2839. <https://doi.org/10.3923/pjbs.2006.2828.2830>
- Agrisystems (2000). National Livestock Development Study for Zimbabwe. Draft Main Report, Phase 1. Harare, Zimbabwe. Agrisystems Ltd and Price Waterhouse.
- Alex R, Raghavan KC, Mercey KA (2010). Prediction of body weight of Malabari goats from body measurements under field conditions. *J. Vet. Anim. Sci.*, 41: 21-27.
- Assan N (2013). Bio prediction of body weight and carcass parameters from morphometric measurements in livestock and poultry. *Sci. J. Rev.*, 2: 140-150.
- Bello AA, Adama TZ (2012). Studies on body weight and linear body measurements of castrates and non-castrate Savan-nah Brown goats. *Asian J. Anim. Sci.*, 6:140-146. <https://doi.org/10.3923/ajas.2012.140.146>
- Berhe A, Bariagabre SA, Balehegn M (2020). Estimation of greenhouse gas emissions from three livestock production systems in Ethiopia. *Int. J. Clim. Chang. Str.*, 12: 669-685. <https://doi.org/10.1108/IJCCSM-09-2019-0060>
- BM SPSS (2010): Statistical packages for social sciences for windows: base system user's guide. – IBM statistics, 19. Chicago: SPSS Inc. [doi:10.2527/jas.2013-6967](https://doi.org/10.2527/jas.2013-6967)
- Cam MA, Olfaz M, Soydan E (2010a). Possibilities of using morphometrics characteristics as a tool for bodyweight prediction in Turkish Hair Goats (Kilkeci). *Asian J. Anim. Vet. Adv.*, 5(1): 52-59. <https://doi.org/10.3923/>

[ajas.2010.52.59](https://doi.org/10.3923/ajas.2010.52.59)

- Cankaya S, Ocak N, Sungu M (2008). Canonical correlation analysis for estimation of relationships between sexual maturity and egg production traits upon availability of nutrients in pullets. *Asian-Australas. J. Anim. Sci.*, 21: 1576-1584. <https://doi.org/10.5713/ajas.2008.80106>
- Central Statistical Office (CSO) (2000). Agriculture and Livestock Surveys in Communal Lands. Central Statistical Office, Causeway, Harare, Zimbabwe
- Chitra R, Rajendran S, Prasanna D, Kirubakaran A (2012). Prediction of body weight using appropriate regression model in adult female Malabari goat. *Vet. World*, 5: 409-411. <https://doi.org/10.5455/vetworld.2012.409-411>
- Dakhlan A, Saputra A, Hamdani MDI, Sulastri (2020). Regression models and correlation analysis for predicting body weight of female Ettawa Grade goat using its body measurements. *Adv. Anim. Vet. Sci.*, 8: 1142-1146. <https://doi.org/10.17582/journal.aavs/2020/8.11.1142.1146>
- Dakhlan A (2019). Experimental Design and Data Analysis Using R. Graha Ilmu (Matematika), Yogyakarta. Indonesian.
- Dakhlan A, Hamdani MDI, Putri DR, Qisthon SA (2021). Short Communication: Prediction of body weight based on body measurements in female Saburai goat. *Biodiversitas*, 22: 1391-1396. <https://doi.org/10.13057/biodiv/d220341>
- Das N, Joshi HB, Bishi DS (1990). Prediction of body weight from body measurements in Barbari and Jamnapari goats reared under intensive management system. *Indian Vet. J.*, 67: 347-351.
- Devendra C, Burns, M (1994). Goat Production in the Tropics. Translation. ITB Publisher, Bandung.
- Eyduran E, Zaborski D, Waheed A, Celik S, Karadas K, Grzesiak W (2017). Comparison of the predictive capabilities of several data mining algorithms and multiple linear regression in the prediction of body weight by means of body measurements in the indigenous Beetal goat of Pakistan. *Pak. J. Zool.*, 49:1-15. <https://doi.org/10.17582/journal.pjz/2017.49.1.257.265>
- Fahim A, Singh M, Patel BHM, Mondal SK, Dutt T (2013). Reproductive performance and milk yield of Rohilkhand goats. *Indian J. Small Rumin.*, 19, 32-35.
- Farhad HS, bolghasem L (2013). Asad, A. Estimation of body weight from body measurements in four breeds of Iranian sheep. *Songklanakarin J. Sci. Technol.*, 35: 507-511.
- Habib MA, Akhtar A, Bhuiyan AKFH, Afroz MF (2019). Genetic Expression of Different Coat Colour Variants of BlackBengal Goat (BBG) in Bangladesh. *Curr. j. appl. sci. technol.*, 1-7.
- Hamayun K, Muhammad F, Ahmad R, Nawaz G, Zubair M (2006). Relationship of body weight with linear body measurements in goats. *J. Agric. Biological Sci.*, 1: 51-54.
- Homann S, van Rooyen AF, Moyo T, Nengomasha Z (2007). Goat production and marketing: Baseline information for semi-arid Zimbabwe. P.O. Box 776. Bulawayo, Zimbabwe: International Crops Research Institute for the Semi-Arid Tropics. 84pp.
- Idamokoro EM, Muchenje V, Masika PJ (2018). Influence of genotype, sex and age on selected body measurements of Nguni, Boer and Non-descript goat kids reared under an extensive system of farming in South Africa. *Trop. Agric.*, 95: 284-294.
- Iqbal M (2013). Prediction of body weight through body

- measurements in Beetal goats. Pakistan J. Sci., 65:1-18.
- Iqbal M, Javed K, Ahmad N (2013). Prediction of body weight through body measurements in Beetal goats. J. Anim. Plant Sci., 65: 458-461.
- Janssens S, Vandeputte W (2004). Genetic parameters for body measurement and linear type trait in Belgian Bleu du Maine, Suffolk and Texel sheep. Small. Rumin. Res., 54:13-24. <https://doi.org/10.1016/j.smallrumres.2003.10.008>
- Janssens S, Vandeputte W, Bodin L (2004). Genetic parameters for litter size in sheep: natural versus hormone induced oestrus. Genetics Selection Evolution, 36(5): 54. <https://doi.org/10.1186/1297-9686-36-5-543>
- Khan H, Muhammad F, Ahmad R, Nawaz G, Rahimullah ZM (2006). Relationship of body weight with linear body measurements in goats. J. Agric. Biol. Sci., 1:51-54.
- Kumar A, Chae BJ, Bhuiyan AKFH, Sarker SC, Hossain MM (2018). Goat production system at Mymensingh district in Bangladesh. Bangladesh J. Vet. Anim. Sci., 47: 13-20. <https://doi.org/10.3329/bjas.v47i1.39396>
- Lesosky M, Dumas S, Conradie I, Handel IG, Jennings A, Thumbi S, de Clare Bronsvort BM (2013). A live weight-Heart girth relationship for accurate dosing of east African shorthorn zebu cattle. Trop. Anim. Health Prod., 45, 311-316. <https://doi.org/10.1007/s11250-012-0220-3>
- Lukuyu MN, Gibson JP, Savage DB, Duncan AJ, Mujibi FDN, Okeyo AM (2016). Use of body linear measurements to estimate liveweight of crossbred dairy cattle in smallholder farms in Kenya. Springer Plus, 5:63. <https://doi.org/10.1186/s40064-016-1698-3>
- Moaeen-ud-Din M, Bilal G, Reecy JM, Sajjad M (2019). Effect of breed, age and sex on body weight and various body measurements in Azad Jammu and Kashmir goat breeds. Pak. J. Agric. Sci., 56(4).
- Musa AM, Idam NZ, Elamin KM (2012). Regression analysis of linear body measurements on live weight in Sudanese Shugor sheep. Online J. Anim. Feed Res., 2(1): 27-29.
- Nurhayati R, Dilaga WS, Lestari CMS (2014). The correlation between body measurements and body weight of young and adult female jawarandu goats in blora regency. Anim. Agric. J., 3: 575-580.
- Ojedapo LO, Adedeji TA, Olayemi TB, Adedeji OS, Abdullah AR, Ojebiyi OO (2007). Influence of age and sex on body weight and some body linear measurements of extensively reared WAD Goats in derived savannah zone of Nigeria. J. Anim. Vet. Adv., 6:114-117.
- Ouchene-Khelifi NA, Ouchene N (2021). Statistical models based on morphometric traits for live body weight estimation in goats. Agric. Sci. Technol., 13:134-140. <https://doi.org/10.15547/ast.2021.02.022>
- Raja TV, Venkatachalapathy RT, Kannan A, Bindu KA (2013). Determination of best-fitted regression model for prediction of body weight in Attappady black goats. Glob. J. Anim. Breed. Genet., 1(1): 20-25.
- Rashid MM, Hoque MA, Huque KS, Bhuiyan AKFH (2016). Prediction of live weight for Brahman crossbred cattle using linear body measurements in rural area. Adv. Anim. Vet., 4:99-106. <https://doi.org/10.14737/journal.aavs/2016/4.2.99.106>
- Rather MA, Bashir I, Hamdani A, Khan NN, Ahangar SA, Nazki M (2021). Prediction of body weight from linear body measurements in Kashmir Merino sheep. Adv. Anim. Vet. Sci. 9(2): 189-193. <https://doi.org/10.17582/journal.aavs/2021/9.2.189.193>
- Rather MA, Bashir I, Shanaz S, Alam S, Shah R, Hamdani A, Ahanger S, Mir SA (2022). Prediction of Body Weight from Linear Body Measurements in Kashmiri (Kashir) Goat. Bhartiya Krishi Anusandhan Patrika. 37: 281-284. <https://doi.org/10.18805/BKAP490>
- Rather MA, Hamdani A, Ayaz A, Shanaz S, Mir SM, Nabi N (2020). Morphological, phenotypic, performance traits of nondescript goats in Budgam district of Kashmir. Ruminant Sci., 8: 137-140.
- Ravimurugan T, Thiruvankadan AK, Sudhakar K, Panneerselvam S, Elango A (2013). The estimation of body weight from body measurements in Kilakarsal Sheep of Tamil Nadu India. Iranian J. Appl. Anim. Sci., 3: 357-360.
- Sabbioni A, Beretti V, Superchi P, Ablondi M (2019). Bodyweight estimation from body measures in Cornigliese sheepbreed. Italian J. Anim. Sci., 19(1): 25-30.
- Semakula J, Mutetikka D, Kugonza RD, Mpairwe D (2010). Smallholder goat breeding systems in humid, sub-humid and semi-arid agro-ecological zones of Uganda. Global Vet., 4: 283-291. <https://doi.org/10.3923/aj.2010.89.97>
- Shettar VB, Rudres BH (2003). Body measurements of Bidri goats. Indian. Vet. J., 80: 367-368.
- Shirzeyli FH, Lavvaf A, Asadi A (2013). Estimation of bodyweight from body measurements in four breeds of Iranian sheep. Songklanakarin J. Sci. Technol., 35(5): 507-511.
- Simela L, Merkel R (2008). The contribution of chevon from Africa to global meat production. Meat Sci. Rev., 80: 101-109. <https://doi.org/10.1016/j.meatsci.2008.05.037>
- Singh SG, Kaur A, Kumar B (2020). Predicting the Body Weight Using Appropriate Regression Model in Beetal Goat Kids. Theriogenology Insight, 10: 01-06. <https://doi.org/10.30954/2277-3371.01.2020.1>
- Tabbaa J, Al-Atiyat R (2009). Breeding objectives, selection criteria and factors influencing them for goat breeds in Jordan Mohammad. Small Ruminant Res., 84:8-15. <https://doi.org/10.1016/j.smallrumres.2009.03.007>
- Tadesse A, Gebremariam T (2010). Application of linear body measurements for live body weight estimation of highland sheep in Tigray region. North-Ethiopia. J. Dry Lands, 3: 203-207.
- Thiruvankadan AK (2005). Determination of best model for estimation of body weight in Kanni Adu kids under farmers' management system. Livestock Res. Rural Dev., 17
- Topal M, Macit M (2004). Prediction of body weight from linear body measurements in local goats. Indian J. Anim. Bre. Gen., 142: 31-32
- Tsegaye D, Belay B, Haile A (2013). Linear body measurements as predictor of body weight in Hararghe highland goats under farmers' environment: Ethiopia. Glob. Vet., 11: 649-656.
- Ulaganathan V, Krishnapa K, Shanmugasunda S (1992). Prediction of body weight from linear body measurements in local goats. Indian J. Anim. Bre. Gene., 142: 31-32.
- Van Rooyen AF, Freeman A, Moyo S, Rohrbach D (2007). Livestock development in Southern Africa: Future Research and Investment Priorities. International Crops Research Institute for the Semi-Arid Tropics, Bulawayo, Zimbabwe.
- Waheed HM, Moaeenud-Din M, Khan MS, Saifur-Rehman M, Nawaz-ul-Rehman MS (2020). Prediction of monthly

- body weight from body measurements in Beetal goats reared under field and farm conditions. J. Anim. Plant Sci., 30: 25-31. <https://doi.org/10.36899/JAPS.2020.1.0003>
- Walstra P (1980). Growth and carcass composition from birth to maturity in relation to feeding level and sex in Dutch Landrace pigs. Wageningen University and Research.
- Ward HK, Richardson FD, Denny RP, Dye PJ (1979). Matopos Research Station: A perspective: Rhodesia Agric. J., 76:5-18.
- Yakubu A (2009). Fixing collinearity instability in the estimation of body weight from morpho- biometrical traits of West African dwarf goats. Trakia J. Sci., 7: 61-66.