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Using Morphometric Traits to Estimate Live Body Weight of South African Bapedi Sheep

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Abstract: This study was carried out for the estimation of Body Weight (BW) of bapedi sheep from Body Length (BL), Sterna Height (SH), Heart Girth (HG), Height at Withers (WH), Rump Height (RH) and Head Length (HL). Correlation and regression were used. Correlation displayed that body weight is highly positively associated ($p<0.01$) with WH and HG in males while for females, correlation is highly positively associated ($p<0.01$) with WH, HG, and HL. Regression analysis revealed that the equation with HG was the best-fitted regression model (R^2 = 0.64, RMSE = 5.06, AIC = 77.69, BIC = 78.86) for estimating Body Weight in the Bapedi sheep males while an equation including HG, WH, R, SH and HL, was the most suitable regression model (R^2 = 0.79, RMSE = 3.72, AIC = 274.49, BIC = 287.66) for female Bapedi sheep body weight estimation. These findings suggest that HG may be chosen during selection and production for the improvement of body weight in males while HG, WH, RH, SH, and HL may be selected for the improvement of body weight in females. Therefore, outcomes may assist sheep farmers during the breeding stock selection and precisions during daily animal welfare routines such as feeding, veterinary services, and marketing.

Keywords: Best-Fitted Model, Correlation, Goodness of Fit, Heart Girth, Regression

Introduction

In economically developing nations, sheep represent a key part of the economy and well-being of smallholders. The animals are usually raised under extensive systems (Avalos-Castro *et al*., 2023). Bapedi sheep is an Indigenous breed originating from the semi-arid regions of Limpopo province in South Africa and is reared to produce lean meat and it offers a source of income to resource-limited farmers (Maqhashu, 2019; Ngcobo *et al*., 2022). Body weight is the vastly utilized metric for evaluating an animal's performance since it is accurate and useful for selecting animals, determining nutritional needs, managing health, and setting selling prices (Melesse *et al*., 2013). Despite being a significant economic characteristic, live body weight is rarely assessed in rural areas because of the lack of weighing scales (Kumar *et al*., 2018). Moreover, the usage of morphometric traits in estimating live body weight is more practical, fast, cheap, and easy in rural conditions with the farmers having insufficient materials (Melesse *et al*., 2013). The high and positive relationship that body weight has with morphometric traits can be used to derive a formula for the equation, namely the regression equation (Dakhlan *et al*., 2021). Stepwise regression analysis' ability to detect the most influencing variable makes it a widely used and preferred method for adopting the most suitable and best regression model (Landau and Everitt, 2003; Smith, 2018). Prior studies by Sowande and Sobola (2008); Tadesse and Gebremariam (2010); Kumar *et al*. (2018); Sam *et al*. (2023) used morphometric traits to develop models that estimated live body weight in non-native sheep breeds. To the best of our knowledge, there is no reported information on the use of morphometric traits for the estimation of the live body weight of Bapedi sheep in South African Bapedi. Given that the animals represent a gene pool that is acclimatizing to the local climate and welfare practices, this is an extremely important need. Thus, the study aimed to determine the association between live body weight and morphometric traits in the Bapedi sheep and to develop the most suitable regression models for estimating the live body weight under an extensive production system. Knowledge of the associations among live body weight and morphometric traits will assist the investigation of this slight and at-risk indigenous sheep populace and will supply information that is key for their improvement and conservation.

Materials and Methods

Study Area

The study was carried out at two key locations. The first location is the four villages (Strydkraal, Vlakplaas, Ga-Mashabela, and Ga-Nchabeleng) of Fetakgomo local Municipality, Sekhukhune district, Limpopo province. With the coordinates; -24.42248°S and 29.79016°E. The district is found in semi-arid regions of the Limpopo province with approximately 560 mm annual rainfalls and the most recent highest temperature of 33.2°C reported in 2007 (Mpandeli *et al*., 2015). The second location is the Mara Research Station, Makhado local municipality, Vhembe district, Limpopo province. With the coordinates; -23.03506° S and 29.65910°E. According to Mpofu *et al*. (2017), Makhado consists of a sweet veld type with the prevailing grass species of *Panicum* maximum and *Eragrostis Frichophora.* The area ranges from 23°C maximum temperature in June to 30°C maximum temperature in January with an average annual rainfall of 452 mm (Nesengani *et al*., 2018).

Experimental Animals and Study Design

The research used 127 Bapedi sheep (103 ewes and 24 rams) 1-5 years of age. The study employed a population study where all the animals within the population were used. This was due to farmers having fewer numbers of the Bapedi sheep. Multi-stage purposive sampling was utilized. The first stage was the selection of Bapedi sheep farmers, and the second stage was the random selection of farmers that were in the Bapedi sheep breeding society. The sheep were kept under an extensive, in which they were released to go out and graze in the morning and come back to their kraals later in the day. Bapedi sheep were kept under observation two times a day, prior to leaving for grazing and upon their return to the kraals. There was a quality water supply. A cross-sectional study design was employed and this type of observational research method is when data is collected at a single point in time from a population. The data was collected on various morphometric traits from a sample of individuals at a single point in time.

Data Collection

The live Body Weight (BW) and morphometric trait properties of 127 Bapedi sheep breeds were estimated. The morphometric traits investigated were as follows: Body Length (BL), Sterna Height (SH), Heart Girth (HG), Height at Withers (WH), Rump Height (RH) and Head Length (HL) as demonstrated in Fig 1. The morphometric trait assessments were carried out conforming to recommendations by Tyasi *et al*. (2020); and Dinesh *et al*. (2024). Briefly, morphometric traits were measured as follows: BL as the distance between the tip of the humerus and the pubic bone's distal end, HG as body circumference just behind the scapula, WH from the apex of the shoulder to the solid ground in relation to the horizontal plane of the forelimbs, SH as upright length between the sterna bottom tip and solid surface, RH from the apex of the hip to the solid surface about horizontal plane of hindquarters and HL on the midline between top of occipital region and the nasal apex. A single individual was chosen to carry out all the measurements to evade oversights. The morphometric trait evaluations were recorded in cm and carried out using a flexible tape measure. BW was depicted in kg utilizing a weight scale (micro T7E sheep/pig scale, South Africa) that does not impart pain to the sheep.

Statistical Analysis

SPSS version 27.0 (IBM Corp, 2013) was employed for the analysis of data. The descriptive data was quantified for all the measured traits. Pearson correlation was used to quantify the association between the traits. Regression models that can be used for the estimation of live body weight using the morphometric traits were generated using stepwise regression emanating the equation:

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

where,

Y = Experimental changeable (BW)
A = Intercept
b_1-b_n = Regression coefficient and
X_1-X_n = Input changeable (morphometric traits)

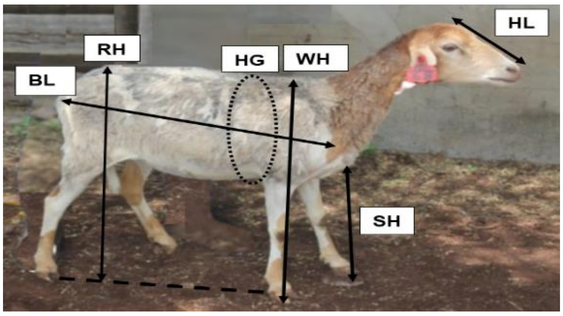

Fig. 1: Bapedi sheep showing morphometric traits measured. HL, head length; SH, sterna height; WH, height at withers; HG, heart girth; RH, rump height; BL, body length

The models' accuracies were assessed by the goodness of fit test which was employed to examine the best and most suitable model in this study. The following criteria were used:

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

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

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

$$BIC = NLn\left(\frac{SSE}{N}\right) + pLnN$$

where,

R^2 = Determination coefficient
SST = Total Sum of Square
SSE = Residual Sum of Square
RMSE = The Residual Mean Square Error
N = The Number of observations
P = Number of Parameters in the regression equation
AIC = Akaike Information Criterion
BIC = Bayesian Information Criterion
Ln = Natural logarithm in calculator

Results

Descriptive Data

The selected traits summary as described in Table 1 indicated that the CV ranges from 2.25-67.77% in males and 2.62-61.19% in females. The results showed that mean and SE values for all traits were higher in males than females. Equal maximum values of 60 kg in males and females for BW are shown. Males reported higher maximum values for BL (79 cm), HG (92 cm), and WH (76 cm) than females, while females reported higher maximum values for SH (58 cm), RH (80 cm) and HL (25 cm).

Correlation Matrix

Table 2 displays the correlation coefficients between BW and morphometric traits. In males, BW had highly correlated (p<0.01) with HG, WH, and HL, correlated (p<0.05) with SH and RH, and non-significantly correlated with BL. In females, the results revealed that BW highly correlated with HG and WH and correlated with BL, SH, RH, and HLBW = Body Weight; BL = Body Length; HG = Heart Girth; SH = Sterna Height; WH = Height at Withers; RH = Rump Height; HL = Head Length.

Regression Analysis

Regression findings (Table 3) revealed that HG, WH, HL, RH, and SH formed part of the five models established for the males and HG, WH, HL, RH, SH, HL and BL formed part of the six models established for the females.

Predictive Performance of the Established Regression Models

The predictive performance (Table 4) results indicated that the best and most suitable model was attained from the best decision based on the calculated R^2, RSME, BIC, and AIC estimates of the models. The best model had the greatest R^2 values with the least RSME, BIC, and AIC estimates. In males, the results indicated that model 1 (BW = -33.59 + 0.96 HG) had the least RSME, AIC, and BIC with the 64% (R^2 = 0.64) explaining variation in body weight of Bapedi sheep. In females, model 5 (BW = -46.19 + 0.99 HG + 0.41 WH - 0.20 RH - 0.25 SH + 0.36 HL) had the lowest RSM.

Table 1: Descriptive data for body weight and morphometric traits of South African Bapedi sheep

	Males					Females				
Trait	LSM	Min	Max	SE	CV	LSM	Min	Max	SE	CV
BW	40.17	25	60	1.68	67.88	35.16	18	60	0.77	61.19
BL	67.13	52	79	1.16	32.38	61.87	45	70	0.50	25.92
HG	76.54	64	92	1.40	46.78	72.59	54	87	0.63	41.13
WH	67.08	60	76	1.06	26.69	63.71	48	72	0.44	19.99
SH	46.79	40	52	0.64	09.91	45.73	33	58	0.37	14.16
RH	69.75	60	78	0.90	19.50	66.50	52	80	0.43	18.74
HL	20.92	18	23	0.31	02.25	20.33	16	25	0.16	02.62

Table 2: Correlation matrix, males above the diagonal and females below the diagonal

	BW	BL	HG	WH	SH	RH	HL
BW		0.26^{ns}	0.80**	0.65**	0.32*	0.33*	0.54**
BL	0.33*		0.43*	0.51**	0.49*	0.48*	0.53**
HG	0.87**	0.40*		0.88**	0.43*	0.54**	0.70**
WH	0.65**	0.35*	0.68**		0.57**	0.67**	0.65**
SH	0.47*	0.26^{ns}	0.55**	0.73**		0.49*	0.89**
RH	0.49*	0.56**	0.58**	0.67**	0.48*		0.63**
HL	0.38*	0.22^{ns}	0.36*	0.37*	0.37*	0.31*	

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Table 3: Regression analysis

Model	Equation
Males	
1	BW = -33.59+0.96 HG
2	BW = -27.33+1.22 HG -0.38 WH
3	BW = -27.05+1.22 HG -0.38 WH -0.34 HL
4	BW = -22.68+1.16 HG -0.24 WH +0.23 HL -0.21 RH
5	BW = -24.64+1.20 HG -0.30 WH +0.09 HL -0.21 RH +0.13 SH
Females	
1	BW = -42.17+1.07 HG
2	BW = -48.32+0.97 HG +0.21 WH
3	BW = -44.11+1.00 HG +0.30 WH -0.18 RH
4	BW = -42.63+1.01 HG +0.42 WH -0.19 RH -0.21 SH
5	BW = -46.19+0.99 HG +0.41 WH -0.20 RH -0.25 SH +0.36 HL
6	BW = -46.73+1.00 HG +0.41 WH -0.18 RH -0.25 SH +0.36 HL -0.03 BL

BW, live Body Weight; HG, Heart Girth; WH, Height at Withers; HL, Head Length; RH, Rump Height; SH, Sterna Height; BL, Body Length

Table 4: Predictive performance of the regression models

	Model						
Criterion	1	2	3	4	5	6	Decision
Males							
R^2	0.64	0.65	0.65	0.66	0.66		Greater is better
RSME	5.06	5.08	5.20	5.29	5.43		Lower is better
AIC	77.69	78.79	80.79	82.39	84.30		Lower is better
BIC	78.87	81.15	84.32	87.10	90.19		Lower is better
Females							
R^2	0.76	0.77	0.78	0.78	0.79	0.79	Greater is better
RSME	3.83	3.79	3.76	3.74	3.72	3.74	Lower is better
AIC	287.99	275.18	274.86	274.60	274.49	276.40	Lower is better
BIC	279.22	280.45	282.76	285.14	287.66	292.21	Lower is better

Discussion

Analysis by regression is often applied in animal studies to narrate quantitative relations among an experimental changeable and one or more input changeable such as live body weight and morphometric traits (Melesse *et al.*, 2013). This study aimed to find the most suitable predictive regression model that can be employed to estimate the live body weight of Bapedi sheep. The summary of the collected data reported higher mean values for morphometric traits in males than in females. Similar results were reported in Harnali sheep by Kumar *et al*. (2018). However, this disagrees with the results of Avalos-Castro *et al*. (2023) which reported higher mean values for evaluated morphometric traits in females than in males in Criollo sheep. The variations between studies might be due to breeds. This study suggests that males are heavier than females in Bapedi sheep. The findings of the current study showed that BW correlated with morphometric traits in the two sexes except for no correlation between body length and BW in male Bapedi sheep. The outcomes of this study disagree with the outcomes in Criollo sheep (Avalos-Castro *et al*., 2023), which reported that all morphometric measurements correlated with each and every trait and, specifically, with the BW. Correlation outcomes of the current study revealed that HG had the greatest correlations with BW in both males and females. The findings are in harmony with the prior studies on Farta sheep by Taye *et al*. (2012) and Native sheep of Southern Ethiopia by Melesse *et al*. (2013), which found that HG had the greatest coefficients with BW in the two sexes. The correlation outcomes revealed a correlation between BW and morphometric traits involving HG, RH, WH, SH, HL, and BL in Bapedi sheep. Therefore, improving HG, WH, RH, SH, HL, and BL might enhance live body weight in the Bapedi sheep breed. Regression analysis of this study revealed that in males HG was the indicator in the most suitable and best model for estimating BW while in females the model containing HG, WH, RH, SH, and HL was the most suitable and best.

The outcomes of the current study disagree with findings reported by Sam *et al*. (2023) in blackhead Somali and West African dwarf sheep, respectively, which reported body length fit for models in males. These results also showed that as more morphometric traits were involved in the predictive model a better determination coefficient was attained by Taye *et al*. (2012); Kumar *et al*. (2018); Avalos-Castro *et al*. (2023);

Castillo *et al*. (2023). Taye *et al*. (2012) reported that HG was the primary variable to clarify more variability succeeded by the BL in both sexes of Farta sheep.

The outcomes of this study disagree with Taye *et al.* (2012) as the HG was the first variable followed by WH in both sexes of Bapedi sheep. Cam *et al*. (2010); Tadesse and Gebremariam (2010); Musa *et al*. (2012); Ravimurugan *et al*. (2012); Kumar *et al.* (2018) in Karayaka, Highland, Sudanese Shogur and Harnali sheep, respectively, reported HG is a vital measure of adult live BW. The outcomes of the current study agree with the results of Kumar *et al*. (2018) as the findings indicated HG as the vital measure in live body weight estimation in Harnali sheep. However, they are not in agreement with Ali Rather *et al*. (2020) which reported WH as the vital and dependable measure in Kashmir Merino sheep BW estimation. If HG is employed as the only measure of BW, it has to examine certain models for different sexes, a suggestion that will be applicable to what was distinguished (Castellaro *et al*., 2019; Avalos-Castro *et al*., 2023). The current study investigated the sexes separately and found that the best and most suitable predictive equation had HG as the only measure of BW in males and measures were HG, WH, RH, SH, and HL for live body weight in females. These differences in predictions of BW in these sexes could be attributed to differences in fat accumulation in the sexes (Sam *et al*., 2023). Regression analysis suggests that better predictions of live body weight in Bapedi sheep might be attained by integrating different morphometric traits of at the minimum any of these six (HG, WH, RH, SH, and HL) measured traits depending on the sex. Measuring HG with a flexible measuring tape is cheap, fast, and easy. Commonly, the greater associations of BW with HG were maybe a result of the proportionately bigger involvement in BW by HG (Made up of the skeletal, muscular, and visceral parts). Therefore, BW prediction from heart girth alone would be a more practical alternative under extensive environments with an accuracy that is reasonable. More studies including several morphometric traits can be done for the body weight estimation in Bapedi sheep.

Conclusion

The study concludes that HG highly correlated with body weight and that HG might be used as the only morphometric trait for the live body weight estimation in males while HG, WH, RH, SH, and HL might be used as the trait measures for estimation of BW in Bapedi sheep females.

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Author’s Contributions

Thabang Sako: Conceptualised, data collection, data analysis, written, revised and approved the final manuscript.
Jones Ng’ambi: Conceptualised, supervised, written, revised, and approved the final manuscript.
Thomas Raphulu: Conceptualised, data collection, revised, and approved the final manuscript.
Julius Sebei: Conceptualised, data collection, revised and approved the final manuscript.
Kabelo Madia: Conceptualised, data collection, revised and approved the final manuscript.
Thobela Louis Tyasi: Conceptualised, supervised, data analysis, written revised and approved the final manuscript.

Ethics

An ethical consent verification (project number: AREC/46/2023: PG) was acquired from the animal research ethics committee of the University of Limpopo before the initiation of the investigation. All procedures were fulfilled in accordance with the principles and methods put forth by the committee. Ethical issues including similarities, wrongdoing, clinical permission, data deception, and deception were reviewed by all authors.

Conflicts of Interest

The was a declaration of no clash of interests by all the authors.

Availability of Data

Kindly liaise with (T.L.T.) the corresponding author for the data requests.

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