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Article

Sex-based analysis of linear body measurements and their correlation with body weight in indigenous Sabi sheep

Abbegal Dube[1], Never Assan[2,*], Nicholas Mwareya[3], Michael Musasira[4]

[1] Mechanization and Irrigation Development, Esigodini Agricultural College, Ministry of Agriculture, Private Bag 5808, Bulawayo, Zimbabwe
[2] Department of Agriculture Management, Faculty of Agriculture, Zimbabwe Open University, Bulawayo Regional Campus, Bulawayo, Zimbabwe
[3] Department of Mathematical Sciences, Faculty of Science, Zimbabwe Open University, Manicaland Regional Campus, Mutare, Zimbabwe
[4] Department of Research and Extension, Ministry of Lands and Agriculture, Matopos Research Station, Private Bag 5137, Bulawayo, Zimbabwe
*** Corresponding author:** Never Assan, neverassan@gmail.com

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Abstract: Body weight estimation accuracy is key to efficient sheep management and improved animal performance. This study investigated sex-based differences in the correlation between body weight (BWT) and linear body measurements (LBM) in indigenous Sabi sheep. A dataset comprising 173 Sabi sheep (112 ewes, 22 rams, and 39 wethers) from Zimbabwe's Matopos Research Institute was analyzed, revealing significant positive correlations between body weight and linear measurements, particularly in ewes and rams. Heart girth exhibited the strongest positive correlation with body weight across sexes, with rams demonstrating higher correlation coefficients than ewes. Notably, body length in rams (r = 0.90) had a significantly higher correlation coefficient with body weight compared to ewes (r = 0.79). Conversely, weaker correlations were observed for Thurl width and pin bone width in wethers. The study identified sex-based differences in the relationships between body weight and linear measurements, indicating sexual dimorphism. Heart girth, body length, and chest depth emerged as key predictors of body weight in indigenous Sabi sheep. These findings underscore the importance of considering sex in understanding the relationship between body weight and linear body measurements in this breed, with implications for enhancing breeding programs and management practices for indigenous Sabi sheep. In conclusion, this study emphasizes the necessity of sex-specific data analysis when examining the correlation between body weight and linear body measurements in indigenous Sabi sheep to ensure accurate and reliable results.

Keywords: body weight; linear body measurements; sex; correlation analysis; indigenous Sabi sheep

1. Introduction

The Sabi sheep represents the most prevalent indigenous breed in Zimbabwe, with an estimated population of 350,000, primarily reared for meat production [1]. The sheep population in Zimbabwe is classified into exotic, indigenous, and hybrid breeds [2]. Lamb production exhibits considerable variation based on breed and environmental factors, facilitating selective breeding for specific objectives and conditions. The Sabi breed is distinguished by its fat-tailed, non-wooled coat and resilience against local diseases and pests [3]. This breed is extensively distributed due to its hardiness, with ewes maturing at 35 kg and rams at 45 kg, while males reach puberty at 169 days and females conceive at ten months [4]. A notable characteristic of the Sabi breed is its distinctive fat tail, which serves as an energy reserve.

Accurate estimation of body weight is essential for optimizing sheep production practices, assessing lamb growth, and informing management decisions [5,6].

However, limited access to weighing scales in rural areas presents a challenge. Body weight serves as a critical indicator for decision-making regarding management, health, production, and marketing [1,7]. Developing objective methods for evaluating body weight and conformation traits is crucial, particularly in small-scale livestock systems [8,9]. Traditional subjective assessments can result in errors, underscoring the need for innovative methods to enhance accuracy and reduce management errors.

Body measurements provide a valuable tool for distinguishing between animal breeds and strains based on their phylogenetic characteristics [8,10,11]. These descriptions can also be utilized to evaluate and establish breeding objectives, particularly in traditional systems where documentation is limited [12]. Furthermore, linear measurements offer a straightforward and cost-effective method for estimating animal size and weight [13]. Additionally, linear measurements have been employed to assess the type, function, and breeding potential of various livestock species, including cattle [5,14,15], goats [16–18], and sheep [19,20]. Linear body measurements (LBM) offer a practical alternative for estimating body weight without scales [21]. Kusminanto et al. [22] reported that body measurement traits can serve as highly accurate predictors of BWT, explaining up to 90% of the actual BWT.

LBM provides valuable insights into breed structure and population diversity; however, exclusive reliance on correlation coefficients may oversimplify the complex biological relationships involved [23]. They are generally categorized into tissue-based measures—such as heart girth and chest depth—and skeletal measurements, including height and body length. Numerous studies have reported key morphometric traits, such as wither height, body length, and heart girth, as essential indicators in livestock characterization [24–27]. These measurements offer a practical and cost-effective alternative for estimating body weight, particularly in contexts lacking access to weighbridges or scales [21]. Beyond weight estimation, LBM contributes significantly to understanding breed conformation, genetic diversity, and the development of morphological models. Nonetheless, sole dependence on correlation coefficients to interpret the relationships between body weight and morphometric parameters may obscure the multifactorial nature of these interactions and fail to reveal underlying physiological mechanisms [23]. LBM are broadly categorized into two primary types: tissue measurements—which include parameters such as punch girth, chest depth, hip width, and heart girth—and skeletal measurements, which encompass height and length dimensions [28]. Commonly documented measurements in this context include wither height, body length, heart girth, rump height, and width [8,9,29,30].

The accurate determination of livestock BWT is often constrained by the high cost and limited accessibility of digital weighing scales, particularly for smallholder farmers [31]. As a result, alternative, cost-effective approaches using morphometric traits such as heart girth, wither height, and body length have been explored for predicting body weight in sheep [32]. However, the predictive accuracy of these methods varies significantly by breed and sex, with studies reporting moderate to strong correlations between specific body measurements and body weight in certain breeds [33]. The present study seeks to examine sex-specific differences in the relationship between BWT and LBM in indigenous Sabi sheep, aiming to identify potential variations in these correlations based on sex.

2. Materials and methods

2.1. Description of the study site

This research study was undertaken at the Matopos Research Station in Bulawayo, Zimbabwe, situated at 22.23° S latitude and 31.30° E longitude. The region experiences a dry season from April to October and a rainy season from November to March, with a mean annual rainfall of below 446.8 mm [1]. The area is characterized by high temperatures, ranging from 21.6 °C to 11.4 °C during the hottest months, and low rainfall (<450 mm) [34,35]. The research area comprises a rangeland with sweet veld vegetation, offering high nutritional value suitable for sustaining ruminants [36].

2.2. Flock management and body parts measured

Dube et al. [37] and Assan et al. [38] have provided recent insights into the management practices of the indigenous Sabi sheep flock at the Matopos Research Station, highlighting nutritional management and animal health strategies. Body weight was measured using a balance weighing scale, while linear body measurements were obtained using a calibrated measuring tape, under the guidelines provided by [39]. A dataset comprising 173 Sabi sheep (112 ewes, 22 rams, and 39 wethers) from Zimbabwe's Matopos Research Institute was analyzed. The LBMs included BL = body length, CD = chest depth, HG = heart girth, RMP = rump height, WTH = wither height, HH = hip height, HW = hip width, TW = Thurl width, and PBW = pin bone width.

Heart girth (HG) is a reliable measure of animal weight, based on the circumference around the chest. It is highly repeatable and correlates with body weight within breeds, sexes, and ages. For mature animals, compress hair when measuring HG, especially in excessively hairy sheep.

Body length (BL) is the distance from the ear to the tail, neck, front of the chest, or nose. It's crucial to maintain a straight backbone in both vertical and horizontal planes.

Hip width (HW) is the distance between the outer edges of major hip bones on the right and left side, easily measured using large, half-round or oval-shaped calipers.

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

Pin bone width (PBW): The lower leg bone length in hoofed mammals is closely linked to bone development, with the fore cannon bone being commonly used to estimate this length. Measurement involves bending the front leg at the pastern and knee, using calipers or measuring tape.

Chest depth (CD) is the distance from the shoulder backbone to the brisket between the front legs, standardized on one of the vertical processes of the thoracic vertebrae.

Height at withers (HH): The distance from a platform to an animal's withers can be measured using a stick with two vertical arms, with the sheep standing on all four legs with equal weight distribution. The vertical arm should be at a right angle to the platform.

Thurl width (TW) is a flat pelvis part of an animal's pelvis, measuring a cow's body condition score or fatness level. It is the external manifestation of the greater trochanter of the femur and is similar in small ruminants, dairy, and beef animals.

Body linear measurements were taken on animals in a standing position with a raised head by the same technician in order to avoid intra-individual variations, according to [40]. Circumference was measured with a flexible calibrated tape, whereas calipers were used for length and width. All animal care and handling procedures of the present study were reviewed and approved by the Ethical Committee of the Matopos Research Institute. All efforts were made to minimize any discomfort during body measurements.

2.3. Statistical analysis

Pearson's correlation coefficients were calculated to examine the relationships between BWT and LBMs within each sex category. The analysis was performed using SPSS software (version 20.0).

3. Results and discussion

3.1. Descriptive statistics for BWT (kg) and LBM (cm) across sexes in Sabi sheep

Table 1 provides descriptive statistics for body weight and linear body measurements in ewes, rams, and wethers. The coefficient of variation for ewes was low, indicating a homogeneous population. Conversely, rams and wethers demonstrated greater variability in body measurements, with coefficients of variation of 22% and 16%, respectively. Indigenous Sabi sheep are characterized by a square body type, with a wither height of 60.05 cm and a body length of 60.85 cm. Significant sex-dependent differences in body measurements were observed, with rams averaging 34.45 kg and being 21.18% heavier than wethers. This sexual size dimorphism aligns with previous research [41]. These differences arise from selective pressures related to mating and reproduction, as well as differences in sex chromosomes and hormone secretion [42].

Table 1. Descriptive statistics for BWT (kg) and LBM (cm) across sexes in Sabi sheep of Zimbabwe.

Ewes (*N* = 112)	**BWT**	**BL**	**CD**	**HG**	**RMP**	**WTH**	**HP**	**HW**	**TW**	**PBW**
Mean	30.92	61.47	37.81	77.05	19.75	59.21	60.91	14.91	16.68	11.63
SE	0.65	0.45	0.36	0.66	0.20	0.40	0.34	0.18	0.18	0.17
SD	6.89	4.75	3.76	6.93	2.09	4.21	3.65	1.85	1.93	1.75
CV%	0.09	0.10	0.09	0.09	0.09	0.09	0.09	0.10	0.09	0.09
Rams (*N* = 22)										
Mean	34.45	61.07	42.51	79.04	20.53	62.11	64.48	14.35	16.11	10.47
SE	2.47	1.10	1.06	2.02	0.48	1.21	1.05	0.37	0.59	0.41
SD	11.61	5.14	4.96	9.47	2.24	5.66	4.93	1.75	2.77	1.93
CV%	0.21	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.21

Table 1. (*Continued*).

Wethers (*N* = 39)	**BWT**	**BL**	**CD**	**HG**	**RMP**	**WTH**	**HP**	**HW**	**TW**	**PBW**
Mean	30.38	58.98	41.77	77.92	20.78	61.44	63.94	14.34	15.96	10.69
SE	0.91	0.63	0.69	1.03	0.33	1.00	0.98	0.27	0.26	0.27
SD	5.66	3.91	4.30	6.43	2.03	6.24	6.10	1.70	1.59	1.69
CV%	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
POOLED (*N* = 173)										
Mean	31.23	60.85	39.28	77.48	20.07	60.05	62.01	14.70	16.44	11.26
SE	0.56	0.36	0.34	0.54	0.16	0.38	0.36	0.14	0.15	0.14
SD	7.45	4.70	4.51	7.17	2.13	5.04	4.72	1.81	1.99	1.82
CV%	0.24	0.8	0.11	0.09	0.11	0.08	0.08	0.12	0.12	0.16

Note: BWT = bodyweight, BL = body length, CD = chest depth, HG = heart girth, RMP = rump, WTH = wither height, HH = hip height, HW = hip width, TW = Thurl width, PBW = pin bone width; SE = standard error, SD = standard deviation, CV% = coefficient of variation.

Research indicates that rams and ewes differ in skeletal dimensions and body weight due to natural hormonal differences [43]. Sexual dimorphism becomes more pronounced with maturity, as observed in Santa Ines lambs [44]. Sexual size dimorphism is prevalent in the subfamily Caprinae, which includes goats and sheep [45,46]. The slower growth rates in ewes are attributed to the effects of estrogen on bone growth [47]. The measured values are consistent with previous reports [48–51].

3.2. Correlation coefficients between BWT and LBMs

Tables 2–5 present the correlation coefficients between BWT and various LBMs for ewes, rams, wethers, and the combined dataset. The results indicate strong positive correlations between BWT and most LBMs, suggesting that BWT can be reliably predicted using these measurements. Specifically, HG, BL, and CD emerged as the dominant predictors of BWT, with correlation coefficients ranging from 0.63 to 0.93 across the different sex groups. The correlation coefficients between BWT and LBM were relatively strong, with values ranging from 0.50–0.90 ($P < 0.05$) in rams, 0.45–0.83 ($P < 0.05$) in ewes, 0.37–0.84 ($P < 0.05$) in wethers, and 0.45–0.84 ($P < 0.05$) in the combined dataset (**Tables 2–5**). Notably, the strongest correlations were observed in rams (BL: 0.93, CD: 0.85, HG: 0.85), followed by ewes (HG: 0.83, BL: 0.79, CD: 0.74) ($P < 0.05$) and wethers (HG: 0.84, BL: 0.68, CD: 0.63) ($P < 0.05$). Analyzing the data by sex classes yielded higher correlation values compared to the pooled data.

Our findings suggest that sex-specific correlations provide a more accurate representation of the relationships between BWT and LBM. This is consistent with previous research by [52], which found stronger correlations in males than females. The correlation coefficients reported in this study are higher than those reported in previous studies [53–57]. However, our findings are consistent with previous research that reported strong positive correlations between BWT and LBMs in various sheep breeds [58–61]. Heart girth emerged as a robust predictor of live weight in animals, suggesting that it may be the most effective parameter for estimating BWT. This finding is supported by previous studies on Awassi Crossbred sheep [62] and other breeds [53].

Table 2. Correlation analysis among characteristics of Sabi ewes in Zimbabwe.

TRAIT	BWT	BL	CD	HG	RMP	WTH	HH	TW	HW	PBW
BWT	1									
BL	0.789**	1								
CD	0.740**	0.619**	1							
HG	0.826**	0.670**	0.648**	1						
RMP	0.618**	0.632**	0.483**	0.561**	1					
WTH	0.636**	0.602**	0.534**	0.558**	0.453**	1				
HH	0.692**	0.681**	0.576**	0.602**	0.471**	0.817**	1			
TW	0.515**	0.484**	0.446**	0.406**	0.454**	0.264**	0.385**	1		
HW	0.745**	0.749**	0.578**	0.636**	0.644**	0.511**	0.655**	0.626**	1	
PBW	0.448**	0.582**	0.322**	0.399**	0.489**	0.384**	0.445**	0.461**	0.520**	1

Note: BWT = bodyweight, BL = body length, CD = chest depth, HG = heart girth, RMP = rump height, WTH = wither height, HH = hip height, HW = hip width, TW = Thurl width, PBW = pin bone width; **. Correlation is significant at the 0.01 level (2-tailed). * = Correlation is significant at the 0.05 level (2-tailed).

Table 3. Correlation analysis among characteristics of Sabi rams in Zimbabwe.

TRAIT	BWT	BL	CD	HG	RMP	WTH	HH	HW	TW	PBW
BWT	1									
BL	0.925**	1								
CD	0.853**	0.878**	1							
HG	0.848**	0.899**	0.871**	1						
RMP	0.701**	0.661**	0.660**	0.648**	1					
WTH	0.853**	0.861**	0.749**	0.791**	0.582**	1				
HH	0.855**	0.854**	0.760**	0.757**	0.662**	0.967**	1			
HW	0.804**	0.772**	0.733**	0.753**	0.687**	0.774**	0.812**	1		
TW	0.478*	0.423	0.275	0.432	0.012	0.383	0.346	0.141	1	
PBW	0.719**	0.801**	0.673**	0.637**	0.410	0.709**	0.752**	0.571**	0.484*	1

Note: BWT = bodyweight, BL = body length, CD = chest depth, HG = heart girth, RMP = rump height, WTH = wither height, HH = hip height, HW = hip width, TW = Thurl width, PBW = pin bone width; **. Correlation is significant at the 0.01 level (2-tailed). * = Correlation is significant at the 0.05 level (2-tailed).

Table 4. Correlation analysis among characteristics of Sabi wethers in Zimbabwe.

BWT		BL	CD	HG	RMP	WTH	HH	HW	PBW	TW
BWT	1									
BL	0.684**	1								
CD	0.635**	0.477**	1							
HG	0.836**	0.568**	0.275	1						
RMP	0.624**	0.622**	0.301	0.506**	1					
WTH	0.505**	0.519**	0.344*	0.366*	0.627**	1				
HH	0.614**	0.551**	0.384*	0.495**	0.641**	0.934**	1			
HW	0.561**	0.451**	0.459**	0.574**	0.366*	0.155	0.248	1		
PBW	0.453**	0.199	0.378*	0.389*	0.157	0.212	0.305	0.409**	1	0.
TW	0.369*	0.186	0.300	0.295	0.375*	−0.072	0.013	0.454**	0.427**	1

Note: BWT = bodyweight, BL = body length, CD = chest depth, HG = heart girth, RMP = rump height, WTH = wither height, HH = hip height, HW = hip width, TW = Thurl width, PBW = pin bone width; **. Correlation is significant at the 0.01 level (2-tailed). * = Correlation is significant at the 0.05 level (2-tailed).

Table 5. Correlation analysis of characteristics across combined sex classes of Sabi sheep in Zimbabwe

TRAIT	BWT	BL	CD	HG	RMP	WTH	HH	HW	TW	PBW
BWT	1									
BL	0.774**	1								
CD	0.674**	0.472**	1							
HG	0.827**	0.661**	0.578**	1						
RMP	0.605**	0.561**	0.495**	0.561**	1					
WTH	0.618**	0.532**	0.552**	0.540**	0.531**	1				
HH	0.644**	0.538**	0.598**	0.572**	0.558**	0.890**	1			
HW	0.679**	0.696**	0.429**	0.610**	0.539**	0.374**	0.445**	1		
TW	0.468**	0.440**	0.261**	0.374**	0.312**	0.150*	0.196**	0.525**	1	
PBW	0.457**	0.555**	0.216**	0.397**	0.333**	0.283**	0.308**	0.521**	0.477**	1

Note: BWT = bodyweight, BL = body length, CD = chest depth, HG = heart girth, RMP = rump height, WTH = wither height, HH = hip height, HW = hip width, TW = Thurl width, PBW = pin bone width; **. Correlation is significant at the 0.01 level (2-tailed). * = Correlation is significant at the 0.05 level (2-tailed).

4. Conclusion

This study highlights the importance of sex-specific approaches in breeding programs and management practices for indigenous Sabi sheep, given the observed sexual dimorphism in body measurements and their correlations with body weight. Heart girth emerged as a reliable predictor of body weight across sexes, suggesting its potential use in cost-effective body weight estimation. The findings provide valuable insights for tailored strategies in sheep production and genetic improvement, emphasizing the need for sex-specific prediction equations and further research across different age groups and environmental conditions.

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Institutional review board statement: The animal study protocol was approved by the Matopos Research Academic and Research Committee for Experimental Animals, Bulawayo, Zimbabwe (Project No.: 24-05/10/2023; approval date: 5 December 2023).

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