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Sex specific path coefficient and path analysis of body weight and linear body measurements in indigenous Sabi sheep of Zimbabwe

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Abstract

The utility of correlation analysis in the life sciences is considerably enhanced when the correlation coefficient is further analyzed to elucidate the direct influences of one trait on another, as well as the indirect effects mediated by other significant characteristics. This nuanced understanding is particularly vital in selection programs, where identifying key drivers of desirable traits can inform strategic decision-making. Path coefficient analysis is a statistical technique that decomposes correlation coefficients to quantify the direct and indirect relationships between variables, offering a nuanced understanding of the complex interactions within a system. This study employed path coefficient and path analysis to investigate the relationships between body weight and linear body measurements in indigenous Sabi sheep, categorized by sex. A total of 173 sheep (112 ewes, 22 rams, and 39 wethers) were analyzed, focusing on body weight and its correlations with nine linear measurements. Descriptive statistics and path coefficients were calculated to summarize the data. Correlation analysis was also conducted to examine the relationships among variables. The results revealed significant sexual dimorphism in all traits. Notably, body weight (BW) and linear body measurements exhibited small coefficients of variation in ewes while being large in rams and wethers. Correlation analysis showed that all linear traits were positively correlated ($p < 0.05$) with BW in ewes, rams, and wethers. The correlation ranges between BW and linear body parameters were 0.50-0.90 for rams, 0.45-0.83 for ewes, and 0.37-0.84 in wethers. Specifically, heart girth (HG) had the highest correlation with BW in ewes and wethers, while body length (BL) had the strongest correlation in rams. The results revealed significant direct effects of body length (BL) on body weight in rams, while heart girth (HG) and body length (BL) had the most substantial impacts in ewes. In wethers, heart girth and chest depth were the primary drivers of body weight. Notably, wither height and pin bone width had negative direct effects on body weight in rams, whereas hip width had a negative impact in wethers. No negative direct effects were observed in ewes. This study underscores the importance of body length and heart girth in predicting body weight in indigenous Sabi sheep, providing valuable insights for improving weight estimation, selection, and breeding programs.

Keywords: *Body Weight; Linear Body Measurements; Path Analysis; Indigenous Sabi Sheep; Zimbabwe.*

INTRODUCTION

Indigenous sheep, mainly kept for meat, are vital to many Zimbabwean farmers. The local sheep population significantly increased from 548,000 to 700,000 between 2020/2021 (Sunday Mail, 2025). Zimbabwe's sheep categories include exotic, indigenous, and hybrid. The native Sabi sheep, a fat-tailed variety, is widely distributed, valued for its hardiness, fertility, and disease resistance, and weighs between 35-45 kg (Ward, 1979; Assan et al., 2024).

Numerous studies have explored predicting sheep body weight from various body traits in livestock and poultry (Birteeb et al 2024; Ormachea et al 2023; Tırınk, et al 2023;

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Fonseca et al 2021). Biometric measurements provide valuable insights into breed growth, environmental influences, and feeding factors. However, traditional methods relying on correlations and regression analyses have limitations. To improve body weight estimates, more comprehensive models accounting for complex relationships between direct and indirect causal factors are necessary.

Path coefficient analysis is a statistical technique used to examine direct and indirect relationships between linear body measurements (LBM) and body weight (BWT) (Rotimi, 2024.). This approach has been applied in various animal studies (Kebede et al. 2022; Bila et al. 2021; Hlokoe and Tyasi 2021; Liswaniso et al 2020)). By using multiple regression models, path coefficient analysis identifies key factors influencing BWT and quantifies their effects. Despite its widespread use, path analysis has limited application in estimating BWT from LBM in Zimbabwe's indigenous sheep. This study aims to address this knowledge gap by assessing direct and indirect effects between BWT and LBM in indigenous Sabi sheep using path analysis, comparing different sex groups.

MATERIALS AND METHODS

Ethical Approval

The study was approved by the Lupane State University Animal Research Ethics Committee (Projects 2023).

Experimental Site Overview

This research was conducted at the Matopos Research Station in Bulawayo, Zimbabwe (22.23°S, 31.30°E), which experiences a distinct seasonal pattern (Matopos Research Station, 2003). The area is characterized by a dry season from April to October and a rainy season from November to March, with average annual rainfall below 446.8 mm (Assan, 2023). The region's climate is marked by high temperatures, ranging from 21.6°C to 11.4°C during the hottest months, and limited rainfall (<450 mm) (Hagreveas et al., 2004; Homann et al., 2007). The research site is a rangeland featuring sweet veld vegetation, which provides high-quality nutrition for ruminants (Van Rooyen et al., 2007). Data collection took place in June 2023.

Study Approach and Measurement Procedures

This study employed a cross-sectional design, where individual animal observations were made once. The research focused on evaluating the direct and indirect effects of linear body measurements (LBM) across various sexes (ewes, rams, wethers, and combined data) of indigenous Sabi sheep. A total of 173 sheep (112 ewes, 22 rams, and 39 wethers) were used for data collection. The management practices of the experimental flock are described in detail by Assan et al. (2024).

Measurement protocols for BWT and LBM

Body weight was recorded in kilograms using the balance weighing scale, while LBMs were taken in centimeters using a calibrated tape, ruler, and clippers, also following FAO guidelines (FAO, 2012). The LBMs assessed included body length, chest depth, heart girth, rump, wither height, hip height, hip width, thurl width, and pin bone width. To ensure accuracy, measurements were taken with minimal influence from the animal's posture, and all animals were positioned consistently. 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 Yilmaz et al. (2013). Circumference was measured with a flexible calibrated tape, whereas calipers were used for length and width.

Heart Girth (HG):

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):

Body length 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 (pin bone width) (HW):

Hip width 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 (RH):

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

Fore cannon bone length (CB):

The length of the lower leg bone in hoofed mammals, from the hock to the fetlock, is closely related to the development of other bones. The fore cannon bone is commonly used to estimate this length. Measurement involves bending the front leg at the pastern and knee, using calipers or measuring tape, and standardizing measurements using the same bony protuberances.

Chest Depth (CD):

Chest depth measures the distance from the backbone at the shoulder (standardize on one of the vertical processes of the thoracic vertebrae) to the brisket between the front legs.

Height at withers (HH):

The distance from a platform to the withers of an animal can be measured using a special stick with two vertical arms. The sheep should stand on all four legs, with equal weight distribution. The vertical arm should be at a right angle to the platform, and the distance can be measured with a measuring tape or scale.

Thurl Width (TW):

The thurl is a flat pelvis part of the animal's pelvis, located halfway between the hips and pins. It is the external manifestation of the greater trochanter of the femur and is used to measure a cow's body condition score or fatness level. The thurl is the same on small ruminants, dairy and beef animals indicating the overall health and fatness.

Hip Width (HW):

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Hip width is the distance between the two outermost points on your hips, measured using a tape measure parallel to the ground and placed across an animals' hips.

Data Analysis

Descriptive statistics, including means, standard deviations (SD), and coefficients of variation (CV), were computed for body weight and morphological traits. To examine the relationships between variables, path coefficient analysis was performed using SPSS (2010). This approach enabled a direct comparison of the relative importance of independent variables in explaining the variation in the dependent variable. Following Mendes et al. (2005), path coefficient analysis was employed to quantify the relationships between explanatory variables (X) and the response variable (Y). The path coefficient (Pyxi) was calculated using the formula:

Pyxi = biSxi / Sy

Where:

Pyxi = path analysis coefficient from Xi to Y (for each linear body measurement: BL, CD, HG, RMP, WTH, HH, HW, TW, PBW)

bi = partial regression coefficient

Sxi = standard deviation of Xi

Sy = standard deviation of Y

To examine the indirect influences of linear body measurements on body weight (BW), the following formula was used:

IEyxi = rxixj / Pyxj

Where:

IEyxi = indirect effect of linear body measurements on BW via a direct effect

rxiyj = correlation coefficient between the ith and jth linear body measurements

Pyxj = path analysis coefficient indicating the direct effect of the jth linear body measurement on BW.

RESULTS AND DISCUSSION

Table 1 presents the descriptive statistics for body weight (BW) and linear body measurements (LBMs), including body length (BL), chest depth (CD), heart girth (HG), rump (RMP), wither height (WTH), hip height (HH), hip width (HW), thurl width (TW), and pin bone width (PBW) for ewes, rams, and wethers. The rams exhibited significantly higher mean values across all measurements compared to ewes. On average, the researchers recorded rams weighing 34.45 kg, while ewes and wethers weighed 30.92 kg and 30.38 kg, respectively. The rams were 21.18% heavier than wethers. These findings align with Kunene et al. (2007) observations on the Zulu sheep breed. This may be attributed the pronounced effect of sex on growth to physiological characteristics, the endocrine system, and hormone secretion, particularly sexual hormones (Gamasaee et al., 2010). The heart girth (HG) had the highest mean value of 84.69 cm, followed by body length (BL) with an average value of 79.14 cm. In contrast, hip width (HW) had the lowest mean value of 14.60 cm. The coefficient of variation ranged from 7.35% to 13.45%. The low standard deviation values indicated that the predicted values closely approximated the actual values.

Table 1: Descriptive statistics for bodyweight (kg) and body linear measurements (cm) in different 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
Wethers (N=39)										
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

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CV%	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16

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.

Table 2 presents the direct and indirect effects of LBM on body weight in indigenous Sabi ewe sheep. The correlation coefficient (r) between body weight (BWT) and heart girth (HG) in this study was the highest (r = 0.8263; p<0.01), with a direct effect on body weight path analysis (r = 0.3831; p<0.01). The indirect effects are primarily mediated through body length (BL), suggesting that body weight can be enhanced through direct selection for BL. Additionally, chest depth (CD) exhibits a significant direct effect (0.1891; p<0.01) and an indirect effect on body weight of 0.5513, predominantly mediated via HG. Conversely, the direct effects of rump width (RMP) (0.0299), withers height (WTH) (0.0821), thurl width (TW) (0.0615), pin bone width (PBW) (-0.0566), and hip height (HH) (0.0297) were small and positive. The data indicate that indirect effects for most LBM were greater than direct effects, except for BL, CD, and HG.

Table 3 reveals the direct and indirect effects of LBM on body weight in ram sheep. The table indicates that the highest direct and positive contribution to body weight was made by BL, followed by HH, with values of 0.046, 0.3112, and 0.3068; p<0.01, respectively. Furthermore, the highest correlation with BWT was observed with BL, followed by CD, with r values of 0.9023 and 0.8600, respectively. The indirect effects of BL (0.3977) were primarily mediated via CD, and 0.5809 was realized via BL. The table 3 shows that the lowest direct effect (-0.0097 on BWT) was recorded along with its indirect effects. A value of 0.6742 was realized via BL, and most of the indirect effects of the variables were mediated via BL. In summary, it can be concluded that BL, CD, and HG are crucial for accurately predicting the body weight of rams in Sabi sheep in Zimbabwe.

Table 4 displays the direct and indirect effects of LBM on body weight in wether sheep. The highest correlation value with BWT was observed for HG, followed by the indirect effect of BL (r=0.8363 vs. 0.6842; p<0.01), respectively. HG exhibited a direct effect on the body weight path coefficient of 0.6323; p<0.01. Its indirect effects, 0.2039; p<0.01, are primarily mediated via CD, indicating that body weight can be improved through direct selection for CD. This is followed by CD, which has a significant direct effect of 0.4046 (p<0.01) and an indirect effect on body weight of 0.2303, predominantly mediated via HG. Conversely, the direct effects of BL (0.0564; p<0.01), TW (-0.0875), and PBW (0.0420) were not significant. The data suggest that, generally, indirect effects were greater than direct effects, except for CD and HG, implying that the observed variations were mainly due to indirect effects. The positive correlation coefficient between the variable and BWT found in the current investigation was largely attributed to the indirect effects of body length and chest girth.

Path coefficient analysis is a statistical technique that decomposes correlation coefficients to quantify the direct and indirect relationships between variables, providing a nuanced understanding of the complex interactions within a system (Norris et al 2025). The path analysis revealed that for most traits, indirect effects outweighed direct effects, except for body length (BL) and hip width (HW) in rams, and chest depth (CD) and heart girth (HG) in wethers, which exhibited higher direct impacts on body weight (BWT). Similar findings regarding direct effects were reported by Jawasrey and Khasawney (2007) and Kunene et al. (2009) in studies on Awassi lambs in Jordan and Zulu (Nguni) sheep in KwaZulu-Natal, respectively.

Our results suggest that HG and BL are valuable for estimating BWT in female indigenous Sabi sheep. Previous studies employing path analysis have demonstrated a link between BWT and linear body measurements (LBM) in various sheep breeds (Temoso et al 2017; Yunusa et al 2014; Yakubu, 2010). For instance, Yakubu (2011), Yakubu (2012), and Mohammed (2012) found that body length had the greatest direct influence on BWT in red Sokoto goats. Similarly, Yakubu and Mohammed (2012) reported a positive and direct impact of HG on BWT, while Vargas et al. (2007) found that HG, BL, and head width had positive and direct effects on BWT.

Consistent with these findings, the present study revealed that BL and CD contributed directly to BWT in ewes, while CD was a significant direct contributor to BWT in rams and wethers. This is in agreement with Egena et al. (2015), who reported similar findings in indigenous Nigerian sheep. However, the present study's results differ from those of Ogah et al. (2009), who found that body length directly affected BWT only in females. In contrast, the current study found that body length had the highest direct effect on BWT in rams, while wither height had the highest indirect effect on BWT via body length.

Notably, the indirect effect of body length on body weight was greater than its direct effect, consistent with findings by Cankaya and Abaci (2012). They reported that although the direct effect of body length was relatively small, its indirect effect was significant, primarily mediated through chest girth and wither height. Similar patterns were observed in the present study, where wither height's indirect effects on body weight in ewes were primarily via body length and heart girth. However, in contrast to Yakubu and Mohammed (2012), who found that wither height was not significantly associated with body weight, the current study revealed a small positive direct effect of wither height in ewes, but a negative direct effect in rams. The strong correlation between body weight and other variables observed in this study can be largely attributed to the indirect effects of body length (in rams), heart girth (in ewes), and chest depth (in wethers).

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Table 2. Direct and indirect effects of morphological traits on the bodyweight of ewes in Sabi sheep in Zimbabwe

Class	Trait	Correlation with BWT	Direct Effects	Indirect Effects									Total
Ewes				BL	CD	HG	RMP	WTH	HH	HW	TW	PBW	
	BL	0.789	0.236		0.117	0.026	0.019	0.0494	0.0202	0.0941	0.030	0.033	0.553
	CD	0.740	0.189	0.146		0.246	0.0145	0.0439	0.018	0.073	0.027	-0.018	0.551
	HG	0.826	0.383	0.158	0.122		0.168	0.045	0.017	0.079	0.025	0.023	0.443
	RMP	0.618	0.029	0.149	0.091	0.215		0.037	0.014	0.080	0.029	0.028	0.588
	WTH	0.636	0.082	0.142	0.101	0.213	0.013		0.024	0.064	0.016	0.021	0.5534
	HH	0.696	0.0297	0.160	0.108	0.230	0.014	0.067		0.082	0.023	0.025	0.6619
	HW	0.745	0.1256	0.176	0.109	0.244	0.019	0.042	0.019		0.038	0.029	0.6191
	TW	0.515	0.0615	0.113	0.084	0.155	0.013	0.021	0.011	0.078		0.026	0.4534
	PBW	0.448	0.0566	0.137	0.060	0.152	0.014	0.031	0.013	0.065	0.028		0.5042

Note: WT= 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,

Table 3. Direct and indirect effects of morphological traits on the body weight in rams in Sabi sheep in Zimbabwe

Class	**Trait**	**Correlation with BWT**	**Direct Effects**	**Indirect Effects**									**Total**
Rams			**-**	**BL**	**CD**	**HG**	**RMP**	**WTH**	**HH**	**HW**	**TW**	**PBW**	
	BL	0.9023	0.5046		0.2443	-0.2644	0.1287	-0.0076	0.0292	0.2345	0.1337	-0.1006	0.3977
	CD	0.8600	0.2790	0.4418		-0.2571	0.1338	-0.0061	0.0259	0.2340	0.0941	-0.0855	0.5809
	HG	0.8458	-0.2933	0.4541	0.2443		0.1293	-0.0067	0.0259	0.2358	0.1384	-0.0810	1.1391
	RMP	0.7383	0.1952	0.3327	0.1912	-0.1946		-0.0042	0.0224	0.2276	0.0225	-0.0546	0.5431
	WTH	0.6645	-0.0097	0.3954	0.1751	-0.2034	0.0833		0.0303	0.1762	0.0955	-0.0781	0.6742
	HH	0.8344	0.0341	0.4321	0.2120	-0.2232	0.1282	-0.0087		0.2444	0.1100	-0.0945	0.8004
	HW	0.8313	0.3121	0.3790	0.2092	-0.2210	0.1424	-0.0055	0.0267		0.0611	-0.0727	0.8313
	TW	0.5029	0.3068	0.2199	0.0856	-0.1325	0.0143	-0.0030	0.0122	0.0622		-0.0625	0.1961
	PBW	0.7213	-0.1250	0.4062	0.1908	-0.1904	0.0852	-0.0061	0.0257	0.1816	0.1533		0.8463

Note: WT= 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

Table 4.: Direct and indirect effects of morphological traits on the body weight in wethers in Sabi sheep in Zimbabwe

Class	**Trait**	**Correlatio**	**Direct**	**Indirect Effects**	**Total**

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		n with BWT	Effects										
Wethers			-	**BL**	**CD**	**HG**	**RMP**	**WTH**	**HH**	**HW**	**TW**	**PBW**	
	BL	0.6842	0.0564		0.1928	0.3592	0.1001	-.0.0455	0.0592	-0.0490	0.0026	0.0084	0.6278
	CD	0.6348	0.4046	0.0269		0.1736	0.0484	-0..0301	0.0412	-0.0498	0.0042	0.0159	0.2303
	HG	0.8363	0.6323	0.0320	0.1111		0.0814	-0.0320	0.0532	-0.0623	0.0041	0.0163	0.2039
	RMP	0.6240	0.1609	0.0351	0.1218	0.3201		0.0549	0.0688	-0.0397	0.0053	0.0066	0.4631
	WTH	0.5046	0.0875	0.0293	0.1392	0.2314	0.1009		0.1003	-0.0169	-0.001	0.0089	0.5921
	HH	0.6143	0.1074	0.0311	0.1552	0.3132	0.1032	-0.0818		-0.0269	0.0002	0.0128	0.5069
	HW	0.5609	-0.1085	0.0255	0.1857	0.3628	0.0588	-0.0136	0.0266		0.0064	0.0174	0.6694
	TW	0.3688	0.0141	0.0105	0.1214	0.1862	0.0603	0.0063	0.0014	-0.0493		0.0179	0.3548
	PBW	0.4523	0.0420	0.0112	0.1528	0.2457	0.0253	-0.0185	0.0327	-0.0444	0.0060		0.4107

WT= 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

CONCLUSION

Path analysis revealed that heart girth (HG), body length (BL), and chest depth (CD) are the primary predictors of body weight in indigenous Sabi sheep, with significant direct effects across sexes. Notably, HG had the most substantial impact on body weight in ewes and wethers, while BL and CD were dominant in rams and wethers, respectively. Furthermore, although other predictor variables showed similar path coefficients and high correlations with body weight, their indirect effects were largely mediated through HG, BL, and CD. These findings suggest that HG, BL, and CD can be used as selection criteria to improve live body weight in breeding programs, particularly in resource-limited settings with limited record-keeping capabilities.

Author contributions

Conceptualization and writing—original draft preparation, DA, NA & MN; methodology, MN; formal analysis, MM and MP provide resources—review and editing, DA, NA and MN; 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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Statement of animal rights

The study was approved by the Academic Research Committee of Experimental Animals, Lupane State University, Lupane, Zimbabwe.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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