

ORIGINAL ARTICLE

## Correlation and path analysis of body weight and biometric traits of Nguni cattle breed

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### ABSTRACT

**Objective:** This work was conducted to examine the association between body weight (BW) and biometric traits viz. head width (HW), head length (HL), ear length (EL), body length (BL), rump height (RH), withers height (WH), sternum height (SH), rump width (RW), and heart girth (HG) and to determine the direct and indirect effects of biometric traits on BW.

**Materials and Methods:** Sixty female and twenty male Nguni cattle between the ages of one to four years were used. Pearson correlation and path analysis were used for data analysis.

**Results:** Correlation results recognized that BW had a positive highly significant correlation with RW ( $r = 0.70^{**}$ ), RH ( $r = 0.90^{**}$ ), HG ( $r = 0.90^{**}$ ), SH ( $r = 0.90^{**}$ ), and WH ( $r = 0.93^{**}$ ) in male, whereas SH ( $r = 0.34^{**}$ ), WH ( $r = 0.55^{**}$ ), RH ( $r = 0.70^{**}$ ), and HG ( $r = 0.76^{**}$ ) had a positive highly significant correlation with BW of female Nguni cattle. Path analysis showed that RW (13.35) had the highest direct effect, whereas SH had an indirect effect on BW of male Nguni cattle. In female Nguni cattle, RH (4.87) had the highest direct effect, whereas HL had an indirect effect on BW.

**Conclusion:** Association findings suggest that improvement of RW, RH, HG, SH, HG, and WH might result in the increase in BW of Nguni cattle. Path analysis results suggest that RW and RH might be used as a selection criterion during breeding to increase BW of Nguni cattle. The results of the current study might be used by cattle farmers to estimate BW using biometric traits.

### ARTICLE HISTORY

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### KEYWORDS

Direct effect, indirect effects, rump height, rump width, sternum height.



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### Introduction

Nguni cattle breed originated from North Africa and an admixture of humpless zebu (*Bos taurus*) and humped zebu (*Bos indicus*) [1,2]. This breed is one of the largest indigenous cattle breeds in South Africa with multi-color features (red, black, white, gray brown, and brindle) [1]. According to Sanarana et al. [1], this breed is originated in South Africa and was brought by Khoi-Khoi.

Path analysis is a mathematical tool which is utilized to examine the cause-effect relationship between independent and dependent variables [3]. Norris et al. [4] indicated that this mathematical tool is the extension of multiple regression models and was developed by Wright [5]. Path analysis computes the direct and indirect effects of independent traits on dependent traits [6,7]. Previous studies indicated that path analysis is a useful technique in

animal breeding for estimation of body weight (BW) using biometric traits in chickens [8], turkey [6], goats [4], sheep [9], and pigs [10]. However, to the best of our knowledge, limited literature documented about the estimation of BW from biometric traits using path analysis technique in cattle. Therefore, the objectives of this work were: 1) to determine the association between BW and biometric traits viz. head width (HW), head length (HL), ear length (EL), body length (BL), rump height (RH), withers height (WH), sternum height (SH), rump width (RW), and heart girth (HG) using correlation analysis, 2) to construct a mathematical equation for prediction of BW from biometric traits by multiple regression analysis, and 3) to reveal direct and indirect effects of biometric traits on BW using path analysis. The study will help cattle farmers for the selection of useful biometric traits during breeding to improve BW.

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## Materials and Methods

### Study area

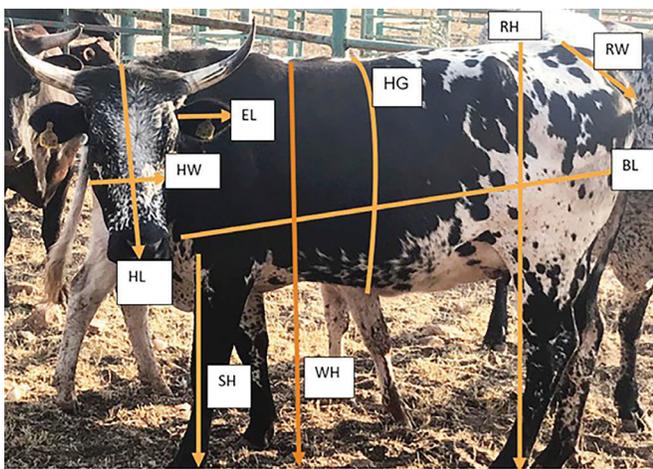
The work was carried at the experimental farm of the University of Limpopo, South Africa as explained by Alabi et al. [11].

### Experimental animals and management

Nguni cattle at the ages of one to four years were used in the study. A total of eighty (80) (males = 20 and females = 60) Nguni cattle were used; however, sick and pregnant animals were excluded to achieve accurate data. Nguni cattle were kept under an extensive system. Females and males were kept in separate kraals. The cattle were released to graze in the morning and then kraaled later in the afternoon.

### Data collection

BW was measured and nine biometric traits were taken for each cattle. The balance weighing scale was employed to measure individually live weight for both sexes. Measuring tape which was calibrated in centimeters (cm) was used to measure all the biometric traits as shown in Figure 1. All the measured traits were measured as described by Lukuyu et al. [12]. Briefly, EL: space from the position of attachment to the tip of the ear. BL: measured as the space from the highest position of shoulders to the pin bone. HW: measured as the space between the edges of the head. RH: measured as the space from the surface of a platform to the rump. HL: measured from the temple of the head to the tip of the horn. HG: measured as the distance from the body circumference at a position immediately posterior to the



**Figure 1.** Nguni cattle breed displaying biometric traits measured for the study. HW = head width, HL= head length, EL= ear length, BL= body length, RH = rump height, WH = withers height, SH = sternum height, RW = rump width and HG = heart girth.

front leg and shoulder and perpendicular to the body axis. SH: measured as the vertical position from the lower tip of the sternum to the ground as the animal standing. RW: measured as the position between two tuber coxae. WH: measured as a vertical position between the ground and the apex of the tourniquet, immediately behind the hump, on the top of the scapula. We decided to use the same person for all the measurements to avoid differences in measurements between individuals.

### Data analysis

The descriptive statistics including mean, standard error, and coefficient of variation (CV) of BW and independent variables were calculated and boxplot was plotted using the Statistical Analysis System [13]. The simple correlation was used to determine the association between BW and biometric traits. Multiple regression was used to establish a formula to predict the BW using biometric traits. The below multiple linear regression was adopted:

$$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_8 X_8 + b_9 X_9$$

where

Y = dependent variable (BW),

a = intercept,

$b_1 - b_9$  = coefficient of regression, and

$X_1 - X_9$  = independent variables (biometric traits).

The standardized partial regression coefficient used as path coefficients (beta weight) was computed from the multiple regression analysis. This value was used as a direct effect of the biometric traits on BW. The path analysis procedure was conducted as described by Mendes et al. [6]. Briefly, path analysis was computed as follows:

$$Pyxi = \frac{biSxi}{Sy}$$

where

$Pyxi$  = path analysis coefficient from  $X_i$  to  $Y$  ( $i = HW, HL, EL, BL, RH, WH, SH, RW, HG$ ),

$b_i$  = partial regression coefficient,

$Sxi$  = standard deviation ( $\sigma$ ) of  $X_i$  and

$Sy = \sigma$  of  $Y$ .

Remarkably of the path analysis coefficient was tested using  $t$ -statistic in multiple regression analysis. Indirect influences of biometric traits on BW through direct effect were calculated as follows:

$$IEyxi = r_{ixij} Pyxj$$

where

$IEyxi$  = direct effect of biometric traits via a direct effect on body weight,

$r_{ixij}$  = correlation coefficient ( $r$ ) between  $i$ th and  $j$ th biometric traits, and

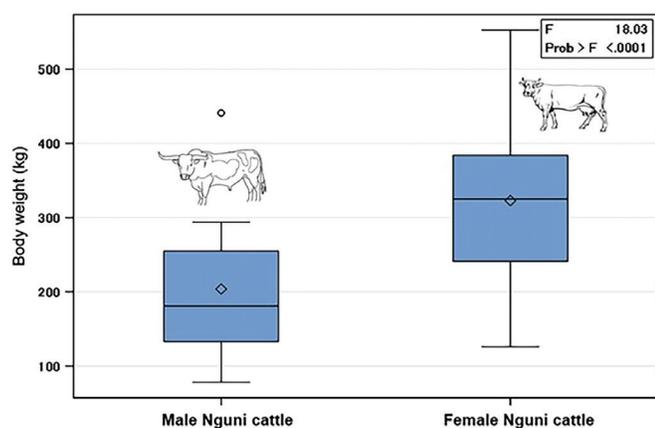
Pyxj = path analysis coefficient that indicates the direct effect of jth biometric trait on body weight.

Statistical Package for Social Sciences (SPSS) [14] software was employed for computing of simple correlation, multiple regression, and path coefficient analysis.

## Results

Boxplot (Fig. 2) shows the summary of BW distribution of Nguni cattle bull and cow. The results indicate that there was a remarkably at ( $p < 0.001$ ) probability level across both Nguni cattle sexes. The female had a higher BW than the male. Boxplot further shows the minimum, 25th percentile (first quartile), median, 75th percentile (third quartile), and maximum values of BW for both sexes. In the boxplot, male BW showed minimum values of less than 100 kg, first quartile, and median of less than 200 kg, whereas third quartile had a maximum of less than 300 kg, respectively. Meanwhile, boxplot of female BW revealed minimum values greater than 100 kg, first quartile greater than 200 kg, median greater than 300 kg, third quartile less than 400 kg, and the maximum greater than 500 kg. The boxplot summary suggests that the data regarding BW in male Nguni cattle had one outlier which was greater than 400 kg, whereas female Nguni cattle data were well distributed short of outliers.

The summary of BW and biometric traits (HW, HL, EL, BL, RH, WH, SH, RW, and HG) is presented in Table 1. The BW mean numerical values of female Nguni cattle ( $322.94 \text{ kg} \pm 15.61 \text{ kg}$ ) were higher than those of male Nguni cattle ( $203.86 \text{ kg} \pm 22.53 \text{ kg}$ ). Descriptive statistics of linear body measurement traits indicated that the female had higher mean numerical values in all the traits except for HW ( $22.05 \text{ cm} \pm 0.20 \text{ cm}$ ), HL ( $56.14 \text{ cm} \pm 1.16 \text{ cm}$ ), and WH ( $62.30 \pm 2.82$ ), respectively. The CV was computed by dividing the mean with the standard deviation and the



**Figure 2.** Boxplot indicating the median, minimum, maximum, 25th, and 75th percentile values of BW of Nguni cattle breed.

results showed a range of 0.10%–50.65% in males and 0.08%–52.33% in females.

Pearson's correlation was employed to determine the association between BW and biometric traits of Nguni cattle breed for both sexes (Table 2). The results above diagonal line show correlation results of male Nguni cattle. The findings indicated that BW had a positive highly significant correlation with RW ( $r = 0.70^{**}$ ), RH ( $r = 0.90^{**}$ ), HG ( $r = 0.90^{**}$ ), SH ( $r = 0.90^{**}$ ), and WH ( $r = 0.93^{**}$ ), with a negative highly significant correlation with HL ( $r = -0.51^{**}$ ) and not significant with HW ( $r = 0.31^{ns}$ ) in turn. These results further showed that EL had a negative highly association with BL ( $r = -0.67^{**}$ ) and HL ( $r = -0.71$ ). However, phenotypic correlation results of female Nguni cattle below the diagonal line revealed that BW had a positive highly significant correlation with four biometric traits (SH,  $r = 0.34^{**}$ , WH,  $r = 0.55^{**}$ , RH,  $r = 0.70^{**}$ , and HG,  $r = 0.76^{**}$ ) and positive significant association with HW ( $r = 0.26^*$ ) and BL ( $r = 0.29^*$ ) but not significantly correlated with HL ( $r = 0.19^{ns}$ ), EL ( $r = (-0.06^{ns})$ , and RW ( $r = -0.10^{ns}$ ), respectively. Again, the results also indicated that EL had a negative high association with BL ( $r = -0.67^{**}$ ) and HL ( $r = -0.71$ ).

## Establishment of preliminary regression equations

Preliminary equations were computed by multiple regression analysis (Tables 3 and 4). In male Nguni cattle (Table 3), RW (13.35) had the highest single contribution and to the BW of female Nguni cattle ( $p < 0.05$ ) followed by HL (12.44) with  $R^2 = 0.94$  and  $MSE = 1,134.77$ . These findings show that 94% of the variation in BW was explained by this model. Multiple regression equation was developed as

**Table 1.** Descriptive statistics for BW and linear body measurements of the Nguni cattle breed.

TRAITS	Male (n = 20)		Female (n = 60)	
	MEAN $\pm$ SE	CV (%)	MEAN $\pm$ SE	CV (%)
BW (kg)	203.86 $\pm$ 22.53	50.65	322.94 $\pm$ 15.61	33.83
HW (cm)	22.05 $\pm$ 0.20	4.17	21.73 $\pm$ 0.15	4.97
HL (cm)	56.14 $\pm$ 1.16	9.44	53.90 $\pm$ 1.03	13.32
EL (cm)	12.90 $\pm$ 0.41	14.50	14.55 $\pm$ 0.48	22.89
BL (cm)	147.10 $\pm$ 11.37	35.41	210.24 $\pm$ 15.72	52.33
RH (cm)	115.71 $\pm$ 2.09	8.28	127.49 $\pm$ 1.47	8.08
WH (cm)	62.30 $\pm$ 2.82	11.76	52.8 $\pm$ 1.83	10.74
SH (cm)	65.76 $\pm$ 1.40	0.10	68.41 $\pm$ 0.74	0.08
RW (cm)	41.04 $\pm$ 0.97	0.10	42.33 $\pm$ 0.63	0.10
HG (cm)	45.81 $\pm$ 4.11	12.08	50.3 $\pm$ 3.27	12.44

BW = body weight, HW = head width, HL = head length, EL = ear length, BL = body length, RH = rump height, WH = withers height, SH = sternum height, RW = rump width, HG = heart girth, SE = Standard error and CV = coefficient of variance.

**Table 2.** Phenotypic correlation among traits male above diagonal and female below diagonal.

TRAITS	BW	HW	HL	EL	BL	RH	WH	SH	RW	HG
BW (kg)		0.3 <sup>ns</sup>	-0.51**	0.44*	0.43*	0.90**	0.93**	0.90**	0.70**	0.90**
HW (cm)	0.26*		-0.04 <sup>ns</sup>	0.09 <sup>ns</sup>	-0.17 <sup>ns</sup>	0.35 <sup>ns</sup>	0.32 <sup>ns</sup>	0.37*	0.33 <sup>ns</sup>	0.20 <sup>ns</sup>
HL (cm)	0.19 <sup>ns</sup>	0.16 <sup>ns</sup>		-0.69**	0.16 <sup>ns</sup>	-0.41*	-0.61**	-0.63**	-0.82**	-0.53**
EL (cm)	-0.06 <sup>ns</sup>	-0.03 <sup>ns</sup>	-0.71**		0.02 <sup>ns</sup>	0.52**	0.57**	0.62**	0.40*	0.56**
BL (cm)	0.29*	0.17 <sup>ns</sup>	0.80**	-0.67**		0.54**	0.37*	0.29 <sup>ns</sup>	-0.08 <sup>ns</sup>	0.58**
RH (cm)	0.70**	0.36**	0.55**	-0.31*	0.59**		0.95**	0.92**	0.50*	0.93**
WH (cm)	0.55**	0.41**	0.21 <sup>ns</sup>	-0.07 <sup>ns</sup>	0.32*	0.57**		0.93**	0.68**	0.94**
SH (cm)	0.34**	0.08 <sup>ns</sup>	0.22 <sup>ns</sup>	-0.10 <sup>ns</sup>	0.15 <sup>ns</sup>	0.43**	0.35**		0.66**	0.90**
RW (cm)	-0.10 <sup>ns</sup>	-0.17 <sup>ns</sup>	-0.20 <sup>ns</sup>	0.34**	-0.30*	-0.19 <sup>ns</sup>	-0.04 <sup>ns</sup>	-0.12 <sup>ns</sup>		0.57**
HG (cm)	0.76**	0.25*	0.41**	-0.13 <sup>ns</sup>	0.45**	0.74**	0.57**	0.48**	-0.12 <sup>ns</sup>	

BW = body weight, HW = head width, HL = head length, EL = ear length, BL = body length, RH = rump height, WH = withers height, SH = sternum height, RW = rump width, HG = heart girth, ns = not significant. \* Significant ( $p < 0.05$ ) and \*\* Significant ( $p < 0.01$ ).

**Table 3.** Multiple linear regression analysis for males.

Regression parameters	Biometric traits								
	HW	HL	EL	BL	RH	WH	SH	RW	HG
Coefficient (B)	-13.10	12.44	8.09	0.58	-6.92	8.53	11.22	13.35	-1.82
SE	12.69	5.14	9.17	0.45	5.88	4.12	5.41	4.72	2.28
p-value	0.32	0.03	0.40	0.23	0.26	0.06	0.06	0.02	0.44

Intercept (a) = -1,555.22, Coefficient of determination ( $R^2$ ) = 0.94, MSE = 1,134.77

HW = head width, HL = head length, EL = ear length, BL = body length, RH = rump height, WH = withers height, SH = sternum height, RW = rump width and HG = heart girth, SE = Standard error and MSE = Mean square error.

**Table 4.** Multiple linear regression analysis for females.

Regression parameters	Biometric traits								
	HW	HL	EL	BL	RH	WH	SH	RW	HG
Coefficient (B)	-1.87	-4.63	-5.18	-0.10	4.87	0.82	-1.76	0.20	2.67
SE	10.45	2.54	4.95	0.17	1.70	1.04	2.27	2.39	0.70
p-value	0.86	0.08	0.30	0.54	0.01	0.43	0.44	0.93	0.00

Intercept (a) = -385.10, Coefficient of determination ( $R^2$ ) = 0.69, MSE = 457.04

HW = head width, HL = head length, EL = ear length, BL = body length, RH = rump height, WH = withers height, SH = sternum height, RW = rump width, HG = heart girth, SE = Standard error and MSE = Mean square error.

$$BW = -385.10 - 13.10 HW + 12.44 HL + 8.09 EL + 0.58 BL - 6.82 RH + 8.53 WH + 11.22 SH + 13.35 RW - 1.82 HG$$

HW, EL, BL, RH, WH, SH, and HG were not statistically significant ( $p > 0.05$ ) in the model.

In female Nguni cattle (Table 4), the results indicated that RH (4.87) had the highest single contribution to BW ( $p < 0.05$ ) followed by HG (2.67) with a coefficient of determination ( $R^2$ ) value of 0.69 and mean square error (MSE) of 457.04. This point out that 69% of the variations in BW was explained by the equation. The regression model was established as

$$BW = -385.10 - 1.87 HW - 4.63 HL - 5.18 EL - 0.10 + 4.87 RH + 0.82 WH - 1.76 SH + 0.20 RW + 2.67 HG$$

The findings acknowledged that HW, HL, EL, BL, WH, SH, and RW were unremarkably ( $p > 0.05$ ) in the model.

#### Direct and indirect influences of biometric traits

Regression coefficient (B) value from multiple regression analysis was used as a direct influence of biometric traits on BW and an indirect effect was computed using the path analysis procedure. Path analysis findings are shown in Tables 5 and 6. Table 5 indicates the direct and indirect effects of biometric traits on BW of male Nguni cattle. The

**Table 5.** Path coefficient analysis of body measurements traits and BW of male Nguni cattle.

Linear body measurement Traits	Correlation coefficient with body weight	Direct effect	Indirect effects								
			HW	HL	EL	BL	RH	WH	SH	RW	HG
HW (cm)	0.31 <sup>ns</sup>	-13.10 <sup>ns</sup>		-0.50	0.73	-0.10	-2.42	2.73	4.15	4.41	-0.36
HL (cm)	-0.51 <sup>**</sup>	12.44 <sup>*</sup>	0.52		-5.58	0.09	2.84	-5.21	-7.07	-10.95	0.97
EL (cm)	0.44 <sup>*</sup>	8.09 <sup>ns</sup>	-1.18	-8.58		0.01	-3.60	4.86	6.96	5.34	-1.02
BL (cm)	0.43 <sup>*</sup>	0.58 <sup>ns</sup>	2.23	1.99	0.16		-3.74	3.16	3.25	-1.07	-1.06
RH (cm)	0.90 <sup>**</sup>	-6.92 <sup>ns</sup>	-4.59	-5.10	4.20	0.31		8.11	10.32	6.68	-1.70
WH (cm)	0.93 <sup>**</sup>	8.53 <sup>ns</sup>	-4.19	-7.59	4.61	0.21	-6.57		0.93	9.08	-1.71
SH (cm)	0.90 <sup>**</sup>	11.22 <sup>ns</sup>	-4.85	-7.84	5.01	0.17	-6.36	7.94		8.81	-1.64
RW (cm)	0.70 <sup>**</sup>	13.35 <sup>*</sup>	-4.32	-10.20	3.23	-0.05	-3.46	5.80	7.40		-1.04
HG (cm)	0.90 <sup>**</sup>	-1.82	-2.62	-6.59	4.53	0.34	-6.43	8.02	10.10	7.61	

HW = head width, HL = head length, EL = ear length, BL = body length, RH = rump height, WH = withers height, SH = sternum height, RW = rump width, HG = heart girth, ns = not significant. \* Significant ( $p < 0.05$ ) and \*\* Significant ( $p < 0.01$ ).

**Table 6.** Path coefficient analysis of body measurements traits and BW of female Nguni cattle.

Linear body measurement Traits	Correlation coefficient with body weight	Direct effect	Indirect effects								
			HW	HL	EL	BL	RH	WH	SH	RW	HG
HW (cm)	0.26 <sup>*</sup>	-1.87 <sup>ns</sup>		-0.74	0.16	-0.02	1.75	0.34	-0.14	-0.03	0.67
HL (cm)	0.19 <sup>ns</sup>	-4.63 <sup>ns</sup>	-0.30		3.68	-0.08	2.68	0.17	-0.39	0.00	1.09
EL (cm)	-0.06 <sup>ns</sup>	-5.18 <sup>ns</sup>	0.06	3.29		0.07	-1.51	-0.06	0.18	0.00	0.91
BL (cm)	0.29 <sup>*</sup>	-0.10 <sup>ns</sup>	-0.32	-3.70	3.47		2.87	0.26	-0.26	0.00	1.20
RH (cm)	0.70 <sup>**</sup>	4.87 <sup>**</sup>	-0.67	-2.55	1.61	-0.06		0.47	-0.76	0.00	1.98
WH (cm)	0.55 <sup>**</sup>	0.82 <sup>ns</sup>	-0.77	-0.97	0.36	-0.03	2.78		-0.62	0.00	1.47
SH (cm)	0.34 <sup>**</sup>	-1.76 <sup>ns</sup>	-0.15	-1.02	0.52	-0.02	2.09	0.29		0.00	0.91
RW (cm)	-0.10 <sup>ns</sup>	0.20 <sup>ns</sup>	0.32	0.93	-1.76	0.03	-0.93	-0.03	0.21		-0.32
HG (cm)	0.76 <sup>**</sup>	2.67 <sup>**</sup>	-0.47	-1.16	0.67	-0.05	3.60	0.47	-0.84	0.00	

HW = head width, HL = head length, EL = ear length, BL = body length, RH = rump height, WH = withers height, SH = sternum height, RW = rump width, HG = heart girth, ns = not significant. \* Significant ( $p < 0.05$ ) and \*\* Significant ( $p < 0.01$ ).

results recognized that only two biometric traits (RW and HL) were statistically significant as direct effects on BW of male Nguni cattle. However, RW (13.35) made the biggest direct influence on the BW of male Nguni cattle. SH showed the highest indirect effect on BW via RW and HL. In female Nguni cattle (Table 6), RH (4.87) followed by HG (2.67) made the highest influence on the BW of female Nguni cattle. HL had the highest indirect contribution to the BW via RH and HG of female Nguni cattle.

#### **Removal of less remarkably biometric traits in the development of best equation to predict BW**

In male Nguni cattle, results of path analysis indicated that coefficients of HW (-13.10), EL (8.09), BL (0.58), RH (-6.92), WH (8.53), RH (-6.92), SH (11.22), and HG (-1.82) were statistically non-significant, whereas RW and head

height were statistically significant on the BW. In females, HW (-1.87), HL (-4.63), EL (-5.18), BL (-0.10), WH (0.82), SH (-1.76), and RW (0.20) were statistically non-significant, whereas RH and HG were statistically significant on the BW. All the biometric traits that were statistically not significant on the BW of both sexes were deleted from the multiple linear regression equation. The deletion of statistically not significant biometric traits changed the  $R^2$  and MSE in the regression model.

#### **Development of optimum regression equations for prediction of BW in Nguni cattle**

Best regression equations for the prediction of BW from biometric traits of Nguni cattle are presented in Table 7. For males, after removal of non-significant biometric traits (HW, EL, BL, RH, WH, SH, and HG), the remaining biometric

**Table 7.** Optimum regression models for prediction of BW.

Sex	Model	Coefficients			R <sup>2</sup>	SE	MSE	Sig
		β <sub>0</sub>	β <sub>1</sub>	β <sub>2</sub>				
Male	RW + HL	-719.82	19.29	2.20	0.50	77.32	1,506.66	0.00
Female	RH + HG	-560.82	3.33	2.50	0.62	69.09	4,773.89	0.00

Sig = Significant at  $p < 0.05$ ,  $R^2$  = coefficient of determination, MSE= residual mean square, HG = Heart girth, RH = Rump height, RW = Rump width, HL = Head length, SE = Standard error, β<sub>0</sub>: Constant, β<sub>1</sub> and β<sub>2</sub> = Regression coefficients.

traits were examined again using the multiple regression method to predict BW. The model of RW and HL was statistically significant ( $p < 0.05$ ) with  $R^2 = 0.50$  and MSE = 1,506.66. The regression model was established as

$$BW = -719.82 + 19.29 RW + 2.20 HL$$

This indicates that 50% of the variance in BW of male Nguni cattle explained by the model. In female, after deleting of non-significant biometric traits (HW, HL, EL, BL, WH, SH, and RW), the outstanding biometric traits were used again to predict BW of female Nguni cattle using the multiple regression procedure. The regression equation was remarkably ( $p < 0.05$ ) with  $R^2 = 0.62$  and MSE = 4,773.89. The regression model was established as

$$BW = -560.82 + 3.33 RH + 2.50 HG$$

This indicates that 62% of the variance in BW of male Nguni cattle explained by the model.

## Discussion

The accessibility of computer packages for data analysis in the field of animal breeding results in the rapid growth in the use of path analysis technique [15,16]. The data collected discovered that female Nguni cattle had higher numerical values on descriptive statistics of most measured traits than male Nguni cattle. Similar results were observed by Tebug et al. [17] in Bunaji cattle of Zaria, Nigeria. However, the data collected in this study were higher than of Francis et al. [18]. This variation might be due to breed differences. Moreover, Vanvanhossou et al. [19] found male summary data higher than female data. This study firstly investigated the association between BW and biometric traits viz. HW, HL, EL, BL, RH, WH, SH, RW, and HG of Nguni cattle breed using Pearson's correlation in both sexes. In male Nguni cattle, the results specified that SH, RH, HG, WH, and RW had a positive highly significant correlation with BW. The ultimate findings of this study revealed that by improving SH, RH, HG, WH, and RW; BW of male might also be improved. Therefore, SH, RH, HG, WH, and RW may well be included in the selection criteria during breeding to improve BW in male Nguni cattle.

In female Nguni cattle, results showed that BW had a positive highly significant correlation with WH, SH, RH,

and HG. These results validated that by improving SH, WH, RH, and HG might also improve BW of female Nguni cattle. Therefore, SH, WH, RH, and HG may be employed in the selection criteria during breeding to improve BW in female Nguni cattle. Moreover, our study revealed that SH, WH, RH, and HG might be used to improve BW in male and female Nguni cattle. Findings in this study are consistence with previous studies [6,19]. Additionally, Kashoma et al. [20] indicated that BW of Tanzania shorthorn zebu cattle was a positively strong significant association with HG measurements. According to Lorentz et al. [21] and Tyasi et al. [7], the phenotypic correlation coefficient only aid to specify the magnitude associations without discovering the cause influence association between the traits. Hence, the employment of path analysis technique is to investigate the direct and indirect effects of biometric traits on BW of Nguni cattle breed in both sexes. Multiple regression analysis was employed to compute the beta coefficient (path coefficient) for biometric traits. Multiple regression results were used to establish a regression model and all the measured biometric traits were included in the regression models in both sexes. However, RW and HL were remarkably in a regression model of males, whereas in females, RH and HG were statistically significant.

The regression findings are in agreement with the work of Kashoma et al. [20] in Tanzania shorthorn cattle and Ige et al. [22] in White Fulani cattle of Nigeria. These results suggest that RW and HL had a connotation on BW on male Nguni cattle, whereas direct effect RH and HG had a significant direct effect on body of female Nguni cattle. The path analysis procedure was used to estimate the indirect effect of biometric traits on BW using the path coefficient (regression beta coefficient). The results indicate that RW had a higher direct effect and sternum had a higher indirect effect in male. In females, RH had a higher direct effect and HL had a higher indirect effect. These results suggest that RW made the most contribution to BW of males, whereas RH made the most contribution to BW of females. The path analysis results put forward that BW could be predicted using RW and SH in males and RH and HL in females. Path analysis provides factors that might affect the BW of Nguni cattle. All the non-significant biometric traits were removed for the establishment of the optimum regression

equation. After the removal of non-significant biometric traits from the regression models, the regression equation model was included on RW and HL in male Nguni cattle, whereas RH and HG were included in the regression equation of female Nguni cattle. Based on prior knowledge, there are a few path analysis studies determining the association between BW and morphological traits in cattle.

However, several studies of path analysis in cattle focused on milk yield improvement: Triveni crossbred cattle [23], Brown Swiss cattle [24], Jersey dairy cattle [25], and Zavot cattle [26]. Naskar et al. [27] suggested that path analysis might be useful in determining the calving interval in Sahiwal cattle. It is very important to determine biometrical differences in livestock which might give the idea in genetic differences and sexual dimorphisms. Moreover, Nesamvuni et al. [28] estimated a BW of Nguni cattle from biometric traits using regression analysis and concluded that WH and HG are the best traits for the prediction of BW in Nguni cattle. Machila et al. [29] established that estimation of BW using biometric traits in cattle might help during the drug dosage for farmers who don't have weighing scale. The limitations of the current study are that most of Nguni cattle used from the current study were five years old which makes difficult to predict age effect on BW.

## Conclusion

Correlation coefficients were used to determine the correlation between BW and biometric traits of Nguni cattle. It is concluded that WH, SH, RH, and HG had a high positive correlation with BW of male Nguni cattle, whereas WH, SH, RH, and HG were highly positive correlation with BW of female Nguni cattle. Path analysis revealed that RW had the highest direct effect, whereas SH had an indirect effect on BW of male Nguni cattle. In female Nguni cattle, RH had the highest direct effect, whereas HL had an indirect effect on BW. Established regression equations might be used by cattle farmers to estimate BW. Further studies need to be done in path analysis with the main purpose of improving BW in other cattle breeds or more sample size of Nguni cattle.

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## Conflict of interests

The authors declare that there is no conflict of interest for this work.

## Authors' contribution

Thobela Louis Tyasi designed the experiment, analyzed the data, and wrote the manuscript. Kgotlelelo Maaposi Makgowo, Kwena Mokoena, Lebo Trudy Rashijane, Madumetja Cyril Mathapo, Lebogang William Danguru, Kgotlelelo Maaposi Makgowo, Paul Mogowe Bopape, Nhlakanipho Divine Mathye, and Dannis Maluleke performed fieldwork and wrote the manuscript. Kwena Mokoena and Kagisho Madikadike Molabe reviewed the manuscript. Thobela Louis Tyasi read, edited, and approved the final manuscript.

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