
Prediction of Body Weight from Linear Body Measurements for Horro Sheep Breeds in Oromia, Ethiopia

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Abstract: The study was carried out in Bako Agricultural Research Center's sheep farm and Horro district to determine the relationship between live weight and linear measurements and predict live weight from morphometric traits and morphometric measurements from 1589 Horro sheep (1131 female and 456 male) were used to determine relationships between body weight and linear body measurements. Accordingly, Body weight, Body length, Height at wither, Chest girth, Chest width, Rump length and Pelvic width measurements were recorded for each animal. Correlation and regression analysis between body weight and the linear body measurements were conducted independently for male and female within the different age categories defined using dentition. In most of the analyses, there was a significantly ($p < 0.001$) higher correlation between body weight and the linear body measurements. Chest girth has showed the most higher and consistent correlation with body weight in both sex and the different age categories. Based on the correlation results chest girth was primarily used to fit the equation for prediction of body weight in stepwise regression. Thus, the general equations developed from the regression analyses were based only on sex rather than for different age categories. As a result the equations $BW = -24.24 + 0.68CG$ for male Horro sheep, and $BW = -29.03 + 0.75CG$ for female Horro sheep can accurately predict body weight of the breed at any age.

Keywords: Body Weight, Chest Girth, Horro Sheep, Morphometric Measurements

1. Introduction

Sheep meat production is indispensable to meet protein needs of people throughout the world. Most scientific studies in relation to growth, one of the critical characteristics in sheep production, have been conducted to increase meat production per sheep. Information on body weight with several body measurements is necessary not only to monitor the growth of the sheep but also to estimate genetic correlations between body weight and body measurements. Body weight is measured not only to evaluate carcass yield [1] and condition of the animal as a selection criterion but also to determine suitable medication dosage during health care and required feed amount of the animal [8].

Body measurements, an indicator of breed standards [9], provides great convenience for the prediction of body weight without weighbridges [1, 3, 4, 5 and 13].

Again body weight is often the most common and informative measure of animal performance [2]. In order to

develop a very good model for genetic improvement of sheep, it is important to measure traits such as live weight with some level of accuracy. Body weights of animals are usually measured using weighing scale. However, proper measure of this trait is often difficult under on-farm conditions basically due to unavailability and cost of weighing scale. The best method of weighing animals without scale is to regress body weight on certain linear measurements which can be easily measurable and interpretable [1].

Few studies have been carried out to predict live body weights of Horro sheep from various linear body measurements. However, due to small data size the prediction models developed so far fail to represent the breed at the vast location. Thus, it has been crucial to conduct this study for developing a measuring tape that can accurately determine live body weight of Horro sheep.

This study was therefore carried out to determine the relationship between body weight and linear body measurements of Horro sheep. In addition, the best

regression model for prediction of live body weight of Horro sheep under field condition was determined.

Therefore, this study was intended with the following objectives;

- 1) to determine the best equation to predict live body weight of Horro sheep from linear body measurements, and
- 2) to develop a measuring tape from the fitted model.

2. Materials and Methods

2.1. Study Area

The study was carried out in Bako Agricultural Research Center's sheep farm and Horro district. Two villages (Gitilo and Laku), where Community Based Sheep Breeding Program is undergoing were exclusively considered in this study.

2.2. Data Collection Methods

A total of 1589 Horro sheep (1131 female and 456 male) were used in this study. A total of seven phenotypic measurements were taken for both sex and all age groups. Age and sex were considered as independent variables that could determine the body measurement traits. These traits include; Body weights, Body length, Height at wither Chest girth, Chest width, Rump length and Pelvic width. Live body weight was measured using a 100kg capacity weighing scale with 500gm graduation. The other linear body measurements were recorded using a flexible tailor's measuring tape. All animals were measured in their standing position under field condition.

The animals were grouped into different age categories using the number of pairs of permanent incisors (PPI). Accordingly; 0PPI (Milk teeth or there is no permanent incisor), 1PPI (one pair of permanent incisor), 2PPI (two pairs of permanent incisor), 3PPI (three pairs of permanent incisor), and 4PPI (four pairs of permanent incisor).

2.3. Statistical Analysis

Correlations (Pearson's correlation coefficient) between body measurements under consideration were computed for Horro sheep for both sex and age groups. The stepwise REG procedure of SAS (2003) was used to determine the relative importance of live-animal body measurements in a model designed to predict body weight. Live weight was regressed on the body measurements separately for males and females, for each dentition class and for the pooled data by sex categories. Due to

inadequate sample size, measurements in 3PPI and 4PPI dentition for male Horro sheep were included in 2PPI dentition class. The choice of the best fitted regression model was assessed using coefficient of determination (R^2).

Multiple linear regression models for females;

$$Y_j = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e_j$$

Where:

Y_j = the dependent variable body weight; β_0 = the intercept; X_1 , X_2 and X_3 are the independent variables body length, chest girth and height at wither, respectively.

β_1 , β_2 , and β_3 are the regression coefficient of the variable X_1 , X_2 and X_3

e_j = the residual error

Multiple linear regression models for males;

$$Y_j = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e_j$$

Where:

Y_j = the dependent variable body weight; β_0 = the intercept; X_1 , X_2 and X_3 are the independent variables body length, chest girth and height at wither, respectively.

β_1 , β_2 , and β_3 are the regression coefficient of the variable X_1 , X_2 and X_3

e_j = the residual error

3. Results

3.1. Correlation Between Body Weight and Linear Body Measurements

The relationships between body weight and the linear body measurements (body length, chest girth, height at wither, rump length and pelvic width) are presented in terms of coefficients of correlation in Table 1 below. According to the result, all linear body measurements have showed a significantly ($p < 0.0001$) strong relationship with body weight for the overall pooled data of both sexes. However, higher correlation coefficients were observed for chest girth, body length, and height at wither with r^2 values of 0.87, 0.82, and 0.79 for males and 0.80, 0.77 and 0.73 for females, respectively. Among the three measurements chest girth has showed the highest correlation coefficient for both male (0.87) and female (0.80). This shows that body weight can be better predicted from chest girth than the other measurements.

Table 1. Correlation coefficients of relationships between body weight and linear body measurements in Horro sheep.

Age	Sex	No of observation	BL	CG	HW	RL	PW
0PPI	F	500	0.82***	0.82***	0.75***	0.58***	0.49***
	M	335	0.83***	0.85***	0.78***	0.61***	0.65***
	F & M	837	0.80***	0.84***	0.76***	0.59***	0.55***
1PPI	F	219	0.41***	0.77***	0.48**	0.29*	0.25 ^{NS}
	M	97	0.61***	0.70***	0.56***	0.34***	0.29***
	F & M	307	0.50***	0.73***	0.44***	0.12 ^{NS}	0.27**
2PPI	F	125	0.42***	0.69***	0.32***	0.29***	0.25*
	M	73	0.65***	0.78***	0.37**	0.25 ^{NS}	0.21 ^{NS}
	F & M	140	0.25***	0.72***	0.24***	0.19**	0.18**

Age	Sex	No of observation	BL	CG	HW	RL	PW
3PPI	F	60	0.32***	0.78***	0.21*	0.22 ^{NS}	0.19*
	M	-	-	-	-	-	-
	F & M	-	-	-	-	-	-
4PPI	F	210	0.52***	0.74***	0.28**	0.21**	0.19 ^{NS}
	M	-	-	-	-	-	-
	F & M	-	-	-	-	-	-
All age groups	F	1131	0.77***	0.80***	0.73***	0.44***	0.52***
	M	456	0.82***	0.87***	0.79***	0.60***	0.69***
	F & M	1589	0.79***	0.87***	0.75***	0.49***	0.59***

PPI = Pair(s) of Permanent Incisors; F= female; M= male; HG= heart girth; BL= body length; HW= height at wither; RL= rump length; PW= pelvic width; * = P<0.05; **= P<0.01; ***= P<0.001; NS= Non-significant.

3.2. Live Body Weight Prediction Using Linear Body Measurements

Based on higher correlation coefficients between body weight and linear body measurements, BL, CG and HW were selected to develop the regression equation. The regression equations for both sex and different age categories are given in Table 2 below. According to the result the established equations for the pooled data (both sex and all age groups)

when only CG considered was; $-27.36 + 0.73CG$ ($r^2 = 0.87$). The result showed that as more of the linear body measurements are included in the equation, better correlation coefficient was obtained. The following two equations depict an increase in correlation between body weight and linear body measurements; $-28.26 + 0.60CG + 0.16BL$ ($r^2 = 0.88$) and $-29.55 + 0.56CG + 0.11BL + 0.11HW$ ($r^2 = 0.89$) with a stepwise inclusion of body length and height at wither in to the equation.

Table 2. Models for prediction of live weight from different body measurements and their R² values for Horro sheep.

Age	Sex	No of observation	Models	R ²	R ² change	P value	
1 PPI	F	500	$-21.62 + 0.6198CG$	0.82	0.00	<0.0001	
			$-22.73 + 0.40CG + 0.27BL$	0.84	0.00	<0.0001	
			$-24.95 + 0.03CG + 0.19BL + 0.20HW$	0.86	0.01	<0.0001	
	M	333	$-18.53 + 0.57CG$	0.85	0.00	<0.0001	
			$-19.21 + 0.35CG + 0.26BL$	0.87	0.00	<0.0001	
			$-20.47 + 0.29CG + 0.20BL + 0.14HW$	0.88	0.00	<0.0001	
	F & M	837	0 PPI	0.84	0.00	<0.0001	
				0.85	0.00	<0.0001	
				0.86	0.03	<0.0001	
	F	208	$-44.56 + 0.96CG$	0.78	0.00	<0.0001	
			$-46.10 + 0.87CG + 0.12BL$	0.79	0.02	<0.0001	
			$-50.54 + 0.82CG + 0.90BL + 0.16HW$	0.80	0.01	<0.0001	
M	97	$-24.63 + 0.71CG$	0.70	0.00	<0.0001		
		$-27.75 + 0.52CG + 0.25BL$	0.72	0.03	<0.0001		
		$-29.91 + 0.44CG + 0.19BL + 0.17HW$	0.74	0.02	<0.0001		
F & M	307	$-35.76 + 0.85CG$	0.73	0.00	<0.0001		
		$-37.80 + 0.73CG + 0.17BL$	0.74	0.01	<0.0001		
		$-40.98 + 0.66CG + 0.12BL + 0.16HW$	0.75	0.01	<0.0001		
2 PPI	F	125	$-41.30 + 0.92CG$	0.70	0.00	<0.0001	
			$-43.49 + 0.88CG + 0.08BL$	0.71	0.00	<0.0001	
			$-44.86 + 0.85CG + 0.78BL + 0.05HW$	0.73	0.02	<0.0001	
	M	73	$-47.60 + 1.01CG$	0.78	0.00	<0.0001	
			$-39.81 + 1.25CG - 0.39BL$	0.80	0.00	<0.0001	
			$-25.87 + 1.47CG - 0.42BL - 0.42HW$	0.82	0.02	<0.001	
	F & M	198	$-39.35 + 0.90CG$	0.61	0.00	<0.0001	
			$-42.30 + 0.83CG + 0.12BL$	0.62	0.02	<0.0001	
			$-45.59 + 0.78CG + 0.11BL + 0.15HW$	0.63	0.01	<0.0001	
	3 PPI	F	80	$-31.32 + 0.77CG$	0.75	0.00	<0.0001
				$-43.69 + 0.72CG + 0.24BL$	0.79	0.00	<0.0001
				$-43.83 + 0.73CG + 0.24BL + 0.00HW$	0.80	0.02	<0.0001
M		-	-	-	-	-	
			-	-	-	-	
			-	-	-	-	
F & M		-	-	-	-	-	
			-	-	-	-	
			-	-	-	-	
4 PPI		F	210	$-47.30 + 0.10CG$	0.73	0.00	<0.0001
				$-52.15 + 0.94CG + 0.14BL$	0.75	0.01	<0.0001
				$-56.53 + 0.91CG + 0.10BL + 0.14HW$	0.76	0.03	<0.0001
	M	-	-	-	-	-	
			-	-	-	-	
			-	-	-	-	
	F & M	-	-	-	-	-	
			-	-	-	-	
			-	-	-	-	

Age	Sex	No of observation	Models	R ²	R ² change	P value
All age groups (0 and above PPI)	F	1131	-29.03 + 0.75CG	0.80	0.00	<0.0001
			-29.99 + 0.63CG + 0.15BL	0.88	0.00	<0.0001
			-31.38 + 0.59CG + 0.11BL + 0.10HW	0.88	0.00	<0.0001
	M	456	-24.24 + 0.68CG	0.87	0.00	<0.0001
			-25.04 + 0.49CG + 0.23BL	0.88	0.00	<0.0001
			-26.36 + 0.42CG + 0.15BL + 0.16HW	0.88	0.00	<0.0001
F & M	1589	-27.36 + 0.73CG	0.87	0.00	<0.0001	
		-28.26 + 0.60CG + 0.16BL	0.88	0.01	<0.0001	
		-29.55 + 0.56CG + 0.11BL + 0.11HW	0.89	0.00	<0.0001	

4. Discussion

The higher the correlation coefficient of live body weight with a given linear body measurement, the more likely that the linear body measurement is to predict live body weight more accurately. Accordingly, results of the current study show that there is a strong correlation between chest girth and body weight for both sex and all age groups. Also it showed that there was a strong relationship for both male ($r=0.87$) and female animals ($r=0.80$). For male animals of all age groups, there was also a strong correlation between body weight and body length ($r=0.82$), and height at wither ($r=0.79$). Similarly data from female animals of all age groups showed strong correlation between body weight and body length ($r=0.77$), and height at wither ($r=0.73$). For the overall data set (both sex and all age groups), the correlation between body weight and chest girth was higher ($r=0.88$) followed by body length ($r=0.79$) and height at wither ($r=0.75$). According to [6] a higher correlation between body weight and chest girth was observed for both male ($r=0.85$) and female ($r=0.77$). This finding is almost similar to that of the current study. The better association of body weight with chest girth was possibly due to the relatively larger contribution to body weight of chest girth which consists of bones, muscles and viscera [11].

In this study, it was observed that chest girth measurement can accurately predict body weight of the animals in both sex and the different age categories. In the pooled data it has been clearly seen that chest girth alone can predict the live body weight ($r=0.87$). However, inclusion of body length and height at wither into the prediction regression equation showed increment in the coefficient of correlation with $r=0.87$, 0.88 and 0.89 for only chest girth, chest girth + body length, and chest girth + body length + height at wither respectively, in the equation. The result showed further improvement in the precision of the equation to predict body weight more accurately.

Similarly, the findings reported by [5] on Bonga and Horro sheep; and [10] on Menz and Afar sheep indicated that incorporating more of linear body measurements in the prediction equation has improved prediction accuracy. This implies that considering more parameters of linear body measurements could provide better precision in predicting the body weight using the established equation. However, heart girth parameter is the easiest way to use for live weight prediction in field conditions especially under small

holder farmers and where extensive measurements are practiced like in CBBP (community based breeding programs). Thus, the equations $Bwt = -29.03 + 0.75CG$ ($r=0.80$) and $Bwt = -24.24 + 0.68CG$ ($r=0.87$), for female and male Horro sheep respectively, can be used. Different research works have also suggested that chest girth is the easiest and more reliable parameter to predict live body weight of sheep [6].

5. Conclusion

The linear body measurements, chest girth, body length and height at wither can predict body weight of Horro sheep independently or in combination. However, for a better precision and ease of measurement chest girth is the best estimate of body weight for the breed. Accordingly, a standard commercial measuring tool can be developed using the equations fitted for chest girth and body weight. These may also be used as selection criteria. However, further research is needed to investigate the relationship between the body weight and linear body measurements in other breeds of sheep in Ethiopia to standardize the work.

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