Original Research Article

Technical Options for Body Weight Estimation: Prediction of Body Weights of Indigenous Sheep Populations from their Linear Body Measurements

Abstract

The field data collection was conducted before the war (before October 2020) in Tigray Regional State, Ethiopia. The objective of the study was to determine the relationships between the linear body traits (LBTs) and body weight of the indigenous sheep, and to develop regression equations for predicting live body weights of each population. Begait (173), Rutanna (151) and Arado (164) sheep of sample animals were randomly involved in the field data collection. Dentition was used to determine the age of the animals and were from one permanent incisor up to four permanent incisors. The data were analyzed by Statistical Package for Social Sciences software. The indigenous sheep populations were kept under low input extensive production system. The overall mean direct field weighed live body weights of the Begat, Rutanna and Arado sheep populations were 40.4±0.49 Kg, 48.3±0.94 Kg and 28.3±0.29 Kg, respectively. The correlations (P<0.01) between LBTs and direct field weighed live body weights of the indigenous sheep revealed that the LBTs could be used as indirect selection traits and could also be used to predict the live body weights of the indigenous sheep in areas where weighing scale is not available by using different regression equations. Chest depth (ChD = 0.817) and chest girth (ChG = 0.880) in Begait, ChD (0.874) and ChG (0.913) in Rutanna, and ChD (0.705) and ChG (0.788) in Arado sheep were among the highly significantly (P<0.01) correlated LBTs with the body weights of the indigenous sheep populations. Except in male Rutanna, **chest girth or chest circumference** could be solely used to predict the live body weights of the indigenous sheep breeds. Hence, Rutanna sheep (a transboundary breed) could be primarily used for mutton production due to their large live body weights. Genetic characterization of the indigenous sheep populations should be conducted for the identification of economically important candidate genes of the populations.

Key words: Body weight prediction, correlation, indigenous sheep, linear body traits, regression equation

INTRODUCTION

Morphological characterization of livestock breeds is very important for developing a breeding strategy in a particular production system [1]. Human societies selected sheep for their meat, milk, and wool [2]. All livestock production management practices depend on livestock weight assessment knowledge [3]. There is a balanced relationship between body linear traits and live weight in animals. Moreover, estimating the live weight using linear body traits is practical, faster, easier, and cheaper in rural areas where weighing scales are lacking by the breeder [4,5]. Linear body traits that influence positively the body weight of animals are evaluated as indirect selection criteria in sheep breeding strategy [6]. Body weight prediction is important both for commercial purposes and veterinary dosages of medicines which usually depend on the estimated live body weight of the animals [7].

Physical characteristics and body conformation of livestock species can be determined by morphometric characterization and body trait correlations [8]. The knowledge of the weight and age of sheep is very useful information for making appropriate management decisions. Linear dimensions of animals can be used to estimate body weight in most farms which lacked accurate scales [9]. In remote rural areas, it is impossible to obtain any accurate measurement of body weight for the genetic improvement program. Moreover, there is difficulty in the price setting of sheep marketing, and usually marketing is based on subjective practices of physical appraisal, visual judgment and loin-eye-area palpation [10] and scientifically inaccurate [3]. Linear body traits were used to predict live body weight by several authors in many breeds of sheep when there is no access to weighing scale [11,12,13]. The study of correlations between different body traits allows for a comprehensive understanding of the relationships between different physical traits [14]. Linear body traits can be used as indirect selection criteria to improve live body weight if there exists a strong correlation between linear body traits with body weight [15,16] or could be used to predict the live body weight of animals [17,18] and/or monitor growth and choosing replacement males and females [19]. Linear body traits are important traits in reflecting the breed standards [20] and are important in describing the morphostructure of the animals.

Knowledge of livestock live body weight is essential in livestock breeding and production. The output of this study will be paramount important for breeders, veterinarians, nutritionists, development agents (DAs) and marketing. This is because the regression equations will be used for selection by the breeders and DAs, administrating of treatment doses by the veterinarians, and determining the feed ration of an individual or group of sheep by the nutritionists. Moreover, the regression equations will be essential in marketing of the indigenous sheep particularly in farms involved in mutton production. Regression equations for the prediction of live body weight from the linear body traits of the indigenous sheep (Begait, Rutanna and Arado) are not yet developed and practiced. Therefore, the objective of the study was to determine the quantitative relationships between the linear body traits (explanatory variables) and body weights (response variable), and to develop regression equations for predicting the live body weights of each indigenous sheep population.

MATERIALS AND METHODS

Description of the Study Areas

The field data collection was carried out in Kafta Humera, Tsegede and Welkait districts. Kafta Humera district is the lowland part of Western Zone of Tigray Region, Ethiopia whereas Welkait and Tsegede districts are the highland areas of Western Zone of Tigray Regional State, Ethiopia. The Western Zone of Tigray is located at 570 and 991 kilometers (km) far from Mekelle and Addis Ababa, respectively [21]. The Zone also lies at 13°42′ to 14°28′ North latitudes and 36°23′ to 37°31′East longitudes [22].

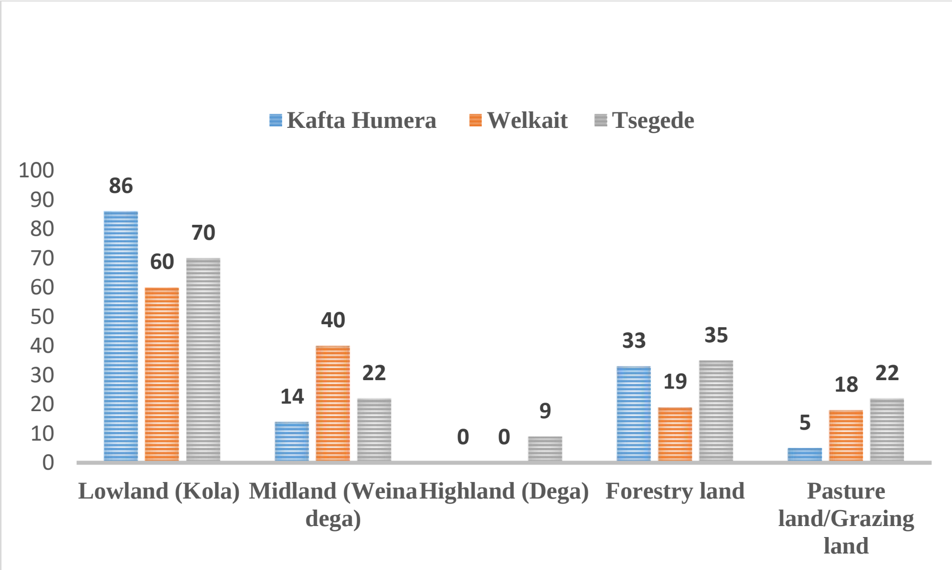
The altitude, rainfall and temperature of Kafta Humera, Welkait and Tsegede districts are presented hereunder (Table 1). Agro-ecology, forestland and grazing land of Kafta Humera, Welkait and Tsegede districts are also presented below (Figure 1) [23].

Table 1 Altitude, rainfall and temperature of Kafta Humera, Welkait and Tsegede districts

District	Altitude (MASL)		Rainfall (mm)		Temperature (℃)	
	Min-Max	Average	Min-Max	Average	Min-Max	Average
Kafta Humera	500-1849	1174.5	650-750	700	25-48	36.5
Welkait	700-2354	1527	700-1800	1250	18-25	21.5
Tsegede	680-3008	1844	1200-2500	1850	12-35	23.5

Meter Above Sea Level (MASL), millimeter (mm), Minimum-Maximum (Min-Max)

Source: [23]



Source: [23]

Figure 1 Agro-ecology, forestland and pastureland of each district (%)

Data collection and statistical analysis

Begait (173), Rutanna (151) and Arado (164) adult sheep which totaled 488 sample animals kept at on-farm management system were randomly involved in the field data collection. Animal age could be determined from its dentition status according to the technical bulletin (number 23) on estimation of age of sheep of the Ethiopian Sheep and Goat Productivity Improvement Program [9]. Hence, dentition was used to determine the age of the study animals and were included from one permanent pair of incisor (1PPI) up to four permanent pair of incisors (4PPI).

The quantitative and qualitative data were collected according to the standard breed descriptor list for the sheep breeds developed by FAO [24] guideline and precautions developed by ESGPIP [9]. The linear body traits were measured using flexible measuring tape while body weight (BW) was measured using suspended spring balance having 100 kg capacity with 0.2 kg precision. There were eighteen (18) linear body traits measured (in centimeter) which comprised of Body length (BL), Chest girth (ChG), Chest depth (ChD), Height at withers (HW), Rump height (RuH), Rump length (RuL), Rump width (RuW), Hair/wool length (HWL), Scrotal girth (ScG), Scrotal depth (ScD), Teat length (TtL), Head length (HdL), Head width (HdW), Ear length (EL), Horn length (HL), Shin circumference (ShC), Tail length (TL) and Tail width (TW), and pictorial representations of some linear body measurement traits are presented (Figure 2). The hair/wool length was measured from the rump area of each animal.

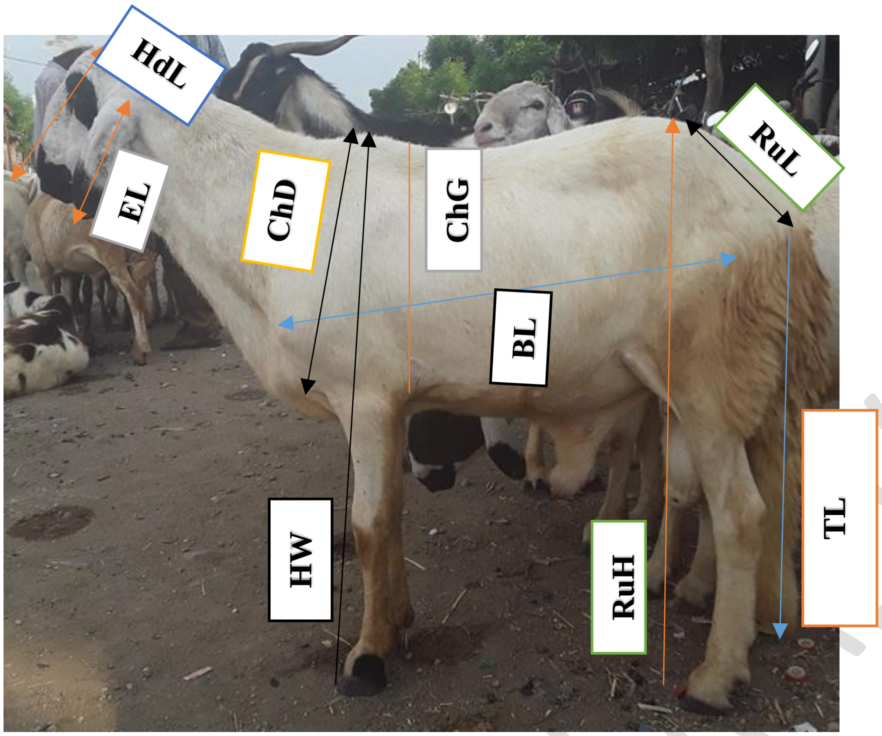


Figure 2 Pictorial representations of some linear body measurement traits

A correlation and regression analyses between linear body measurements as predictor variables and body weight as a response variable were conducted. Mean comparison of sex and age class of the animals was made, and correlation analysis of linear body measurements and body weights of the indigenous sheep was performed. Stepwise Multiple Regression Analysis (SMRA) procedure of Statistical Package for Social Sciences [25] was the statistical method used to determine the best fitted regression equations for the prediction of live body weights of the three indigenous sheep.

Multiple linear regression model for female Rutanna sheep

$Y_j = \alpha + \beta_1(X_1) + \beta_2(X_2) + \beta_3(X_3) + \beta_4(X_4)\ e_j$…………………………………… (1)

Y_j-the response variable (BW), α (Regression intercept), β1, β2, β3, β4 (Regression coefficients of the predictor variables), X_1, X_2, X_3, X_4 are the predictor variables (ChG, BL, RuW and ShC), respectively, and e_j is the residual random error

Multiple linear regression model for male Rutanna sheep:

$$Y_j=\alpha + \beta_1(X_1) + \beta_2(X_2) + \beta_3(X_3) + \beta_4(X_4) + \beta_5(X_5) + e_j \quad (2)$$

Y_j-the response variable (BW), α (Regression intercept), β_1, β_2, β_3, β_4, and β_5 (Regression coefficients of the predictor variables), X_1, X_2, X_3, X_4 and X_5 are the predictor variables (ChD, ScD, ChG, TL and HdL), respectively, and e_j is the residual random error

RESULTS

Live body weights, and Correlations between Linear Body Measurements and Body Weights of the indigenous sheep populations

The indigenous sheep populations were kept under low input extensive production system. The sample photos of the indigenous sheep are presented hereunder (Figures 3, 4 and 5). The overall direct field weighed live body weights of Begat, Rutanna and Arado sheep were 40.4±0.49 kilograms (Kg), 48.3±0.94 Kg and 28.3±0.29 Kg, respectively. The direct field weighed live body weights of the indigenous sheep increased with the advancement of age class of the animals (Table 2). The body weight of Begait sheep revealed highest positive significant (*P*<0.01) correlations with BL (r =0.684), ChG (r =0.880), ChD (r =0.817), HW (r =0.629) and RuH (r =0.618) whilst little or no (*P*>0.05) correlations were exhibited with ScG (r =0.443), ScD (r =0.252) and EL (r =0.039). The body weight of Rutanna sheep revealed highest positive significant (*P*<0.01) correlations with BL (r =0.777), ChG (r =0.913), ChD (r =0.874), HW (r =0.742) and RuH (r =0.697) whilst little or no (*P*>0.05) correlations were exhibited with HaL (r = -0.079), ScD (r =0.350), TtL (r =0.167) and EL (r =0.031) (Table 3). The body weight of Arado sheep revealed highest positive significant (*P*<0.01) correlations with ChG (r =0.788), ChD (r =0.705) and HL (r =0.645) whilst little or no (*P*>0.05) correlations were exhibited with ScG (r =0.481), ScD (r =0.156), EL (r =0.005) and TL (r =0.104) (Table 4).

Table 2 Direct field weighed live body weights (Kg) of indigenous sheep across breed, sex and age class

Classes	**Breed**		
	Begait sheep	**Rutanna sheep**	**Arado sheep**
Sex			
Male	52.7±1.25	70.5±1.92	36.6±2.25
Female	39.5±0.44	45.3±0.70	28.0±0.28

Overall	40.4±0.49	48.3±0.94	28.3±0.29
P	**<0.001**	**<0.001**	**<0.001**
Age Class			
1PPI	33.9±0.81	40.8±1.2	24.7±0.48
2PPI	40.9±0.84	47.9±1.7	28.6±0.88
3PPI	41.4±0.94	50.2±3.1	29.1±0.74
4PPI	43.2±0.78	53.2±1.4	29.4±0.33
Overall	40.4±0.49	48.3±0.94	28.3±0.29
P	**<0.001**	**<0.001**	**<0.001**

Permanent Pair of Incisors (PPI)

Figure 3 Sample Photo of Ram of Begait sheep (Adebay, Kafta Humera district)

Figure 4 Sample Photo of Ram of Rutanna sheep (May Kadra, Kafta Humera district)

Figure 5 Sample Photo of Arado sheep (Chegar Kudo, Tsegede district)

Table 3 Pearson's Correlation Coefficients of Linear Body Measurements and Body Weight of Indigenous Begait (above diagonal) and Rutanna (below diagonal) Sheep Populations

	BL	ChG	ChD	HW	RuH	RuL	RuW	HaL	ScG	ScD	TtL	HdL	HdW	EL	ShC	TL	TW	BW
BL		0.653**	0.753**	0.675**	0.621**	0.300**	0.455**	-0.269**	0.532	0.493	0.069	0.619**	0.386**	-0.039	0.393**	0.542**	0.422**	0.684**
ChG	0.710**		0.868**	0.641**	0.607**	0.369**	0.572**	-0.290**	0.347	0.180	0.328**	0.621**	0.452**	0.048	0.386**	0.482**	0.412**	0.880**
ChD	0.726**	0.830**		0.714**	0.671**	0.357**	0.534**	-0.274**	0.051	-0.144	0.171*	0.665**	0.462**	0.043	0.488**	0.562**	0.502**	0.817**
HW	0.706**	0.735**	0.775**		0.839**	0.368**	0.457**	-0.127	0.695**	0.329	0.093	0.652**	0.482**	0.055	0.423**	0.555**	0.426**	0.629**
RuH	0.639**	0.671**	0.735**	0.870**		0.339**	0.397**	-0.045	0.618*	0.701**	0.150	0.657**	0.575**	0.049	0.417**	0.557**	0.359**	0.618**
RuL	0.334**	0.345**	0.415**	0.373**	0.425**		0.301**	0.009	0.092	0.066	0.207**	0.273**	0.247**	0.092	0.159*	0.109	0.224**	0.285**
RuW	0.340**	0.276**	0.417**	0.280**	0.299**	0.385**		-0.174*	0.074	-0.060	0.230**	0.393**	0.151*	-0.084	0.184*	0.291**	0.271**	0.522**
HaL	-0.014	-0.063	-0.078	-0.035	-0.056	0.066	-0.109		-0.435	-0.298	-0.038	-0.047	0.054	0.060	-0.130	-0.017	-0.050	-0.279**
ScG	0.343	0.357	0.790**	0.346	0.408	-0.075	0.444	0.016		0.790**	a	0.460	0.169	0.387	0.248	0.545	-0.142	0.443
ScD	0.145	0.065	-0.138	0.088	0.010	-0.236	-0.219	0.348	-0.194		a	0.521	0.443	0.164	0.309	0.273	-0.124	0.252

TtL	0.212*	0.220*	0.277**	0.263**	0.227**	-0.055	0.247**	-0.129	a	a		0.098	0.208**	-0.077	-0.021	-0.013	-0.160*	0.243**
HdL	0.676**	0.735**	0.761**	0.730**	0.695**	0.245**	0.295**	-0.105	0.333	-0.107	0.237**		0.588**	0.115	0.410**	0.441**	0.452**	0.624**
HdW	0.559**	0.587**	0.684**	0.559**	0.494**	0.387**	0.418**	-0.015	0.410	-0.297	0.093	0.675**		0.056	0.259**	0.325**	0.263**	0.439**
EL	0.104	-0.006	0.059	0.152	0.182*	0.069	-0.033	-0.011	0.113	-0.347	0.147	0.174*	0.068		0.015	0.017	-0.005	0.039
ShC	0.570**	0.607**	0.614**	0.524**	0.556**	0.188*	0.252**	-0.078	0.581*	-0.325	0.026	0.599**	0.527**	0.053		0.300**	0.462**	0.424**
TL	0.546**	0.553**	0.531**	0.546**	0.628**	0.218**	0.287**	-0.006	0.496*	-0.304	0.110	0.569**	0.392**	0.020	0.526**		0.363**	0.493**
TW	0.398**	0.492**	0.527**	0.444**	0.454**	0.432**	0.172*	0.078	0.414	0.074	-0.288**	0.349**	0.363**	-0.060	0.413**	0.355**		0.479**
BW	0.777**	0.913**	0.874**	0.742**	0.697**	0.352**	0.346**	-0.079	0.704**	0.350	0.167	0.773**	0.642**	0.031	0.671**	0.582**	0.540**	

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed), [a]Cannot be computed because at least one of the variables is constant, Body length (BL), Chest girth (ChG), Chest depth (ChD), Height at withers (HW), Rump height (RuH), Rump length (RuL), Rump width (RuW), Hair length (HaL), Scrotal girth (ScG), Scrotal depth (ScD), Teat length (TtL), Head length (HdL), Head width (HdW), Ear length (EL), Shin circumference (ShC), Tail length (TL), Tail width (TW), Body weight (BW)

Table 4 Pearson's Correlation Coefficients of Linear Body Measurements and Body Weight of Indigenous Arado Sheep Population

	BL	ChG	ChD	HW	RuH	RuL	RuW	WL	ScG	ScD	TtL	HdL	HdW	EL	HL	ShC	TL	TW	**BW**
BL	1																		
ChG	0.620**	1																	
ChD	0.623**	0.777**	1																
HW	0.504**	0.641**	0.668**	1															
RuH	0.489**	0.552**	0.621**	0.837**	1														
RuL	0.354**	0.356**	0.315**	0.333**	0.277**	1													
RuW	0.514**	0.469**	0.469**	0.323**	0.275**	0.193*	1												
WL	-0.218**	-0.230**	-0.188*	-0.151	-0.163*	-0.195*	-0.181*	1											
ScG	0.565	0.648	0.509	0.797	0.858*	0.034	0.301	0.226	1										
ScD	0.113	-0.091	-0.070	0.433	0.420	-0.653	0.581	0.000	0.420	1									
TtL	0.184*	0.187*	0.245**	0.088	0.071	0.119	0.317**	-0.194*	a	a	1								
HdL	0.536**	0.652**	0.600**	0.575**	0.477**	0.450**	0.405**	-0.150	0.625	-0.420	0.254**	1							
HdW	0.507**	0.507**	0.537**	0.537**	0.457**	0.216**	0.367**	0-.117	0.752	0.387	0.137	0.523**	1						
EL	0.043	0.044	-0.007	0.049	0.079	0.024	-0.021	-0.034	0.162	0.658	-0.089	-0.057	-0.001	1					

HL	0.499**	0.582**	0.756**	0.635**	0.541**	0.034	0.170	0.172	0.640	0.095	0.183	0.591**	0.649**	-0.136	1				
ShC	0.247**	0.346**	0.301**	0.278**	0.353**	0.119	0.154*	-0.046	-0.050	0.000	0.179*	0.271**	0.220**	0.038	0.483**	1			
TL	0.190*	0.102	0.167*	0.199*	0.261**	-0.008	0.030	0.162*	0.165	-0.245	0.000	0.226**	0.110	-0.003	0.421**	0.190*	1		
TW	0.286**	0.344**	0.352**	0.209**	0.188*	0.145	0.279**	0.024	-0.034	-0.131	0.185*	0.269**	0.099	0.035	0.224	0.099	0.233**	1	
BW	0.599**	0.788**	0.705**	0.528**	0.491**	0.184*	0.497**	-0.259**	0.481	0.156	0.249**	0.570**	0.480**	0.005	0.645**	0.266**	0.104	0.367**	1

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed), [a]Cannot be computed because at least one of the variables is constant, Body length (BL), Chest girth (ChG), Chest depth (ChD), Height at withers (HW), Rump height (RuH), Rump length (RuL), Rump width (RuW), Wool length (WL), Scrotal girth (ScG), Scrotal depth (ScD), Teat length (TtL), Head length (HdL), Head width (HdW), Ear length (EL), Horn length (HL), Shin circumference (ShC), Tail length (TL), Tail width (TW), Body weight (BW)

Developing Regression Equations: Prediction of Live Body Weights of the Indigenous Sheep Populations from their Linear Body Measurements

A stepwise multiple regression analysis was used to predict the live body weights of the male and female indigenous sheep. The numbers of technical options for prediction of the live body weights of the female and male Begait, Rutanna and Arado sheep are different. There are three technical live body weight prediction options for female Begait sheep, and male (2PPI-3PPI) Arado sheep whilst there is only one for female Arado sheep, four for female Rutanna, two for male Begait and five technical live body weight prediction options for male Rutanna sheep (Table 5).

One of the established regression equations (Table 5) of each breed and sex is presented below.

Begait (1PPI-4PPI)

Yj = -65.662 + 1.078(ChG) + 0.264(BL) + 0.375(TW)…………………………(Female)

Yj = -80.228 + 0.770(ChG) + 0.844(RuH)………………………………………(Male)

Rutanna (1PPI-4PPI)

Yj = -85.003 + 1.081(ChG) + 0.378(BL) + 0.475(RuW) + 0.684(ShC)…………………(Female)

Yj = -163.956 + 1.522(ChD) + 1.461(ScD) + 0.987(ChG) + 0.285(TL) + 0.893(HdL)…. (Male)

Female Arado (1PPI-4PPI)

Yj = -16.034 + 0.632(ChG)

Male Arado (2PPI-3PPI)

Yj = -18.832 + 1.741(ChG) + -5.360(HdW) + -0.575(RuL)

Table 5 Technical Options for Prediction of Live Body Weights of the Indigenous Sheep from their Linear Body Measurements

Breeds and models	α	β1	β2	β3	β4	β5	R^2	AdR^2
Female Begait (1PPI-4PPI)								
α + β1(ChG)	-55.848	1.245					0.723	0.721
α + β1(ChG) + β2(BL)	-67.415	1.108	0.306				0.743	0.739
α + β1(ChG) + β2(BL) + β3(TW)	-65.662	1.078	0.264	0.375			.751	0.746
Female Rutanna (1PPI-4PPI)								
α + β1(ChG)	-64.245	1.360					0.774	0.772
α + β1(ChG) + β2(BL)	-81.810	1.138	0.484				0.805	0.801
α + β1(ChG) + β2(BL) + β3(RuW)	-85.137	1.128	0.425	0.490			0.813	0.808
α + β1(ChG) + β2(BL) + β3(RuW) + β4(ShC)	-85.003	1.081	0.378	0.475	0.684		0.819	0.813
Female Arado (1PPI-4PPI)								
α + β1(ChG)	-16.034	0.632					0.509	0.495
Male Begait (1PPI-4PPI)								
α + β1(ChG)	-20.402	0.869					0.606	0.557
α + β1(ChG) + β2(RuH)	-80.228	0.770	0.844				0.784	0.722
Male Rutanna (1PPI-4PPI)								
α + β1(ChD)	-41.294	2.362					0.786	0.770
α + β1(ChD) + β2(ScD)	-65.173	2.342	1.256				0.873	0.852
α + β1(ChD) + β2(ScD) + β3(ChG)	-107.019	2.049	1.142	0.621			0.916	0.893
α + β1(ChD) + β2(ScD) + β3(ChG) + β4(TL)	-147.283	1.671	1.568	0.902	0.363		0.951	0.931
α + β1(ChD) + β2(ScD) + β3(ChG) + β4(TL) + β5(HdL)	-163.956	1.522	1.461	0.987	0.285	0.893	0.969	0.952
Male Arado (2PPI-3PPI)								
α + β1(ChG)	-67.366	1.364					0.888	0.851
α + β1(ChG) + β2(HdW)	-37.114	1.790	-4.900				0.992	0.983
α + β1(ChG) + β2(HdW) + β3(RuL)	-18.832	1.741	-5.360	-0.575			1.000	1.000

Adjusted R^2(AdR^2), Body length (BL), Chest girth (ChG), Chest depth (ChD), Rump height (RuH), Rump length (RuL), Rump width (RuW), Scrotal depth (ScD), Head length (HdL), Shin circumference (ShC), Tail length (TL), Tail width (TW)

DISCUSSION

The indigenous sheep populations were kept under low input extensive production system. Overall mean of 40.4±0.49 Kg, 48.3±0.94 Kg and 28.3±0.29 Kg were the direct field weighed live body weights (BW) of the Begat, Rutanna and Arado sheep populations, respectively. BW (34.7±0.24) of Zulu sheep with two or more permanent incisors [26], BW (22.09±0.19 Kg) of *Holla* sheep types in Ethiopia [27], Ouled Djellal sheep of Algeria (male =95.87 Kg and female =61.27) [28], BW of Awasi (54.12±0.70), Il de France (55.29±0.99), Shkodrane (33.63±0.61) and Lara e Polisit (35.89±0.61 Kg) sheep in Albania [29], BW of Afar (18.9±0.49) and Gumuz (35.9±0.50 Kg) sheep [2], BW (23.5±0.2 Kg) of sheep in Tahtay Maichew district, Northern Ethiopia [30], BW (29.70 Kg) of Bonga and BW (31.66 Kg) of Horro [31], and BW (35.8 Kg) of Pahari or Kashmiri sheep in Pakistan [32] are not similar with the BW of Begait, Rutanna and Arado sheep populations. BW (25.80±0.20 Kg) of ewe Blackhead Somali [33] and BW (22.81±0.8Kg) of ewe Blackhead Somali [34] are not similar with BW of ewes of Arado sheep. The differences could be due to genotype, age and sex proportions used, environment and the interaction effects of genotype and environment. Different flocks of different sheep genotypes in different agro-climatic conditions do not receive the same management and result in live body weight variations.

Arado sheep (Tigray highland sheep) has similar BW with Blackhead Somali sheep (27.2 Kg) [35] and Awassi sheep (28.75±0.49 Kg) [36], however, the current live body weight of Arado sheep is not similar with the past live body weight study of the Tigray highland sheep (20.46±2.98) reported by Alemayehu and Tikabo [37]. The deviation could be due to age and sex proportions used for the study, management, agro-climatic and temporal effect. The earlier study of Deribe *et al*. [2] indicated that the BW of Begait (39.7±0.53 Kg) is similar with the present BW of Begait sheep whilst the BW of Rutanna (43.1±0.49) is not similar with the present BW of Rutanna sheep. The differences might be due to environmental, the interaction effects of genotype and environment, temporal effects, animal sampling and measurement methods.

The direct field weighed live body weight of the indigenous sheep increased with the advancement of age class of the animals. The body weights of Begait and Rutanna sheep revealed highest positive significant (P<0.01) correlations with BL (r =0.684, r =0.777), ChG (r =0.880, r =0.913), ChD (r =0.817, r =0.874), HW (r =0.629, r =0.742) and RuH (r =0.618, r =0.697), respectively whilst the body weight of Arado sheep revealed highest positive significant (*P*<0.01) correlations with ChG (r =0.788), ChD (r =0.705) and HL (r =0.645). The correlations of body weights of the indigenous sheep with these linear body traits indicate that selection practice based on these linear body traits could improve the live body weights of the indigenous sheep. The field live body weight prediction equations of male and female of each indigenous sheep populations are developed by stepwise multiple regression analysis and set regression equations of each breed and sex which will solve the lack of weighing scale at the remote rural areas. Farmers and professionals could use the regression equations to predict the live body weights of the indigenous sheep in the remote rural areas.

The linear body measurements of the indigenous sheep populations were reported by Mekonnen *et al.* [38], and Rutanna sheep outperformed in the major linear body traits than the other populations which confirmed the body weight outperformance of Rutanna sheep.

CONCLUSION AND RECOMMENDATIONS

Male Rutanna (70.5±1.92 Kg) sheep were not comparable with male Begait (52.7±1.25 Kg) and Arado (36.6±2.25 Kg) sheep. The variations in body weight is a function of genotype, feeding, health, sex, age and flock management situations where the populations were kept. There was highest positive significant (*P*<0.01) correlations between the linear body measurements and direct field weighed live body weights of the indigenous sheep populations. These correlations revealed that the linear body measurements could be used as selection traits and used to predict the live body weights of the indigenous sheep populations. The live body weights of the male and female indigenous sheep at field level (remote rural areas) could be predicted by the **regression equation option(s)** of each breed and sex developed.

Except in male Rutanna sheep, **chest girth or chest circumference** could be solely used to predict the live body weights of the indigenous sheep breeds for facilitating management decisions in breeding (selection and genetic improvement), nutrition (ration formulation), health (medicinal doses of veterinary services) and marketing (animal pricing). Genetic characterizations of the indigenous sheep populations should be conducted to identify the novel and economically important candidate genes.

Ethical Approval:

There was no ethics approval obtained from an institution because there was no damage on animal body part(s) due to data collection. Therefore, all farmers who owned the indigenous sheep were volunteer for data collection on the exterior body characteristics of the animals.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

REFERENCES

1. Deribe, B., Beyene, D., Dagne, K., Getachew, T., Gizaw, S., & Abebe, A. (2021). Morphological diversity of northeastern fat-tailed and northwestern thin-tailed indigenous sheep breeds of Ethiopia. *Heliyon*, 7(7), e07472. https://doi.org/10.1016/j.heliyon.2021.e07472.
2. Ruiz-Larrañaga, O., Langa, J., Rendo, F., Manzano, C., Iriondo, M., Estonba, A. (2018). Genomic selection signatures in sheep from the Western Pyrenees. *Genet Sel Evol*. 50: 9. doi: 10.1186/s12711-018-0378-x.
3. Otoikhian, C.S.O., Akporhuarho, A.M., Oyefia, O.P., and Isidahomen, C.E. (2008). Body measurement parameters as a function of assessing body weight in goats under on-farm research environment. *African Journal of Genetics & Agriculture*. 4: 1595-6984.
4. Nsoso, S.J., Aganga, A.A., Moganetsi, B.P. and Tshwenyane, S.O. (2003). Body weight, body condition score and hearth girth in indigenous Tswana goats during the dry and wet seasons in southeast Bostwana. *Livestock Research Rural Development* (15) 4. http://www.lrrd.org/lrrd15/4/nsos154.htm.
5. Atta, M. and El khidir, O. A. (2004). Use of heart girth, wither height and scapuloischial length for prediction of live weight of Nilotic sheep. *Small Ruminant Research* 55: 233-237.
6. Çelik, Ş., Eyduran, E., & Tariq, M. (2017). Comparison of predictive performance of data mining algorithms in predicting body weight in Mengali rams of Pakistan. *Revista Brasileira de Zootecnia*, 46, 863-872. https://doi.org/10.1590/S1806-92902017001100005.

7. Worku, A. (2019). Body weight had highest correlation coefficient with heart girth around the chest under the same farmers feeding conditions for Arsi Bale sheep. *International Journal of Agricultural Science and Food Technology*, 006-012. https://doi.org/10.17352/2455-815X.000035.
8. Salako, A.E. (2006). Application of morphological indices in the assessment of type and function in sheep. *International Journal of Morphology*, 24(1), pp.13-18.
9. ESGPIP (Ethiopia Sheep and Goat Productivity Improvement Program) (2009). Estimation of weight and age of sheep and goats. Technical Bulletin No.23, http://www.esgpip.org.
10. Gebreyesus G., Haile A. and Dessie T. (2012). Body Weight Prediction Equations from Different Linear Measurements in the Short-Eared Somali Goat Population of Eastern Ethiopia. *Research Journal of Animal Sciences*, 6: 90-93. http://medwelljournals.com/abstract/?doi=rjnasci.2012.90.93.
11. Sowande OS, Sobola OS. (2007). Body measurements of west African dwarf sheep as parameters for estimation of live weight. *Tropical Animal Health Production* 40(6): 433-439.
12. Cankaya, S. (2008). A comparative study of some estimation methods for parameters and effects of outliers in simple regression model for research on small ruminants OndokuzMayis University, *Biometry and Genetics Unit*, Kurupelit / Samsun, Turkey.
13. Abera M, Kebede K, Mengesha Y. (2016). Phenotypic Characterization of Indigenous Sheep Types in Northern Ethiopia. *Journal of Natural Science Research* 6(15): 16-27.
14. Daniel Markos, WorkuMasho, Mekuanent Baye and Elias Bayou. (2023). Morphometric traits and stepwise regression of indigenous sheep in Southwestern Region, *Ethiopia. Journal of Agriculture and Food Research*. 14(100666). https://doi.org/10.1016/j.jafr.2023.100666.
15. Kosgey, I.S., Baker, R.L., Udo, H.M.J. and Van Arendonk, J.A.M. (2006). Successes and failures of small ruminant breeding programmes in the Tropics: A review. *Small Ruminant Research*. 61:13-28.
16. Solomon Gizaw (2008). Sheep resources of Ethiopia: genetic diversity and breeding strategy. PhD Thesis, Wageningen University, The Netherlands.

17. Afolayan, R.A.I. A. Adeyinka, and C.A.M. Lakpini. (2006). The estimation of live weight from body measurements in Yankasa sheep. *Czech Journal of Animal sciences*, 51(8): 343-348.

18. Fasae, O.A., Chineke A.C and Alokan J.A. (2006). Relationship between some physical parameters of Grazing Yankasa Ewes in the Humid Zone of Nigeria. Department of Animal Production and Health. University of Agriculture. P.M.B. 2240, Abeokuta., Nigeria.

19. Mahieu M., Navès M. and Arquet R. (2011). Predicting the body mass of goats from body measurements. *Livestock Research for Rural Development*. Volume 23, Article #192. http://www.lrrd.org/lrrd23/9/mahi23192.htm.

20. Riva J, Rizzi R, Marelli S, Cavalchini G (2002). Body Measurements in Bergamasca Sheep. *Small Ruminant Research* 2: 221-227.

21. ZOIC (Western Zone Office of Information and communication) (2015). *Hiza'eti* Tigray. Western Zone Office of Information and communication. 2015; 3:5- 6.

22. Mekonnen H, Kalayou S, Kyule M, Asfaha M, Belihu K. (2011). Effect of Brucella Infection on Reproduction Conditions of Female Breeding Cattle and Its Public Health Significance in Western Tigray, Northern Ethiopia. *Veterinary medicine international*.

23. Tesfay B, Tsegay G, Haftu K, Teferi A, Bereket H (eds.) (2019). Participatory Agricultural Production Constraints Appraisal: Implication for Research and Development Interventions in Southern, North Western and Western Zones of Tigray. Tigray Agricultural Research Institute and Agricultural Growth Program-II, Proceedings of the Workshop held 09-15 November 2018, Capital Hotel, Wukro, Tigray, Ethiopia and Working paper no. 1.

24. FAO (Food and Agricultural Organization of the United Nations). (2012). Phenotypic characterization of animal genetic resources. FAO Animal Production and Health Guidelines No.11. Rome, Italy.

25. SPSS (Statistical Package for Social Sciences) (2019). Statistical Package for Social Sciences software, version 26.

26. Mavule Bafowethu Sibanda (2012). Phenotypic characterization of Zulu sheep: Implications for conservation and improvement. MSc. Thesis, University of Zululand, South Africa.

27. Kefale A, Awoke T, Getu A and Abegaz S. (2017). On-farm phenotypic characterization of *Holla* sheep types in South Wollo Zone Eastern Amhara Ethiopia. *Online Journal Animal Feed Research*, 7(5): 113-123.

28. Harkat S., A. Laoun, R. Benali, D. Outayeb, M. Ferrouk, A. Maftah, A. DA Silva, M. Lafri (2015). Phenotypic characterization of the major sheep breed in Algeria. *Revue Médical Véterinary*, 2015, 166, 5-6, 138-147.

29. Hoda, A., Mecaj, R., Hykaj, G. (2022). Morphometric characterization of four sheep breeds reared in South East of Albania. *Agriculture and Forestry*, 68(3): 241-253. doi: 10.17707/AgricultForest.68.3.18.

30. Hailu, A., Mustefa, A., Aseged, T., Assefa, A., Sinkie, S., Tsewene, S. (2020). Phenotypic characterization of sheep populations in Tahtay Maichew district, Northern Ethiopia. *Genetic Resources* 1(2), 12-22. doi:10.46265/genresj.SHBD3744.

31. Zewdu Edea, Aynalem Haile, Markos Tibbo, A.K, Sharma, Dejene Assefa, Johann Sölkner and Maria Wurzinger (2009). Morphological Characterization of Bonga and Horro Indigenous Sheep Breeds under Smallholder conditions in Ethiopia. *Ethiopian Journal of Animal Production* 9(1) -2009: 117-133.

32. Kuthu, Z.H., Z. Ahmed, I. Ahmed, M. Nawaz, M. Zubair, H. Mustafa, M. Moaeen-ud-Din and G. Bilal (2023). Morphometric Characterization and Body Weight Correlations in Pahari Sheep of Azad Jammu & Kashmir. *Pakistan Journal of Science* 75(2), June, 2023).

33. Fekerte Ferew (2008). On-Farm Characterization of Blackhead Somali Sheep Breed and Its Production System in Shinile and Erer Districts of Shinile Zone. MSc. Thesis, Haramaya University, Ethiopia.

34. Abera Feyissa A., K. Kebede Kefeni and N. Amaha (2018). Application of Body Measurements of Blackhead Somali Sheep as Parameters for Estimation of Live Weight. *Iranian Journal of Applied Animal Science* (2018) 8(4), 647-652.

35. Wendimu Bireda, Kefelegn Kebede, Yoseph Mekashaw and Shibabaw Bejano (2016). Phenotypic Characterization of Black Head Somali Sheep in Gode and Adadile Districts, Ethiopia. *Global Veterinaria* 17(3): 265-270, 2016, ISSN 1992-6197, DOI: 10.5829/idosi.gv.2016.17.03.10568.

36. Nurlign Mohammed, Kefyalew Alemayehu, Tesfaye Getachew (2017). On-farm phenotypic characterization of indigenous sheep population and its cross with Awassi in

selected Districts of South Wollo, Amhara, Ethiopia. *Tropical Drylands*, 1(1), June 2017, Pages: 1-11, E-ISSN: 2580-2828, DOI: 10.13057/tropdrylands/t010101.

37. Alemayehu Tadesse and Tikabo Gebremariam. (2010). Application of Linear Body Measurements for Live Body Weight Estimation of Highland Sheep in Tigray Region, North-Ethiopia. *Journal of the Drylands* 3(2): 203-207.
38. Mekonnen Teweldemedhn, Tesfahun Solomon and Araya Medhanye (2024). Exterior Body Characteristics of Indigenous Sheep Populations in Western Zone of Tigray Region, Ethiopia. *Asian Journal of Research in Animal and Veterinary Sciences*, vol. 7, no. 2, pp. 134-149, 2024, DOI: 10.9734/AJRAVS/2024/v7i2293.