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Predicting Body Weight of Three Ethiopian Thin-Tailed Sheep Breeds from Linear Body Measurements

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Abstract
Growth and conformation are the most important characteristics in small ruminant production for live animal sale and meat production. Linear body measurements are also important parameters to measured growth and as a selection criterion for breeders and prediction of body weight in sheep. Weight is determined by estimating some linear parameters under field condition where weighing scale is inaccessible. The study was conducted to examine the relationship between the body weight and morphological traits of three Ethiopian thin-tailed sheep breeds, Begait, Gumz and Rutana. A total of 327 ewes, the average age of 2-4 years, were used for body weight and body linear measurements. Morphological data on body length, heart girth, height at withers, tail length, pelvic width, ear length, rump height, and rump length and body weight were measured using standard descriptor adopted from Food and Agriculture Organization. Mean, standard error and coefficient of variance of weight and linear measurements of each breed were analyzed and tested for significance using the GLM procedure of SAS. Least square means and standard error of body weight of Begait, Gumz and Rutana sheep were found to be 39.79 ± 0.65, 36.27±0.62 and 43.10±0.69, respectively. Most variables were significantly $p<0.05$ and positively correlated with body weight. All sheep populations showed the highest correlation between body weight and heart girth with a correlation value of 0.72, 0.85 and 0.77 for Begait, Gumz and Rutana, respectively. Two of the body measurements heart girth and pelvic width were fitted for the model with a coefficient of determination R2 value in the range of 52-77% of the live weight in Begait sheep. Four body measurements heart girth, body length, and chest depth and ear length were fitted for the model with a coefficient of determination R2 in range of 72 to 81% for Gumz sheep. Four body measurements heart girth, body length, pelvic width, and chest depth were best fit for the model with coefficient of determination R2 value in the range of 55 to 87% for Rutana sheep. Rutana sheep population has higher $p<0.001$ body weight followed by Begait. Except for body weight and tail length, Rutana and Begait sheep populations have statistically similar body measurements. Gumz Sheep have $P<0.05$ lower body weight and body linear measurement than the others. In this study, the body measurements had a positive and high correlation with body weight implicating that linear body measurements can be used for estimation of body weight. In all studied sheep populations and age groups, heart girth is the first predictor that best fit for the model. The mean actual body weight and predicted body weight have shown almost similar value for all sheep populations and age groups. Therefore, prediction of body weight using only heart girth is preferred due to its reasonable precision and reasonably easy as a single measurement.
Keywords: Body weight, linear body measurement, regression equation, thin-tailed sheep

1. Introduction

Sheep production plays a very important role in Ethiopian farming systems. It contributes considerably to the livelihoods of rural households as a source of income, food meat and milk, and industrial raw materials skins and wool. In addition, sheep contributes socioeconomic and cultural functions, and risk-mitigating during crop failures, increase property security and serve as a form of investment explained by Markos Tibbo, 2006 }. Local sheep breeds have important asset due to their special characteristics like resistance to diseases, fertility, maternal ability, longevity, and adaptation to the environment.

Growth and conformation are the most important characteristics in small ruminant production for live animal sale and meat production. Linear body measurements are also important parameters to measured growth and as selection criteria for breeders and prediction of body weight in sheep as stated by (Salako, 2006). The main purposes of animal breeding practices are to improve traits of economic values. Live body weight measurement can be useful in defining the performance of animal and also evaluate growth. As described by Afolayan *et al.* (2006) measurements such as wither height, body length, heart girth, rump height and width in the estimation of animal weight have been widely documented.

Knowledge of sheep live weight is of paramount significance for determining its food requirements for growth, maintenance and production, and the correct dosages in drug administration (Musa *et al.*, 2012). Direct determination of live weight involves the employment of consideration scales. Proper and correct estimation of weight is troublesome below field condition production systems because of lack of consideration scales. The need to estimate live weight of animals especially sheep from simple and easily measurable morphological variables such as linear body measurements of different parts of the body have become evident as mentioned by (Musa *et al.*, 2012). Kumar *et al.* (2017)stated that measurements of various body conformations are of value in judging quantitative characteristics of meat and are also helpful in developing suitable selection criteria. Moreover, due to the relative ease in measurement linear dimensions, they can be used as an indirect way to estimate live weight. Apart from the traditional use of scale in crucial a load of sheep, weight determination by estimating some linear parameters can be used. Therefore, the objective of this study was to estimate the relationship between the body weight and morphological traits of three Ethiopian thin-tailed sheep breeds.

2. Material and methods

2.1 Study area

The study was conducted in Amhara region of North Gonder and West Administrative zones of Tigray region which are the main breeding tract of the long-thin tailed sheep breeds of Begait, Gumz and Rutana from April to May 2016. The altitude of the area ranges from 550 to 1861 meter above sea level. The mean annual temperature ranges from 22°C to 28°C as described by Solomon[6]. The area is characterized by hot to warm semi-arid lowland plains which are characterized by hot temperature, erratic rainfall, the vast area of lowland plains suitable for large-scale and subsistence agriculture including crop and livestock production systems. The samples were collected from different households for each breed/population.

2.2 Data collection

A total of 327 ewes comprising 102 Begait, 116 Rutana and 109 Gumz that have an average age of 2-4 years old estimated by dentition 2PPI=2 year, 3PPI= 3year and 4PPI=4years were used for body weight and body linear measurements. Measurements were taken early in the morning to overcome the effect of feeding and watering on the animal's size and conformation. Morphological measurements like body length, heart girth, height at withers, tail length, pelvic width, ear length, rump height, and rump length, and body weight were made using the standard descriptor adapted from the FAO (2012). Body weight was measured using suspended spring scales and other body measurements were taken using a flexible metal measuring tape after restraining and holding the animals in a natural position.

2.3 Data analysis

Statistical analyses were carried out on the data using the SAS package program (SAS, 2002). Mean standard error and coefficient of variance of weight and linear measurements of each breed were analyzed and tested for significance using the GLM procedure of SAS. Correlations Pearson's correlation coefficients between body weight and diverse linear body measurements were computed. Stepwise REG procedures of SASver.9.1 was employed to predict live weight from body measurements. The choice of the best-fitted regression model was selected using the coefficient of determination R2 and Mean standard error MSE. The multiple regression models were followed to estimate body weight from body measurements for each breed in separate analyses. Probability values <0.05 were taken as a significant level. Prediction of body weight from linear body measurements using the stepwise multiple regression procedure was carried out adopting the multiple linear regression model:

$$Y = \alpha + \beta_i x_i + \beta_2 x_2 + \dots\dots\dots + \beta_k x_k + \varepsilon$$

Where: Y = endogenous variable body weight, α = intercept, β's = regression coefficients, X's = exogenous variables BL, CD EL, HG, PW, HAW, RH, RL TL, and ε= error term, normally distributed with mean = zero and variance.

3. Result and Discussion

Least square means standard error and coefficient of variance of body weight and linear body measurement of Begait, Gumz and Rutana sheep breeds are summarized in Table 2. The least square means and standard error of body weight were found for Begait, Gumz and Rutana sheep to be 39.79 ± 0.65, 36.27±0.62 and 43.10±0.69, respectively. Rutana sheep population has higher p<0.001 mean body weight followed by Begait. Begait sheep have a higher tail length p<0.0001 followed by Rutana. Except for body weight and tail length, Rutana and Begait sheep populations have statistically similar body measurements.

Gumz Sheep have P<0.05 lower body weight and body linear measurement than the others. Regarding the body weight, the result of the present study showed that Gumz sheep have a higher body weight than the value reported by Solomon Abegaz *et al.* (2011)for the same breed. Similarly, chest girth, height at wither, tail length and ear length were higher than the value reported by the same author for the same breed. In the present study, the body length of Gumz sheep was lower than the value reported by (Solomon Abegaz *et al.*, 2011). The body weight result of Begait, Gumz and Rutana sheep were higher than the value reported for Hissarale sheep at age of 24 months and lower than the same breed of sheep at age of greater than 24 months reported by (Younas *et al.*, 2013). The results of the present study indicated that body weight and other body measurements had a significant difference in age groups except for ear length and tail length. A similar result was reported by (Younas *et al.*, 2013; Mahmud *et al.*, 2014).

The body weight and heart girth increased as age advanced. Other body measurements have similar value in both age group 3PPI and 4PPI animals. Rashid *et al.* (2015) and Musa *et al.* (2012) also reported that live weight and heart girth measurements increase with advances of age. Yilmaz *et al.* (2013), similarly reported that high positive phenotypic correlation coefficients were observed between live weight and body measurements of animals in different age groups. Population by age group interaction has shown a significant difference $p<0.011$, $p<0.0024$ for body weight and pelvic width, respectively. Population with age group interaction for other body measurements do not show the significant difference but numerically, the body weight and body measurements were increased as age advanced for all breed types.

Correlation is one of the most common and useful statistics that describes the degree of relationship between two variables. Pearson correlations between body weight and another body linear measurement of Begait, Gumz and Rutana sheep are summarized in Table 3. Correlation analysis of the measured parameters showed a strong association. Most variables were significantly $p<0.05$ and positively correlated with body weight. Body weight of Begait sheep was positively and significantly $p<0.05$ correlated with heart girth, pelvic width, chest depth, body length, rump height, rump length, tail length and height at wither orderly in their correlation coefficient value. Similarly, the body weight of Gumz sheep was significantly correlated with heart girth, chest depth, height at withers, body length, pelvic width, rump height, tail length, rump length, and ear length. Ear length has no correlation with body weight and other body measurements in Begait sheep population. A similar finding was described by Asefa B (2017) for indigenous sheep population of Bale zone. On the contrary, ear length is positively and significantly correlated with body weight and other boy measurements in Gumz sheep in the present study.

Body weight of Rutana sheep was positively and highly correlated with all body measurements except ear length. In Begait, Gumz and Rutana sheep, the highest correlation was observed between body weight and heart girth with a correlation value of 0.72, 0.85 and 0.77 respectively. Similarly, Cam *et al.* (2010) describe the high phenotypic correlation between body weight and heart girth strongly implicates the importance of the relationship between body weight and heart girth as body weight predictor. The correlation coefficient value 0.72 observed between body weight and heart girth in Begait sheep was lower than Gumz 0.85 and Rutana 0.77 in the present study. Similarly, it is lower than the value reported for Horro sheep 0.77 by Edea *et al.* (2010) and for Abergele sheep 0.82 by (Seare *et al.*, 2010). It is higher than the value reported for local sheep of East Gojam 0.57 by (Kebede and Abera, 2013).

The correlation coefficient value 0.85 observed between body weight and heart girth in Gumz sheep was similar with the value reported for Abergele sheep 0.84 (Seare *et al.*, 2010), local sheep of Tigray highland 0.83 and higher than the value reported for Horro sheep 0.77 by (Edea *et al.*, 2010)and Gumz sheep 0.77 (Solomon Abegaz, 2007). It is lower than the value reported for Hararge highland sheep 0.94 (Wossenie, 2012), Black Head Somali BHS 0.91 wondmu2011 and local sheep of North Wollo 0.94 (Tassew Mohammed *et al.*, 2014). This finding is similar to findings reported by (Asefa *et al.*; Solomon Abegaz, 2007; Tesfaye Getachew, 2008; Edea *et al.*, 2010; Shirzeyli *et al.*, 2013; Mahmud *et al.*, 2014).

The effect of age group on the correlation between body weight and body measurements of Begait, Gumz and Rutana sheep was summarized in table 3. Body weight of Begait was correlated positively and strongly with heart girth 0.85, 0.46 and 0.78 followed by pelvic width 0.71, 0.22 and 0.70 for 1^{st}, 2^{nd} and 3^{rd} age group, respectively. Similarly, the age effect on body weight and body measurements for Gumz and Rutana sheep have shown positive and significant association in most pairs of measurements in all age group. In all the three populations, body weight is positively and strongly associated with heart girth, chest depth, and height at wither in all age groups.

Regression equations used to estimate the weight of animals from other easily measured linear body measurements is very important in the selection and marketing of animals. Different regression models have been developed with a different level of complexity to give users an option to use for different purposes such as medication, marketing, and selection for a replacement stock as reported by (Otoikhian *et al.*, 2008), and (Sowande *et al.*, 2008). Determinant coefficient R2 and mean square error MSE can be considered as criteria important in the selection of the appropriate linear model. Shirzeyli *et al.* (2013)describe the equations with larger R^2 and smallest MSE showed a range similar to the range observed in the actual weight category.

The summary of stepwise multiple regression analysis and models for predicting body weight from interdependent morphological measurements by age group and predicted values are presented in Table 4 for Begait sheep. These regression models were determined using stepwise multiple regression analysis. All nine body measurements were fitted into the model and through stepwise elimination procedure, eight of the body measurements ear length, body length, height at wither, chest depth, rump height, rump length and tail length were observed unfit for the model among different age groups as compared to two major body measurements that were best fit for the model were heart girth HG and pelvic widthPW with coefficient of determination R2 value in the range of 52-77% of the live weight in Begait sheep. The regression model for all Begait sheep is as follow:

$$BWT = \alpha + \square_1 x_1 + \beta_2 x_2$$
$$BWT = -41.54 + 0.77HG + 1.14PW$$

Where BWT= body weight of individual animals, α = the intercept of the best fit straight line, β_1 (0.77) *and* β_2 Error! Bookmark not defined.= the coefficient of heart girth and pelvic width and x_1 *and* x_3 = measurement of heart girth and pelvic width respectively.

Heart girth is the first best-fit entry for all prediction equation for all age groups which have a coefficient of determination value R2 52%, 73%, 22% and 60 % for overall, 1st, 2nd, and 3rd age group, respectively.

The summary of stepwise multiple regression analysis and models for predicting body weight from interdependent morphological measurements by age group and predicted values are summarized in Table 5 for Gumz sheep. Four body measurements heart girth, body length chest depth, and ear length were fitted for the model with a coefficient of determination R2 in range of 72 to 81% for Gumz sheep. The rest body measurement is unfit for the model. The regression model for all Gumz sheep is as follow:

$$BWT = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4$$

BWT=-71.28 + 0.62HG + 0.46BL + 0.70CD + 0.72EL

Stepwise multiple linear regression equations for estimation of live body weight from body measurements, determination coefficient R2, mean square error, least square mean of the actual and predicted value of Rutana sheep are presented in Table 6. Four body measurements heart girth, body length, pelvic width, and chest depth were best fit for the model with coefficient of determination R2 value in the range of 55 to 87% for Rutana sheep. Body measurements like ear length, rump height, height at wither, rump length and tail length were unfit for the model. The regression model for all Rutana sheep is as follow:

$$BWt = \alpha + \beta_1 x_1 + \beta_2 x_2$$

BWT= -60.51 + 1.01HG + 0.34BL

In all populations and age groups, heart girth is the first predictor that best fit for the model. When the predictor increased, the coefficient of determination R2 value also increased. Similar results were reported by (Tesfaye Getachew, 2008) and (Younas *et al.*, 2013). The mean actual body weight and predicted body weight have almost similar value as shown in table 4, 5 and 6 for Begait, Gumz and Rutana respectively. Therefore, prediction of body weight using only heart girth is preferred due to its reasonable precision and as only a single measurement is involved and relatively easy procedure.

4. Conclusion

Rutana and Begait sheep populations have statistically similar body measurements except for body weight and tail length. Gumz Sheep have P<0.05 lower body weight and body linear measurement than the others. Body measurements had a positive and high correlation with body weight implicating that linear body measurements can be used for estimation of body weight. In all investigated sheep population the highest correlation was observed between body weight and heart girth.

The mean actual body weight and predicted body weight have shown almost similar value for all sheep population and age group. Therefore, the prediction of body weight using the above regression model can be used for the estimation of body weight for each population and age group.

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Table 1. Body Weight and Linear Body Measurements Parameter and Their Descriptions

Parameters	**Description**
Body length (BL)	The distance measured from the tip of the sternum to the tail base (cm).
Body weight (BWT)	The overnight fasted live body weight (kg).
Chest depth (CD)	The distance measured from the backbone at the shoulder to the brisket between the front legs (cm).
Heart girth (HG)	The circumference of the body immediately behind the shoulder blades in a vertical plane, perpendicular to the long axis of the body (cm).
Ear length (EL)	Length of the external ear from its root on the poll to the tip (cm).
Height at withers (HAW)	The vertical height from the bottom of the front foot to the highest point of the shoulder between the withers (cm).
Pelvis width (PW)	The horizontal distance between the extreme lateral points of the hook bone (tuber coxae) of the pelvis (cm).
Rump height (RH)	Height from ground to the spinal illiaca (cm).
Rump length (RL)	Distance from the anterior point to the posterior extremity of the pin bone (cm).
Tail length (TL)	Distance from the base to the tip of tail (cm).

Table2. Least square means ± Standard error and Coefficient of Variance of Body Weight and Linear Measurement of Begait, Gumz and Rutana Sheep Populations

variables	N	BL	BWT	EL	HAW	CD	HG	PW	RH	RL	TL
overall	327	57.03	39.99	13.99	73.27	38.64	80.72	16.30	72.38	22.49	46.88
CV		5.39	16.21	13.83	5.72	8.63	6.13	7.80	5.16	8.59	12.82
Population		***	***	***	***	***	***	***	***	***	***
Begait	102	55.99±0.31^{a}	39.79±0.65^{b}	14.53±0.19^{a}	74.57±0.42^{a}	39.54±0.33^{a}	81.49±0.49^{a}	16.53±0.13^{a}	73.83±0.37^{a}	23.25±0.19^{a}	51.80±0.60^{a}
Gumz	109	54.52±0.30^{b}	36.27±0.62^{c}	12.61±0.19^{b}	70.02±0.40^{b}	36.60±0.32^{b}	77.44±0.48^{b}	15.57±0.12^{b}	68.75±0.36^{b}	20.89±0.19^{b}	39.15±0.58^{c}
Rutana	116	58.20±0.33^{a}	43.10±0.69^{a}	14.80±0.20^{a}	74.81±0.44^{a}	39.55±0.35^{a}	82.52±0.52^{a}	16.75±0.13^{a}	74.18±0.39^{a}	23.18±0.20^{a}	49.63±0.64^{b}
Age		***	***	NS	**	**	***	***	**	***	NS
2PPI	85	55.66±0.35^{b}	36.90±0.75^{c}	13.74±0.22	71.79±0.48^{b}	37.64±0.38^{b}	77.88±0.57^{c}	15.71±0.15^{b}	71.09±0.43^{b}	21.75±0.22^{b}	45.88±0.69
3 PPI	115	57.45±0.29^{a}	39.93±0.61^{b}	14.12±0.18	73.57±0.39^{a}	38.75±0.31^{a}	80.66±0.46^{b}	16.52±0.12^{a}	72.61±0.35^{a}	22.58±0.18^{a}	46.94±0.56
4 PPI	127	57.62±0.28^{a}	42.32±0.59^{a}	14.09±0.18	74.04±0.38^{a}	39.30±0.31^{a}	82.93±0.45^{a}	16.63±0.12^{a}	73.07±0.34^{a}	22.98±0.18^{a}	47.76±0.55
Population by Age		NS	*	NS	NS	NS	NS	**	NS	NS	NS
Bx2 PPI	29	57.35±0.57	38.31±1.20^{e}	14.35±0.36	74.00±0.78	39.17±0.62	79.41±0.92	16.14±0.24^{bc}	73.21±0.69	22.48±0.36	51.86±1.12
Bx3 PPI	40	58.00±0.49	39.05±1.03^{e}	14.73±0.31	74.70±0.68	39.35±0.53	81.43±0.78	16.53±0.20^{b}	73.93±0.59	23.38±0.31	51.20±0.95
Bx4 PPI	33	58.64±0.54	42.00±1.13c	14.52±0.34	75.00±0.73	40.09±0.58	83.64±0.86	16.94±0.22^{ab}	74.36±0.65	23.88±0.35	52.33±1.05
Gx2 PPI	39	52.82±0.49	31.87±1.04^{d}	12.15±0.31	68.08±0.67	35.15±0.53	73.56±0.79	14.58±0.20^{d}	67.18±0.60	20.13±0.31	37.00±0.96
Gx3 PPI	34	55.15±0.53	36.04±1.11^{d}	12.69±0.33	70.24±0.72	36.71±0.57	77.77±0.85	15.87±0.22^{c}	68.97±0.64	20.85±0.33	40.03±1.03
Gx4 PPI	36	55.67±0.51	40.89±1.08^{b}	12.97±0.32	71.75±0.70	37.94±0.56	81.00±0.83	16.28±0.21^{b}	70.11±0.62	21.69±0.32	40.42±1.00
Rx2 PPI	17	56.82±0.75	40.53±1.57^{b}	14.71±0.47	73.29±1.02	38.59±0.81	80.65±1.20	16.41±0.31^{b}	72.88±0.91	22.65±0.47	48.77±1.46
Rx3 PPI	41	59.20±0.48	44.71±1.01^{a}	14.94±0.30	75.78±0.65	40.20±0.52	82.78±0.77	17.16±0.20^{a}	74.93±0.58	23.51±0.30	49.59±0.94
Rx4 PPI	58	58.57±0.40	44.07±0.85^{a}	14.76±0.25	75.36±0.55	39.86±0.44	84.14±0.65	16.66±017^{ab}	74.72±0.49	23.38±0.25	50.54±0.79

***= P<0.001, **=p<0.01, *=p<0.05, NS= not significant, CV= coefficient of variance, SL=significant level, 2 PPI =2 pairs of permanent incisor, 3 PPI =3 pairs of permanent incisor, 4 PPI =4 pairs of permanent incisor, B= Begait, G=gumz, R=Rutana and means with the same letter within the same columns are not significantly different.

Table 3. Phenotypic Correlations among Body Weight and Body Measurements of Begait, Gumz and Rutana Sheep and by age group

Breeds		BL	EL	HAW	CD	HG	PW	RH	RL	TL
Bugait		0.52 ***	-0.12 ns	0.24 *	0.53 ***	0.72 ***	0.57 ***	0.43 ***	0.4 ***	0.39 ***
Gumez		0.72 ***	0.47 ***	0.75 ***	0.8 ***	0.85 ***	0.65 ***	0.62 ***	0.51 ***	0.53 ***
Rutana		0.48 ***	0.11 ns	0.53 ***	0.63 ***	0.77 ***	0.46 ***	0.44 ***	0.43 ***	0.32 **
Breed by age group										
Bugait	2PPI	0.66 **	-0.13 ns	0.58 **	0.69 ***	0.85 ***	0.71 ***	0.63 **	0.36 ns	0.42 *
	3PPI	0.15 ns	-0.07 ns	-0.01 ns	0.31 ns	0.46 **	0.22 ns	0.21 ns	0.11 ns	0.16 ns
	4PPI	0.64 ***	-0.17 ns	0.44 *	0.49 **	0.78 ***	0.7 ***	0.53 **	0.62 ***	0.58 **
Gumez	2PPI	0.82 ***	0.32 *	0.82 ***	0.72 ***	0.85 ***	0.75 ***	0.63 ***	0.61 ***	0.51 **
	3PPI	0.64 ***	0.52 **	0.63 ***	0.86 ***	0.79 ***	0.58 ***	0.61 ***	0.33 ns	0.51 **
	4PPI	0.64 ***	0.52 **	0.74 ***	0.72 ***	0.79 ***	0.37 *	0.51 **	0.37 *	0.54 ***
Rutana	2PPI	0.48 ns	0.41 ns	0.64 **	0.35 ns	0.85 ***	0.63 **	0.45 ns	0.6 *	0.21 ns
	3PPI	0.49 **	0.24 ns	0.48 **	0.79 ***	0.82 ***	0.48 **	0.4 *	0.48 **	0.23 ns
	4PPI	0.45	0.01	0.51	0.56	0.74	0.42	0.45	0.37	0.42
	***	ns	***	***	***	***	***	**	**	

*** Significant at p<0.001, **significant at p<0.01and *significant at p<0.05, ns= not significant, BL= body length, BWT=Body weight, EL ear length, HAW= Height at Wither, CD=chest depth, HG= Heart Girth, PW=Pelvic Width, RH= Rump Height, RL=Rump Length and TL= tail length.

Table 4. Stepwise Multiple Linear Regression Equations for Estimation of Live Body Weight, from Body Measurements, Determination Coefficient (R^2), Mean Square Error, and Least Square Mean of Actual and Predicted Value of Begait Sheep.

Age	N	comp	Prediction equation	R^2	MSE	actual	predicted
overall	102	HG	BWT=-37.51 + 0.95HG	0.52	14.88	39.82 ± 0.56	39.94 ± 0.38
		HG PW	BWT= -41.54 + 0.77HG +1.14PW	0.57	13.51		40.11 ± 0.40
2PPI	29	HG	BWT= -55.46 +1.18HG	0.73	11.54	38.56 ± 1.04	38.37 ± 0.76
		HG PW	BWT= -60.56 + 0.94HG + 1.51PW	0.77	10.11		38.68 ± 0.80
3PPI	40	HG	BWT= -10.30 + 0.60HG	0.22	18.18	38.90 ± 0.86	38.55 ± 0.63
4PPI	33	HG	BWT= -48.65 + 1.08HG	0.60	11.18	42.00 ± 0.94	41.68 ± 0.68
		HG PW	BWT= -48.11 + 0.79HG + 1.42PW	0.73	7.85		42.02 ± 0.72

BWT=Body weight, PW=Pelvic Width, HG= Heart Girth and N=number of animals, comp= components, R^2 =determinant coefficient, and MSE= mean square error

Table 5. Stepwise Multiple Linear Regression Equations for Estimation of Live Body Weight from Body Measurements, Determination Coefficient, Mean Square Error, Least Square Mean of Actual and Predicted Value of Gumz Sheep.

Age	N	Comp	Prediction equation	R^2	MSE	Actual	predicted
Over all	109	HG	BWT=-54.46 + 1.17HG	0.72	17.77	35.98±0.70	36.01 ± 0.57
		HG BL	BWT=-74.31 + 0.91HG + 0.74BL	0.77	14.71		36.37 ± 0.60
		HG BL CD	BWT= -72.84 + 0.64HG + 0.66 BL + 0.65CD	0.79	13.47		36.17 ± 0.61
		HG BL CD EL	BWT= -71.28 + 0.62HG + 0.46BL + 0.70CD + 0.72EL	0.81	12.39		36.16 ± 0.62
2PPI	39	HG	BWT= - 52.21 + 1.14HG	0.72	15.07	32.19±1.18	32.00 ± 0.98
		HG BL	BWT= -78.50 + 0.73HG + 1.07BL	0.82	9.96		32.19 ± 1.04
3PPI	34	HG	BWT= -44.63 + 2.19CD	0.73	15.43	35.23±1.25	35.34 ± 1.04
4PPI	36	HG	BWT= --50.88 + 1.13HG	0.62	18.26	40.51±1.21	40.36 ± 1.01
		HG EL	BWT= -60.22 + 1.02HG + 1.45EL	0.75	12.44		40.84 ± 1.06
		HG EL CD	BWT= -62.23 + 0.68HG + 1.48EL + 0.76CD	0.79	10.77		40.47 ± 1.07

BWT=Body weight, BL= body length, HG= Heart Girth, CD= chest depth, EL= ear length and N=number of animals, comp= components, R^2 =determinant coefficient and MSE= mean square error

Table 6. Stepwise Multiple Linear Regression Equations for Estimation of Live Body Weight from Body Measurements, Determination Coefficient (R^2), Mean Square Error, Least Square Mean of Actual and Predicted Value of Rutana Sheep.

Age	N	comp	Prediction equation	R^2	MSE	Actual	predicted
Rutana	116	HG	BWT= -49.81+ 1.12HG	0.60	15.29	43.30 ± 0.66	43.22 ± 0.51
		HG BL	BWT=-60.51 + 1.01HG + 0.34BL	0.62	14.65		43.13 ± 0.51
2PPI	17	HG	BWT= -91.91 +1.64HG	0.72	5.96	41.25 ± 1.52	41.55 ± 1.18
		HG PW	BWT= -102.58 + 1.39HG + 1.87PW	0.87	3.07		41.50 ± 1.21
3PPI	41	HG	BWT= -47.84 + 1.11HG	0.67	10.42	44.59 ± 0.98	45.03 ± 0.76
		HG CD	BWT= -44.60 + 0.69HG + 0.78HD	0.75	8.11		44.49 ± 0.77
		HG CD BL	BWT= -60.47 + 0.62HG + 0.73HD + 0.41BL	0.79	7.02		44.88 ± 0.78
4PPI	58	HG	BWT= -48.47 + 1.10HG	0.55	21.07	44.07 ± 0.80	44.08 ± 0.62

BL= body length, BWT=Body weight, CD=chest depth, HG= Heart Girth and N=number of animals, comp= components, R^2 =determinant coefficient and MSE= mean square error