Journal of Applied Agriculture and Biotechnology **2017 2(2): 28-36**
ISSN (print): 2415-6728
ISSN (online): 2415-6736

Research article

Body weight prediction from linear body measurements in Awassi crossbred sheep of North Eastern Ethiopia

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How to cite
Lakew M., Z. Tesema and A. Zegeye. 2017. Body weight prediction from linear body measurements in Awassi Crossbred Sheep of North Eastern Ethiopia. J. Appl. Agric. Biotechnol., 2(2): 28-36.

Keywords
Awassi crossbred sheep,
body measurements,
body weight,
correlation,
north eastern Ethiopia

ABSTRACT

The study was conducted to investigate the relationship between body weight and morphological measurements and to estimate body weight from body measurements in Awassi x Wollo and Awassi x Tikur crossbreed sheep types in north eastern Ethiopia. For this purpose, data on body weight and body measurements such as heart girth, body length, wither height, hip width, ramp height, ear length, head length and body condition score were collected between 2015 and 2016 from 836 (287 male and 549 females) Awassi crossbred sheep at different ages of the two sheep types (447 Awassi x Wollo and 389 Awassi x Tikur). A correlation and regression analyses between body weight as a response variable and body measurements as predictor variable was conducted. A highly significant and consistent correlation coefficient was detected between body weight and heart girth (r=0.49 to r=0.85; *p*<0.001) in all age groups of both sexes of Awassi x Wollo and Awassi x Tikur sheep. Results on heart girth also supported previous results in literature. It was concluded in this study that body weight could estimated from heart girth with reasonable level of accuracy. It is recommended, therefore, to develop a simple chart that indicates heart girth and corresponding weights to be used by farmers and development agents to support genetic improvement, marketing, feeding and veterinary services.

1. Introduction

Sheep production is an important agricultural activity in the mixed crop livestock farming systems of the highlands of Ethiopia. There are about 28.89 million heads of sheep in Ethiopia of which about 70% are found in the highlands of the country (CSA, 2016). Sheep is a multi- functional animal and plays a significant role in the economy and nutrition of small and marginal farmers. In spite of its large number and great importance, their productivity believed to be low (Markos, 2006) and little attention is given for its improvements.

Nowadays, in the highlands of the country particularly in Amhara region, sheep productivity improvement through crossbreeding is being promoted to enhance meat production under the smallholder farmers. Accordingly, much number of Awassi sheep breed was distributed by different actors so far and achieved impressive success stories in this genetic improvement program of the region.

For the betterment of this genetic improvement program prediction the live weight of sheep is quite important for good animal management, including understanding medication doses, adjusting feed supply (Eyduran *et al.,* 2013), monitoring growth and choosing replacement males and females (Mahieu *et al.,* 2011). Besides the prediction of body weight and its relationships with other morphological measurements produce appreciable knowledge for breeding investigation with regard to meat production per animal (Iqbal *et al.,* 2013; Yilmaz *et al.,* 2013). The most intuitive way to assess body mass is weighing animals using a spring balance, a steelyard balance or any suitable scale. However, such devices are too expensive and not easily available for most of small farmers.

As a result, in these areas it is almost impossible to obtain any accurate measurement of this very important trait for the genetic improvement program. Moreover, there is difficulty in sheep marketing in relation to price setting. Usually in the areas marketing is based on physical appraisal, visual judgment and loin-eye-area palpation which are subjective (Gebreyesus *et al.,* 2012) and scientifically inaccurate (Otoikhian *et al.,* 2008). But estimating the market price based on live weight is quite important in reducing the bargaining practices.

Therefore, there is a need for a method that will be fast, cheap and easy to use for small-scale resource poor farmers (Nsoso *et al.,* 2003). Many research works have been reported the use of linear body measurements in estimating live weight of animals (Khan *et al.,* 2006; Adeyinka *et al.,* 2006; Mahieu *et al.,* 2011). They established regression equation model that could be used as predictor of body weight based on body measurements. This study, therefore, was conducted to establish prediction equations for estimating live weight of Awassi crossbred sheep using linear body measurements under farmers' conditions.

2. MATERIAL AND METHODS

2.1 Study Site

The study was conducted in Legambo (Chiro) district of South Wollo and Wadla (Talet) district of North Wollo administrative zones of Eastern Amhara Region, Ethiopia. Legambo district is located between 10° 10′ N and 38° 28′ E with an average altitude of 3270 masl. Wadla district is located between 12° 25′ N and 40° 5′ E with an average altitude of 3120 masl. The study areas are characterized by bimodal rainy seasons: the main rainy season (Meher) occurring from June to September, and the short rainy season (Belg) occurs from February to April. The minimum and maximum average annual temperatures of the study areas are about 15 and 20°C, respectively. The two zones possess about 2,519,313 million heads of sheep or 8.72% of total sheep population of the country (CSA, 2016).

2.2 Study Animals

For this study, *Awassi x Wollo* and *Awassi x Tikur* sheep types were used. The *Awassi x Wollo* sheep are predominantly found in areas of South Wollo and *Awassi x Tikur* sheep are predominantly found in areas of North Wollo. In this study, linear and body measurements were taken from randomly selected whole flocks including lambs. The system of flock management in the study areas was extensive; where the sheep were let out to graze freely on the natural pasture during the day time and irregularly they were fed supplemental feed mainly crop residue in the evening.

2.3 Methods of Data Collection

Data was collected between 2015 and 2016 by employing field measurements on body weight and body measurements. In all the study areas, measurements were taken from a total of 836 sheep (447 Awassi x Wollo and 389 Awassi x Tikur) comprising 287 male and 549 females. Each of the animals selected for measurement was identified by sex, site and estimated age group. According to Wilson and Durkin (1984), adult sheep were classified into five age groups based on dentition groups, Pair of Permanent Incisors (PPI): 0PPI - sheep with milk teeth (<1 year), 1PPI (1-1½ years), 2PPI (1½-2years), 3PPI (2½-3years), 4PPI and above (>3 years).

2.4 Body Measurements

Heart Girth (HG), Body Length (BL), Wither Height (WH), Hip Width (HW), Ramp Height (RH), Ear Length (EL), and Head Length (HL) were measured using tailors measuring tape. While weight was measured using suspended spring balance having 50 kg capacity with 0.2 kg precision. Body Condition (BC) scoring was done subjectively using scoring from 1 (emaciated) to 5 (obese or extremely fat).

2.5 Data Management and Analysis

Preliminary data analysis like screening of outliers was employed before conducting the main data analysis. Data collected on body weight and other body measurements were analyzed separately for each sheep type; using the Generalized Linear Model (GLM) procedures of the Statistical Analysis System (SAS Release 9.4, 2013). When analysis of variance declares significance, least square means were separated using adjusted Tukey-Kramer test.

Pearson's correlation coefficients for each sheep type were estimated between body weight and other body measurements within sex and age group (SAS Release 9.4, 2013). Body weight was regressed on the body measurements for males and females within each age group using stepwise regression procedure of SAS to determine the best fitted regression equation for the prediction of body weight. Best fitted models were selected based on coefficient of determination (R^2), R^2 change and simplicity of measurement under field condition.

The model for the analysis of multiple linear regressions was:

$$Y_i = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + \beta_8 x_8 + e_i$$

Where:

Y_i = the response variable; body weight,

α = the intercept,

$x_1, x_2, x_3, ...,$ *and* x_8 are the explanatory variables heart girth, body length, height at wither, hip width, ramp height, ear length, head length and body condition respectively,

$\beta_1, \beta_2, \beta_3, ...,$ *and* β_8 are regression coefficient of the variables $x_1, x_2, x_3 ... x_8$,

e_i = the residual random error.

3. RESULTS AND DISCUSSION

3.1 Body Weight and Body Measurements

Information on body size of specific sheep type at constant age has paramount importance in the selection of genetically superior animals for production and reproduction purpose. The mean live body weight of Awassi x Wollo sheep in different age category (0 PPI, 1 PPI and ≥ 2 PPI) were noted as 13.9±0.36, 19.4±0.45 and 20.6±0.41 kg respectively while for Awassi x Tikur sheep were 16.15±0.33, 23.46±0.73, 25.77±0.34 kg respectively. Body weight and body measurements of Awassi x Tikur sheep were relatively higher than Awassi x Wollo sheep. The weight difference between two crossbreds might be due to season of measurement takes place, feed availability and breed difference.

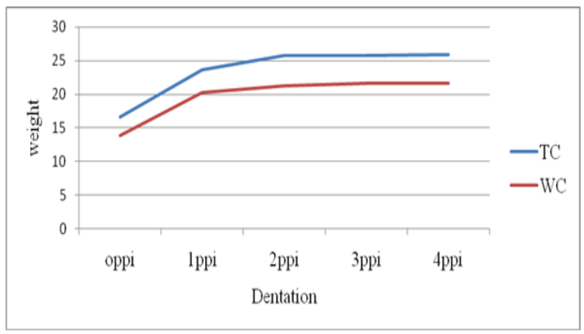

Figure 1: Growth curve of Awassi x Wollo (WC) and Awassi x Tikur sheep (TC)

After dentition class 2 PPI (approximately 22 months) body weight increased at diminishing rate. Similar trend was observed by Tesfaye Getachew (2008) who observed little change in body weight and other measurements after 24 months in Menz and Afar sheep breeds. Thus, subsequent data analysis was done based on grouping sheep in to three age categories: 0 PPI, 1 PPI and ≥ 2 PPI.

3.2 Relationship between body weight and other body measurements

Body weight is a very important characteristic in animal husbandry as a selection criterion and measure of economic profit. Body measurements are important data sources in terms of reflecting the breed standards (Riva *et al.*, 2004) and can also be used as qualitative growth indicators which reflect the conformational changes occurring during the life span of animals. The correlation is one of the most common and most useful statistics that describes the relationship between two variables. Table 1 and 2 displays Pearson correlations among body weight and body dimensions for Awassi x Wollo and Awassi x Tikur crossbreds respectively.

Positive and highly significant (*p*<0.01) correlations were observed between body weight and most of the body measurements. The high correlation would imply measurements can be used as indirect selection criteria to improve live weight or could be used to predict body weight (Afolayan *et al.,* 2006; Fasae *et al.,* 2006; Solomon, 2008). The high correlation coefficients between body weight and body measurements for all age groups suggest that either of these variables or their combination could provide a good estimate for predicting live weight of the crossbreds. Heart girth had consistently showed the highest correlation coefficient (r=0.49 to r=0.85; *p*<0.001) in all age groups of both sexes of Awassi x Wollo and Awassi x Tikur sheep. This highest correlation of heart girth with body weight than other body measurements was in agreement with other results (Fasae *et al.,* 2006; Solomon, 2008; Tesfaye, 2008).

The correlation between body weight and most of the body measurements tend to be higher at early ages of sheep than later age. The result is in agreement with other studies (Zewdu, 2008 and Tsegaye *et al.,* 2013). A higher coefficient was obtained for male as compared to female. The higher correlation coefficients between body weight and measurements for males indicated that, body weight could be predicted more accurately in males than their counterpart female sheep. This result is in agreement with Zewdu (2008), Tadesse and Gebremariam (2010) observed for Horo, Bonga and Highland sheep respectively.

Table 1: Phenotypic correlation between body weight and other body measurements for Awassi x Wollo sheep within age group and sex

		Age group					
		0PPI		**1PPI**		**2PPI**	
Trait		**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Heart Girth	N	83	111	52	81	18	102
	r	0.83***	0.82***	0.77***	0.49***	0.78**	0.65***
Wither height	N	83	111	52	81	18	102
	r	0.73***	0.77***	0.47**	0.42***	0.22^{NS}	0.57***
Body Length	N	83	111	52	81	18	102
	r	0.71***	0.74***	0.55***	0.27*	0.53*	0.47***
Hip width	N	83	111	52	81	18	102
	r	0.52***	0.33**	0.32*	0.26*	0.49*	0.41***
Ramp height	N	83	111	52	81	18	102
	r	0.75***	0.75***	0.46**	0.39**	0.32^{NS}	0.46***
Ear length	N	83	111	52	81	18	102
	r	0.19^{NS}	0.12^{NS}	0.37**	0.37**	0.19^{NS}	0.53***
Head Length	N	83	111	52	81	18	102
	r	0.76***	0.51***	0.49**	0.30**	0.62*	0.47***
Body condition	N	83	111	52	81	18	102
	r	0.08^{NS}	-0.013^{NS}	0.38**	0.27*	0.27^{NS}	0.31**

*Means with different superscripts within the same column and class are statistically different. NS: Not significant association, ***=significant at p<0.001, ** =significant at P<0.01, *=significant at p<0.05. N = number of observations. r = coefficient of correlation. 0 PPI = 0 pair of permanent incisors, 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors.*

Table 2: Phenotypic correlation between body weight and other body measurements for Awassi x Tikur sheep within age group and sex

		Age group					
		0PPI		1PPI		2PPI	
Trait		Male	Female	Male	Female	Male	Female
Heart Girth	N	106	114	15	34	13	107
	r	0.85***	0.78***	0.84**	0.52**	0.62**	0.67***
Wither height	N	106	114	15	34	13	107
	r	0.71***	0.74***	0.74**	0.42*	0.14^{NS}	0.15^{NS}
Body Length	N	106	111	15	34	13	107
	r	0.67***	0.68***	0.81**	0.38*	0.49^{NS}	0.41***
Hip width	N	106	114	15	34	13	107
	r	0.69***	0.72**	0.69*	0.35*	0.09^{NS}	0.44***
Ramp height	N	106	114	15	34	13	107
	r	0.77***	0.67***	0.63*	0.36*	0.32^{NS}	0.20*
Ear length	N	106	114	15	34	13	107
	r	0.22*	0.28**	0.23^{NS}	0.21^{NS}	0.03^{NS}	0.22*
Head Length	N	106	114	15	34	13	107
	r	0.64***	0.38***	0.65*	0.05^{NS}	-0.09^{NS}	0.01^{NS}
Body condition	N	106	114	15	34	13	107
	r	0.41***	0.02^{NS}	0.78**	0.21^{NS}	0.12^{NS}	0.65***

*Means with different superscripts within the same column and class are statistically different. NS: Not significant association, ***=significant at p<0.001, ** =significant at P<0.01, *=significant at p<0.05. N = number of observations. r = coefficient of correlation. 0 PPI = 0 pair of permanent incisors, 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors.*

3.3 Prediction of body weight from other body measurements

In all sex and age category of both sheep breed HG was consistently selected and entered into the model in step one procedure of stepwise regression due to its larger contribution to the model than other variables. Entering of significant (p<0.05) and best among the rest variables continued in consecutive steps until no other variable met the 0.05 significance level for entry into the model. The coefficient of determination (R^2) represents the proportion of the total variability explained by the model. Heart girth was the first variable to explain more variation than other variables in both males (59% to 71%) and females (24% to 68%) of Awassi x Wollo sheep. Similarly, HG was the first variable to explain the largest variation than other body measurements (accounted 68% to 74% in males and 28% to 77% in females) in Awassi x Tikur sheep.

The R^2 was the criterion's used to select the model. The R^2 always increase as new variable was added to the model thus we have to consider when new variable added to the model, which variable will notably increase the R^2 change when added to the model. After HG; the addition of other variables in the model increased the R^2 with a range of 0.1 to 0.18. The result of the multiple regression analyses indicated that the addition of other measurements to HG would result insignificant improvements in accuracy of prediction even though the extra gain was small. Besides the statistical concept and precision we should consider simplicity of measurement in order to select independent variables.

Table 3: Multiple regression analysis of live weight on different body measurements for Awassi x Wollo females by age group

		Parameters							
Age group	**Model**	**Intercept**	**β1**	**β2**	**β3**	**β4**	**β5**	**R^2**	**R^2 change**
0PPI	HG	-13.14±1.77	0.46±0.03					0.67	0.00
	HG+HAW	-15.71±1.82	0.31±0.05	0.22±0.06				0.70	0.03
	HG+HAW+HL	-15.10±1.80	0.35±0.05	0.25±0.06	-0.32±0.14			0.72	0.02
	HG+HAW+HL+RH	-17.09±1.93	0.31±0.05	0.19±0.06	-03.9±0.14	0.16±0.07		0.73	0.01
	HG+HAW+HL+RH+BL	-16.78±1.19	0.26±0.06	0.14±0.07	-0.41±0.13	0.18±0.07	0.11±0.05	0.74	0.01
1PPI	HG	-10.88±5.91	0.43±0.09					0.24	0.00
	HG+BC	-13.33±5.88	0.41±0.09	1.69±0.78				0.28	0.04
	HG+BC+EL	-12.07±5.76	0.32±0.09	1.91±0.76	0.40±0.18			0.33	0.05
2PPI	HG	-13.09±3.82	0.47±0.05					0.43	0.00
	HG+EL	-10.01±3.96	0.38±0.07	0.33±0.14				0.46	0.03
	HG+EL+HW	-13.33±4.09	0.46±0.07	0.53±0.16	-0.38±0.15			0.49	0.03
	HG+EL+HW+BL	-15.71±4.19	0.42±0.08	0.50±0.16	-0.42±0.15	0.11±0.05		0.51	0.02
Overall	HG	-14.21±1.31	0.49±0.02					0.68	0.00
	HG+HAW	-16.05±1.37	0.35±0.04	0.19±0.05				0.69	0.01
	HG+HAW+BC	-17.81±1.51	0.19±0.05	0.75±0.28				0.70	0.01
	HG+HAW+BC+BL	-18.47±1.50	0.28±0.05	0.17±0.05	1.01±0.29	0.12±0.04		0.71	0.01
	HG+HAW+BC+BL+HW	-19.65±1.58	0.31±0.05	0.18±0.05	1.17±0.29	0.12±0.04	-0.19±0.08	0.72	0.01

0 PPI = 0 pair of permanent incisors; 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors. Heart Girth (HG), Body Length (BL), Wither Height (WH), Hip Width (HW), Ramp Height (RH), Ear Length (EL), and Head Length (HL).

Table 4: Multiple regression analysis of live weight on different body measurements for Awassi x Wollo males by age group

		Parameters					
Age group	**Model**	**Intercept**	**β1**	**β2**	**β3**	**R^2**	**R^2 change**
0PPI	HG	-17.07±2.42	0.54±0.04			0.69	0.00
	HG+HL	-17.79±2.33	0.40±0.06	0.55±0.19		0.72	0.03
	HG+HL+EL	-16.45±2.33	0.41±0.06	0.65±0.19	-0.35±0.15	0.74	0.02
1PPI	HG	-32.56±6.37	0.78±0.09			0.59	0.00
2PPI	HG	-109.90±27.46	1.75±0.35			0.60	0.00
	HG+RH	-142.87±28.09	1.75±0.31	0.49±0.21		0.71	0.11
	HG+RH+HAW	-142.84±24.18	2.02±0.29	0.91±0.25	-0.74±0.29	0.79	0.08
Overall	HG	-21.21±2.08	0.61±0.03			0.71	0.00
	HG+HL	-22.28±2.08	0.50±0.05	0.47±0.18		0.73	0.02

0 PPI = 0 pair of permanent incisors; 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors. Heart Girth (HG), Body Length (BL), Wither Height (WH), Hip Width (HW), Ramp Height (RH), Ear Length (EL), and Head Length (HL).

Table 5: Multiple regression analysis of live weight on different body measurements for Awassi x Tikur males by age group

Age group	Model	Parameters						
		Intercept	β1	β2	β3	β4	R^2	R^2 change
0PPI	HG	-23.06±2.77	0.67±0.04				0.68	0.00
	HG+HW	-23.28±2.51	0.51±0.05	0.68±0.14			0.74	0.06
	HG+HW+HAW	-25.84±2.45	0.41±0.06	0.60±0.13	0.18±0.05		0.77	0.03
	HG+HW+HAW+BC	-26.97±2.42	0.38±0.06	0.55±0.13	0.18±0.05	1.15±0.43	0.79	0.02
1PPI	HG	-2.01±5.04	8.47±1.52				0.71	0.00
	HG+BL	-16.29±6.15	5.88±1.47	0.41±0.13			0.83	0.12
2PPI	HG	-13.68±5.74	0.85±0.33				0.68	0.00
Overall	HG	-27.59±2.46	0.74±0.04				0.74	0.00
	HG+HW	-27.04±2.18	0.56±0.05	0.78±0.13			0.79	0.05
	HG+HW+BL	-27.79±2.07	0.45±0.05	0.68±0.12	0.18±0.04		0.82	0.03
	HG+HW+BL+BC	-28.43±2.01	0.43±0.05	0.61±0.12	0.16±0.04	1.36±0.42	0.83	0.01

0 PPI = 0 pair of permanent incisors; 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors. Heart Girth (HG), Body Length (BL), Wither Height (WH), Hip Width (HW), Ramp Height (RH), Ear Length (EL), and Head Length (HL).

Table 6: Multiple regression analysis of live weight on different body measurements for Awassi x Tikur females by age group

Age group	Model	Parameters							
		Intercept	β1	β2	β3	β4	β5	R^2	R^2 change
0PPI	HG	-17.41±2.41	0.53±0.04					0.61	0.00
	HG+HW	-15.19±2.37	0.38±0.06	0.54±0.15				0.65	0.04
	HG+HW+HAW	-16.98±2.48	0.26±0.08	0.49±0.15	0.17±0.08			0.66	0.01
1PPI	HG	-19.73±11.76	0.60±0.17					0.28	0.00
2PPI	HG	-17.96±4.46	0.58±0.06					0.45	0.00
	HG+BC	-14.92±3.68	0.43±0.06	2.65±0.37				0.63	0.18
	HG+BC+HW	-15.84±3.64	0.39±0.06	2.46±0.37	0.24±0.11			0.65	0.02
	HG+BC+HW+HL	-13.25±3.72	0.42±0.06	2.30±0.37	0.29±0.11	-0.28±0.12		0.67	0.02
	HG+BC+HW+HL+BL	-14.63±3.72	0.37±0.06	2.31±0.36	0.28±0.11	-0.32±0.12	0.11±0.05	0.68	0.01
Overall	HG	-25.35±1.53	0.68±0.02					0.77	0.00
	HG+BC	-27.27±1.56	0.65±0.02	1.25±0.30				0.78	0.01
	HG+BC+HW	-27.81±1.52	0.58±0.03	1.17±0.29	0.34±0.09			0.79	0.01
	HG+BC+HW+BL	-28.33±1.53	0.49±0.04	1.29±0.29	0.29±0.09	0.14±0.05		0.80	0.01
	HG+BC+HW+BL+HL	-27.39±1.56	0.52±0.04	1.22±0.29	0.31±0.09	0.16±0.05	-0.23±0.09	0.81	0.01

0 PPI = 0 pair of permanent incisors; 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors. Heart Girth (HG), Body Length (BL), Wither Height (WH), Hip Width (HW), Ramp Height (RH), Ear Length (EL), and Head Length (HL).

Firstly, addition of more variable under field condition increase error incurred by the individual taking measurements and secondly, some variables are more affected by the animal posture so it is difficult to measure such variables accurately. It was recognized that heart girth is among the variables least affected by the animal posture and easy to measure than other measurements (Tesfaye, 2008). In addition to this moderate to high heritability for heart girth and its good indications for skeletal dimension (Janssens and Vandepitte, 2004) noticed in Belgian sheep breeds makes HG preferable to other measurements.

Coefficient of determination obtained for all pooled age group using HG as explanatory variable was higher and comparable with the three (0 PPI, 1 PPI and ≥ 2 PPI) age groups. Thus instead of using separate equation for different age group the overall equation of the pooled age group using HG as explanatory variable might be used for the prediction of body weight.

The prediction of body weight could be based on regression equation: **y = -14.21 + 0.49x** for Awassi x Wollo females, **y = -21.21 + 0.61x** for Awassi x Wollo males, **y= -27.59 + 0.74*x*** for Awassi x Tikur males and **y= -25.35 + 0.68*x*** for Awassi x Tikur females; Where *y* and *x* are body weight and heart girth, respectively.

4. CONCLUSION AND RECOMMENDATIONS

From the current study it can be conclude that live body weight of sheep could be predicted using linear body measurements in Awassi crossbred sheep types. Generally, positive and highly significant correlations were observed between body weight and most of the body measurements. Among those heart girth was the variable which explained more variation than other variables in all age groups of both males and females of Awassi crossbred sheep types. Thus, heart girth could be used as the easiest way to predict live body weight especially under small holder farmers' conditions with reasonable level of accuracy. And hence it is recommended to develop a simple chart that indicates heart girth and corresponding weights to be used by farmers and development agents to support genetic improvement, marketing, feeding and veterinary services.

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