Online Journal of Animal and Feed Research

Volume 2, Issue 1: 98-103 (2012) ISSN 2228-7701

ESTIMATION OF LIVE BODY WEIGHT FROM LINEAR BODY MEASUREMENTS FOR FARTA SHEEP

MENGISTIE TAYE[1,2] *, TEWODROS BIMEROW[1], ASRESU YITAYEW[1], SHIGDAF MEKURIAW[1], GETINET MEKURIAW[2]

[1]*Andassa Livestock Research Center, P.O.Box 27, Bahir Dar, Ethiopia*
[2]*Bahir Dar University, Agriculture and Environmental Sciences College, P.O.Box 380, Bahir Dar, Ethiopia*

*E-mail: mengistietaye@yahoo.com

ABSTRACT: *A study, to develop regression models for prediction of body weight from other linear body measurements, was conducted in Esite, Farta and Lai-Gaint districts of South Gondar, Amhara region. Records on body weight (BW) and other linear body measurements (Body Length (BL), Wither Height (WH), Chest Girth (CH), Pelvic Width (PW) and Ear Length (EL)) were taken from 941 sheep. Non-linear, simple linear and multiple linear regression models were developed using Statistical Package for Social Sciences (SPSS version 12.0). For the multiple linear regressions, step-wise regression procedures were used. Predicting models were developed for different age, sex and for the pool. Positive and significant (P<0.01) correlations were observed between body weight and linear body measurements for all sex and age groups. Among the four linear body measurements, heart girth had the highest correlation coefficient (except ear length) in all age and sex groups which is followed by body length, height at wither and pelvic width. Heart girth was the first variable to explain more variation than other variables in both sex and age groups. The models developed had a coefficient of determination of 0.26 to 0.89; the highest coefficient of determination was depicted for male while the lowest was for dentition groups having two permanent incisors. Regression models in general were poor in explaining weight for the dentition groups above one pair of permanent incisors. Heart girth alone was able to estimate weight with a coefficient of determination of 0.77, for both sexes and the pool. The coefficient of determination of the fitted equations (in general) decreased as the age of sheep advances indicating that the fitted equations can predict weight for younger sheep with better accuracy than for older ones. In general, much of the variation in weight was explained when many traits were included in the model. However, for ease of use and to avoid complexity at field condition, it is possible to use heart girth alone as a predicting tool. As a method to estimate weight using linear body measurements, it is possible to use these linear body measurements for selection in an effort to improve body weight of Farta sheep. In addition, the difference in the correlation coefficients between weight and other linear measurements for different age groups indicates the possibility of using different body measurements at different ages to predict weight and use for selection as well.*

ORIGINAL ARTICLE

Key words: *Farta sheep, body weight, linear body measurements, regression model*

INTRODUCTION

Farta breed of sheep is one of the sheep breeds found distributed in the south Gonder zone of the Amhara national regional state, Ethiopia. These sheep are kept mainly for meat production (sale and slaughter) under the traditional management systems (Shigdaf et al., Unpublished). There is no any specialized breed improvement program designed for this sheep. Genetic improvement of its live weight is required to increase meat yield from this breed.

Body measurements are simple and easily measured variables for estimating live weight with relatively lower costs with a high relative accuracy and consistency (Sowande and Sobola, 2007; Stephen et al., 2010). In addition, body measurements have been used to evaluate performance and characterize breed of animals, assess growth rate, feed utilization and carcass characteristics in farm animals (Anye et al., 2010; Stephen et al., 2010).

Estimation of the relationship between body measurements in sheep may help to provide means for predicting traits which are not normally and easily measured under field conditions. In a breeding programme where improved live weight is the overall breeding objective other body measurements having strong correlation to

To cite this paper: Taye M, Bimerow T, Yitayew A, Mekuriaw SH, Mekuriaw G. 2012. Estimation of live body weight from linear body measurements for Farta sheep. *Online J. Anim. Feed Res.*, 2(1): 98-103.
Scienceline/Journal homepages: http://www.science-line.com/index/; http://www.ojafr.ir

live weight could be considered (Sowande and Sobola, 2007). There is paucity of information on the relationship between live weight and body measurements of Farta sheep. This study was undertaken to investigate the relationship between linear body measurements and obtain prediction equations for estimating live weight of Farta sheep from five body measurements for the purpose of breed characterization.

MATERIALS AND METHODS

Study Area

The study was conducted in Estie, Farta and Lai-Gaint districts of south Gondar zone, Amhara region where Farta sheep is distributed. Farta district is located about 100 km north-east of Bahir Dar, capital of the Amhara National Regional State. Farta lies within an altitude range of 1920-4135 m a.s.l. The district receives an average annual rain fall of 900-1099 mm and a mean-range temperature of 9-25 C° (Farta District OoARD, annual report). The second district, Lai-Gaint district, is located 175 km from Bahir Dar and lies between an altitude ranges 1300-3500 m.a.s.l. Lai-Gaint receives an annual average rain fall of 600-1100 mm and mean minimum and mean maximum temperature of 9 and 19 C°, respectively. The third district, Estie district, is located 157 km North West of Bahir Dar city having an altitude range of 1500-4000 m.a.s.l. The minimum and maximum mean annual rainfall perception of the area is 1307-1500 mm and the mean annual minimum and maximum temperature is 8.3 ^{0}C - 25^{0}C (ENMA, unpublished).

Study Animals and Management

Study animals considered were Farta sheep. They are short fat tail; wooly under coat; medium sized; commonly white (37.5%), brown (27.5%) and black with brown belly (15%), white/brown with brown/white patches (Solomon, 2008). Sheep were managed under traditional systems; the main feed resources were natural pasture (communal and private grazing land), crop residue, improved forage, and crop aftermath.

Data Collection

Data on Weight and other linear body measurements were collected from 941 sheep, with different age/dentition and sex groups. Age was estimated based on dentition groups, Pair of Permanent Incisors (PPI) (0PPI - sheep with milk teeth; 1PPI - sheep with 1 PPI; 2PPI - sheep with 2 PPI; 3PPI - sheep with 3 PPI; 4PPI - sheep with 4 PPI and above). For dentition group 0PPI, sheep approaching to one year of age, based on information from the owner and physical estimation, were used.

Weight measurement, the live weight of an animal, was taken using the Salter scale (50 kg capacity with 200 gram precision). Linear body measurements (heart girth, wither height, body length, pelvic width and ear length) were taken using flexible metal tape (3 meter length) to the nearest 0.5 cm after restraining and holding the animals in an unforced position. The reference points taken were: heart girth - the circumference of the chest posterior to the forelegs at right angles to the body axis; wither height - the highest point measured as the vertical distance from the top of the shoulder to the ground (bottom of forelegs); body length - horizontal length from the point of shoulder to the pin bone; pelvic width - horizontal distance between the extreme lateral points of the hook bone (*tuber coxae*) of the pelvis; and ear length - length of the external ear from its root to the tip.

Statistical Analyses

Statistical analyses were carried out using SPSS Software version 12.0 (SPSS 2003) General Linear Model (GLM) procedures, and linear and nonlinear regression procedures. Sex and dentition were considered as fixed effects. Live weight was regressed on other body measurements for sexes, dentition groups and for the pool. In the multiple regression equation, prediction equations were developed using a stepwise elimination procedure.

The following models were used for data analysis.

$Y_{ij} = \mu + S_i + T_j + (ST)_{ij} + e_{ij}$	(GLM)	Model 1
$W = a + bG$	(Simple linear)	Model 2
$W = a + b1G + b2G^2$	(Quadratic)	Model 3
$W = a + b1G1 + b2G2 + ... + bnGn$	(Multiple linear)	Model 4

Where Y_{ijk} = The observation on body weight and other linear body measurements; W = The observation on live weight of the animal; μ = Overall mean; S_i = Fixed effect of sex (i = Female, Male); T_k = Fixed effect of dentition (k = 0, 1, 2, 3, 4); $(ST)_{jk}$ = the interaction effect of sex with dentition; a = Intercept; b= Regression coefficient of weight on body measurements; G = Body measurements; n = nth number of body measurement; e_{ijk} = effect of random error

RESULT AND DISCUSSIONS

Body Weight and Linear Body Measurements

The mean body weight and linear body measurements of Farta sheep are presented in Table 1. The overall mean body weight, wither height, body length, chest girth, pelvic width and ear length obtained in the present study was 26.2±0.32 kg, 64.3±0.34 cm, 55.6±0.35 cm, 70.9±0.44 cm, 12.8±0.11 and 9.35+0.12 cm, respectively.

There was significant difference ($p<0.05$) in body measurements (except ear length) between sexes and dentition groups. Males were superior over females in all the measurements except pelvic width where they were

To cite this paper: Taye M, Bimerow T, Yitayew A, Mekuriaw SH, Mekuriaw G. 2012. Estimation of live body weight from linear body measurements for Farta sheep. *Online J. Anim. Feed Res.*, 2(1): 98-103.
Scienceline/Journal homepages: http://www.science-line.com/index/; http://www.ojafr.ir

similar (P>0.05). As can be expected, sheep with 0PPI were lower in all the measurements followed by sheep with 1PPI. This might be because they are still growing. Sheep with 2PPI and above were similar almost in all the measurements, may be because Farta sheep attains maturity when it erupts the first 2PPI.

Table 1 - Least squares means and standard errors (LSM±SE) of body weight and linear measurements of Farta sheep as affected by sex and dentition

Variables	N	BW (kg)	WH (cm)	BL (cm)	CG (cm)	PW (cm)	EL (cm)
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	941	26.20±0.32	64.31±0.34	55.59±0.35	70.86±0.44	12.79±0.11	9.35±0.12
Sex		***	***	***	*	NS	NS
Female	800	23.82±0.19	62.16±0.20	54.30±0.20	69.76±0.26	12.83±0.06	9.67±0.07
Male	141	28.58±0.62	66.46±0.65	56.89±0.67	71.96±0.84	12.76±0.22	9.03±0.24
Dent		***	***	***	***	***	NS
0PPI	315	15.82±0.23[a]	56.54±0.24[a]	48.45±0.25[a]	58.91±0.31[a]	10.66±0.08[a]	9.23±0.09
1PPI	64	26.02±0.70[b]	65.12±0.74[b]	55.36±0.76[b]	72.25±0.95[b]	13.00±0.25[b]	9.40±0.27
2PPI	61	28.33±0.65[c]	65.39±0.68[c]	56.33±0.71[b]	73.30±0.88[bc]	12.78±0.23[b]	9.44±0.25
3PPI	74	29.75±0.83[cd]	66.83±0.87[cd]	59.01±0.90[c]	73.67±1.13[bc]	13.69±0.29[c]	8.93±0.32
4PPI	427	31.09±0.98[d]	67.67±1.03[d]	58.82±1.07[c]	76.15±1.33[c]	13.84±0.35[c]	9.75±0.38
Sex*Dent		***	**	NS	NS	NS	NS

NS: Not significant (P>0.05), *P<0.05, **P<0.01, ***P<0.001; BW - Body Weight; CG - Chest Girth; BL - Body Length; PW - Pelvic Width; WH - Wither Height; EL - Ear length; 0PPI - sheep with milk teeth (>about 9 months); 1PPI - sheep with 1 pair of permanent incisor (PPI); 2PPI - sheep with 2 PPI; 3PPI - sheep with 3 PPI; 4PPI - sheep with 4 PPI and above

Correlation between Weight and Linear Body Measurements

The Pearson's correlation of linear body measurements with weight and with each other is presented in Table 2. There were significant and positive relationships between body weight and other linear body measurements and with each other irrespective of age and sex, except ear length to which there was inconsistent relationships.

Chest girth had the highest correlation coefficient (r=0.43-0.87; p<0.01) with body weight in both sexes and all dentition groups which is followed by wither height and body length. Ear length has almost no correlation with body weight (inconsistent relationship). Good correlation coefficients between body weight and chest girth was also reported for Menz and Washera sheep (Tibbo et al., 2004; Mengistie et al., 2010). Strong and positive correlation between body weight and other linear body measurements have also been reported by different scholars (Sowande and Sobola, 2007; Khan et al., 2006).

The relationship between linear body measurements and weight was different for different age groups. The highest correlation coefficient was depicted with chest girth followed by wither height at age group 0PPI. The correlation coefficient, in general, decreases as the age advances. This is in agreement with other findings (Mengistie et al., 2010) and disagrees with the findings of Khan et al. (2006).

With regard to sex, males had better correlation coefficient and agree with literature (Alade et al., 2008; Khan et al., 2006; Stephen et al., 2010). The highest coefficient was found with chest girth (87% for males and 86% for females) followed by wither hight (86%) for males and body length (76%) for females.

The high and significant correlation coefficients between body weight and linear 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 Farta sheep.

Prediction of Weight Using Body Measurements

Regression models developed are presented in Figures 1, 2, 3, 4 and Table 3. Different regression models were developed for different sexes, dentition groups and for the pool.

The regression equations developed had different coefficient of determination and the body measurements used to predict weight were different for different age groups; might be because of the difference in growth and proportion of conformational traits at different ages. This tends to infer that at different ages different conformational traits may be better to predict weight and can be more successful for selection (Thiruvenkadan, 2010). The coefficient of determination of the fitted equations (in general) decreased as the age of sheep advances indicating that the fitted equations can predict weight for younger sheep with better accuracy than for older ones. This is in agreement with literature (Mengistie et al., 2010; Thiruvenkadan, 2010).

Chest girth was the first variable to explain variation in weight for age groups 0PPI and 4PPI followed by body length. However, in age groups 1, 2 and 3PPI height at withers and body length accounted for the greatest amount of variation in body weight.

With regard to sex, the coefficients of determination of prediction equations were almost similar ranged from 75.5-83.8 for female sheep and 76.7-89.3 for male sheep. Chest girth was the first variables to explain more variation followed by body length in both male and female sheep. The highest coefficient of determination was obtained when the equations were fitted for the pool (for all age group) which is in agreement with other findings (Thiruvenkadan, 2010). Chest girth was the first variable to explain most of the variation in weight. Hence, this regression equation alone may be used to predict the body weight of Farta sheep at different age groups.

In general, much of the variation in weight was explained when many traits were included in the model.

To cite this paper: Taye M, Bimerow T, Yitayew A, Mekuriaw SH, Mekuriaw G. 2012. Estimation of live body weight from linear body measurements for Farta sheep. *Online J. Anim. Feed Res.*, 2(1): 98-103.
Scienceline/Journal homepages: http://www.science-line.com/index/; http://www.ojafr.ir

Table 2 - Correlation coefficients between body weight and linear body measurements of Farta sheep by age and dentition groups

Parameter	Measurements	WH	BL	CG	PW	EL
Overall	BW	0.78**	0.78**	0.87**	0.73**	0.12**
	WH		0.75**	0.72**	0.63**	0.19**
	BL			0.66**	0.65**	0.21**
	CG				0.72**	0.11**
	PW					0.16**
Dentition						
0PPI	BW	0.75**	0.68**	0.78**	0.60**	0.17**
	WH		0.62**	0.60**	0.51**	0.16**
	BL			0.44**	0.45**	0.23**
	CG				0.58**	0.15**
	PW					0.11*
1PPI	BW	0.64**	0.41**	0.50**	0.35**	-0.02NS
	WH		0.57**	0.31*	0.24NS	0.18NS
	BL			-0.01NS	0.21 NS	0.25*
	CG				0.30*	-0.22NS
	PW					0.11NS
2PPI	BW	0.51**	0.47**	0.43**	-0.00NS	-0.27*
	WH		0.44**	0.19NS	-0.2NS	-0.12NS
	BL			0.02NS	0.06NS	0.03NS
	CG				0.21NS	-0.24NS
	PW					0.21NS
3PPI	BW	0.46**	0.62**	0.50**	0.49**	-0.03NS
	WH		0.52**	0.14NS	0.13NS	-0.06NS
	BL			0.10NS	0.33**	0.01NS
	CG				0.27*	0.06NS
	PW					0.07NS
4PPI	BW	0.35**	0.45**	0.64**	0.23**	0.00NS
	WH		0.44**	0.25**	0.18**	0.18**
	BL			0.12**	0.22**	0.14**
	CG				0.16**	-0.03NS
	PW					0.07NS
Sex						
Female	BW	0.75**	0.76**	0.86**	0.71**	0.11**
	WH		0.73**	0.70**	0.62**	0.20**
	BL			0.62**	0.62**	0.20**
	CG				0.69**	0.09**
	PW					0.14**
Male	BW	0.86**	0.83**	0.87**	0.71**	-0.00NS
	WH		0.79**	0.78**	0.62**	0.01NS
	BL			0.67**	0.62**	0.09NS
	CG				0.70**	0.00NS
	PW					0.03NS

***P<0.01; *P<0.05; NS Not significant; BW - Body Weight; CG - Chest Girth; BL - Body Length; PW - Pelvic Width; WH - Wither Height; EL - Ear length; 0PPI - sheep with milk teeth (>about 9 months); 1PPI - sheep with 1 pair of permanent incisor (PPI); 2PPI - sheep with 2 PPI; 3PPI - sheep with 3 PPI; 4PPI - sheep with 4 PPI and above*

BW = -34.61+0.93WH

$BW = -53.86+1.58WH-0.0053WH^2$

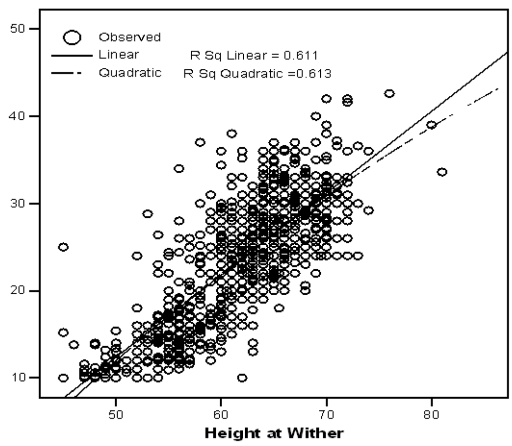

Figure 1. Estimation of weight using height at wither

BW = -26.576+0.9288BL

$BW = -65.519+2.4207BL-0.0141BL^2$

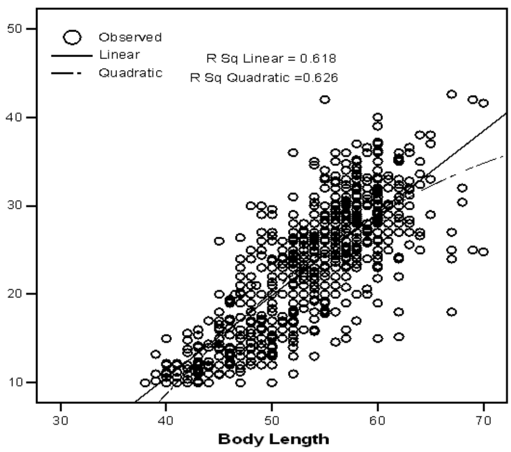

Figure 2. Estimation of weight using body length

To cite this paper: Taye M, Bimerow T, Yitayew A, Mekuriaw SH, Mekuriaw G. 2012. Estimation of live body weight from linear body measurements for Farta sheep. *Online J. Anim. Feed Res.*, 2(1): 98-103.
Scienceline/Journal homepages: http://www.science-line.com/index/; http://www.ojafr.ir

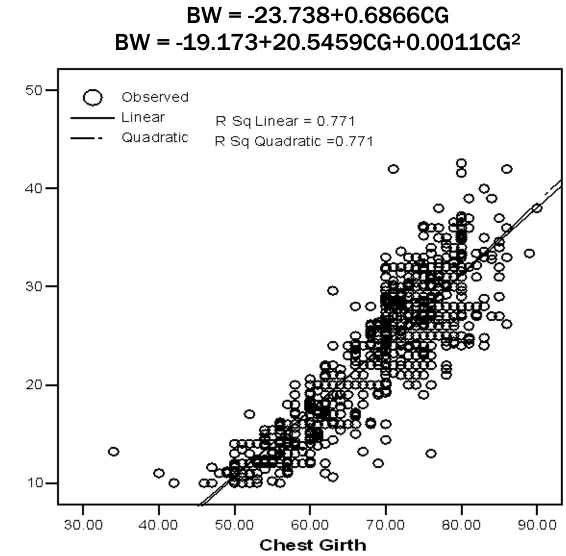

Figure 3. Estimation of weight using chest girth

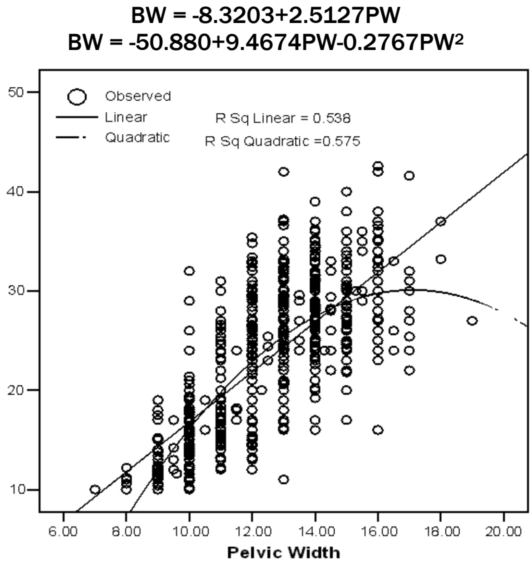

Figure 4. Estimation of weight using pelvic width

Table 3 - Linear and Multiple linear regression equations for predicting body weight from linear body measurements for sex and dentition groups

Age	Model	B_0	X_1	X_2	X_3	X_4	X_5	R^2	R^2 Change	SE
Dentition										
0PPI	CG	-11.482	0.461					0.625	0.625	2.316
	CG+BL	-20.777	0.353	0.324				0.765	0.140	1.837
	CG+BL+WH	-24.781	0.286	0.228	0.224			0.802	0.038	1.686
	CG+BL+WH+PW	-24.815	0.269	0.218	0.214	0.194		0.806	0.003	1.675
1PPI	WH	-17.747	0.665					0.416	0.416	3.740
	CG+WH	-30.006	0.269	0.558				0.516	0.100	3.432
2PPI	WH	-6.071	0.510					0.259	0.259	3.181
	CG+WH	-21.420	0.271	0.442				0.376	0.117	2.945
	CG+BL+WH	-35.729	0.287	0.414	0.286			0.469	0.093	2.741
3PPI	BL	-7.121	0.600					0.396	0.396	3.099
	CG+BL	-32.775	0.385	0.557				0.588	0.192	2.578
	CG+BL+PW	-34.245	0.341	0.495	0.610			0.624	0.036	2.481
4PPI	CG	-16.677	0.601					0.411	0.411	3.192
	CG+BL	-35.765	0.556	0.392				0.549	0.139	2.794
Sex										
Females	CG	-24.306	0.694					0.755	0.755	3.273
	CG+BL	-34.503	0.516	0.416				0.830	0.076	2.722
	CG+BL+PW	-34.108	0.478	0.381	0.319			0.834	0.004	2.691
	CG+BL+PW+WH	-36.183	0.452	0.331	0.288	0.113		0.838	0.003	2.667
	CG+BL+PW+WH+EL	-35.454	0.448	0.336	0.294	0.119	-0.124	0.838	0.001	2.663
Males	CG	-23.534	0.691					0.767	0.767	3.598
	CG+BL	-35.569	0.455	0.525				0.877	0.110	2.625
	CG+BL+WH	-38.688	0.365	0.381	0.269			0.893	0.016	2.453
Pooled										
	CG	-23.686	0.686					0.771	0.771	3.32
	CG+BL	-34.038	0.497	0.433				0.846	0.076	2.72
	CG+BL+WH	-36.822	0.456	0.358	0.156			0.852	0.006	2.67
	CG+BL+WH+PW	-36.399	0.428	0.335	0.149	0.255		0.855	0.002	2.65
	CG+BL+WH+PW+EL	-35.404	0.424	0.341	0.154	0.265	0.255	0.856	0.001	2.64

[2]Dependent Variable: BW (Body weight) - Body Weight; CG - Chest Girth; BL - Body Length; PW – Pelvic Width; WH - Wither Height; EL - Ear length. [1]Dentition 0PPI - sheep with milk teeth (> 9 months); 1PPI - sheep with 1 pair of permanent incisor (PPI); 2PPI - sheep with 2 PPI; 3PPI - sheep with 3 PPI; 4PPI - sheep with 4 PPI and above

To cite this paper: Taye M, Bimerow T, Yitayew A, Mekuriaw SH, Mekuriaw G. 2012. Estimation of live body weight from linear body measurements for Farta sheep. *Online J. Anim. Feed Res.*, 2(1): 98-103.
Scienceline/Journal homepages: http://www.science-line.com/index/; http://www.ojafr.ir

Comparison of Actual Weight and Predicted Weight

An effort to investigate the disparity between the actual weight and the predicted weight using the models developed for the pool (for all sex and age group) resulted with no significant difference between the actual weigh and the predicted weight except for model 5. Though, there were increments and decrements of values of the individual observations from the actual weight when using the equations, the mean of these values indicated that there were no as such a difference.

Table 4 - Comparison of the predicted weight values with the actual weight (for the pool)

Model	Mean	Std. Deviation	Range	Minimum	Maximum
Model 1	23.55[a]	6.04	34.30	3.75	38.05
Model 2	23.52[a]	6.38	36.06	2.78	38.84
Model 3	23.52[a]	6.40	34.30	4.03	38.33
Model 4	23.58[a]	6.41	34.27	4.06	38.33
Model 5	27.51[b]	6.54	35.25	7.73	42.98

Means with in a column with different superscripts are significantly different at 0.05

CONCLUSION

Body weight and other linear body measurements were significantly and positively correlated with weight and each other. From the result, it can be concluded that using linear body measurements can be a simple and reliable method for estimating body weight for Farta sheep. The higher association of body weight with heart girth, in general, over other linear measurements indicates use of this measurement alone or in combination with others can estimate weight with better accuracy and relative ease.

As a method to estimate weight using linear body measurements, it is possible to use these linear body measurements for selection in an effort to improve body weight of Farta sheep. In addition, the difference in the correlation coefficients between weight and other linear measurements for different age groups indicates the possibility of using different body measurements at different ages to predict weight and use for selection as well.

ACKNOWLEDGEMENTS

The authors are grateful for Andassa Livestock Research Center for financing the field work.

REFERENCES

Afolayan R, Adeyinka AIA and Lakpini CAM (2006). The estimation of live weight from body measurements in Yankasa sheep. Czech Journal of Animal Sciences 51(8): 343–348.

Alade NK, Raji AO and Atiku MA (2008). Determination of Appropriate Model for the Estimation of Body Weight in Goats. Journal of Agricultural and Biological Science 3 (4): 51-57.

Anye NH, Manjeli Y and Ebangi AL (2010). A method of live weight evaluation for local guinea pigs (*Cavia porcellus* L.) of the western highlands of Cameroon: synthesis of linear body measurements. Livestock Research for Rural Development. Volume 22, Article #184. Retrieved February 24, 2000, from http://www.lrrd.org/lrrd22/10/anye22184.htm

Benyi K (1997). Estimation of liveweight from chest girth in pure and crossbred West African goats. Tropical Animal Health and Production, 29, 124–128

Brown JE, Brown CJ and Butts WT (1973). Evaluating relationships among immature measures of size, shape and performance on beef bulls. 1. Principal component as measures of size and shape in young Hereford and Angus bulls. Journal of Animal Science 36: 1010-1020.

Fasae OA, Chineke AC and Alokan JA (2005). Relationship between some physical parameters of grazing Yankasa ewes in the humid zone of Nigeria. Archivos de Zootecnia, 54, 639–642

Khan H, Muhammad F, Ahmad R, Nawaz G, Rahimullah and Zubair (2006). Relationship of body weight with linear body measurements in goats. Journal of Agricultural and Biological Science 1 (3): 51-54

Mengistie Taye, Girma Abebe, Solomon Gizaw, Sisay Lema, Abebe Mekoya and Markos Tibbo (2010). Traditional management systems and linear body measurements of Washera sheep in the western highlands of the Amhara National Regional State, Ethiopia. Livestock Research for Rural Development. Volume 22, Article #169. Retrieved February 24, 2000, from http://www.lrrd.org/lrrd22/9/taye22169.htm

Solomon Gizaw (2008). Sheep resources of Ethiopia: genetic diversity and breeding strategy. PhD thesis, Wageningen University, The Netherlands.

Sowande OS and Sobola OS (2007). Body measurements of west African dwarf sheep as parameters for estimation of live weight. Trop Anim Health Prod. DOI 10.1007/s11250-007-9116-z

Stephen Sunday, Acheneje Egena, Garba Husseini, Timothy Silas and Tairu Ciroma Musa (2010). Effect of Sex on Linear Body Measurements of Guinea Pig (*Cavia porcellus*). AU J.T. 14(1): 61-65.

Thiruvenkadan AK (2005). Determination of best-fitted regression model for estimation of body weight in Kanni Adu kids under farmer's management system. Livestock Research for Rural Development. Volume 17, Article #85. Retrieved February 24, 2000, from http://www.lrrd.org/lrrd17/7/thir17085.htm