Predicting live weight using body measurements in Afar goats in north eastern Ethiopia

Theodros Tekle*
College of Veterinary Medicine, Mekelle University. P.O. Box 231. Mekelle, Ethiopia (*theodt2002@yahoo.com)

ABSTRACT
Regression analysis was performed for developing live weight prediction models for Afar goats using data on live weight and linear body measurements of randomly selected 318 goats of different age and sex categories in Gulina woreda, Zone Four of Afar region. Adjusted R^2, root mean square error, conceptual predictive criterion and Akaike information criterion were used to choose the best fitted regression model and the developed models were verified using 173 bucks of the same breed. In both sexes of young goats (0PPI, zero or no pairs of permanent incisors), live weight was significantly and strongly correlated (r=0.80-0.90) with chest girth, body length, height at withers and neck circumference. In young female goats (0PPI), the relationship between live weight and body measurements was higher than male kids. In the pooled data, significant and strong correlation (r=0.81-0.94) between live weight and body measurements chest girth and body length was noted. Whereas the association between live weight and body measurements height at withers, rump height and pelvic width were found to be significant and moderate (r=0.60-0.65). Model based on body length separately was able to explain 89% of the variation in live weight in females while in males models based on chest girth separately explained 35% of variation in live weight. In the pooled data model based on chest girth alone explained 67% of the variation in live weight. Models developed for animals at younger age and for female goats in the pooled data scored higher R^2. Models based on two or more measurements were better in explaining the variation in live weight. In Afar goats, models based on chest girth or a combination of body length and pelvic width were found to be important for predicting body weight irrespective of age and sex.

Keywords: Afar goat, Chest girth, Live weight, Regression, Gulina, Afar Region, Ethiopia.

1. INTRODUCTION

Ethiopia is home for diverse goat genetic resources spread across diverse ecology, communities and production systems (Gizaw, 2008). The goat population in Ethiopia was estimated at 22.7 million, of which, approximately 1.7 million goats (13.3%) were found in Afar region (CSA, 2011), represented mainly by Afar goat breed locally known as ‘widar’ kept mainly under pastoral extensive management system. Afar goat plays an important role in the livelihood of Afar pastoralists as source of cash, meat and milk. Because of the current favorable market in the Middle East, exports of live goats and goat meat have significantly increased as compared to earlier times and in contrast to exports of other livestock and meat (Mekasha, 2007).

Accurate determination of live weight (LW) of goats is required for sound management practices including health care, breeding (selection), feeding and marketing (Thiruvenkadan, 2005). When producers and buyers of livestock are able to relate animal measurements to growth characteristics, optimum production and value-based trading systems will be realized (Birteebi and Ozoje, 2012). According to Afolayan et al. (2006), knowledge of LW would ensure that farmers get value for their stock rather than the middlemen. However, in many developing countries such trading system based on LW is not being practiced. For example, in Afar pastoral area of Ethiopia weight measuring scales are not easily available. Therefore, goat 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). According to Slippers et al. (2000), such questionable estimates of LW lead to inaccuracies in decision-making and husbandry practices. Hence, there is a need for developing indirect methods for estimating LW of goats through regression of LW on body measurements which are measured easily (Thiruvenkadan, 2005).

Though Ethiopia is endowed with diverse goat genetic resources, there is limited information on the indirect methods of estimating LW in goats through the use of regression analysis to establish the relationship between LW and body measurements. So far, LW prediction models are available for the Short-eared Somali (Gebreyesus et al., 2012) and Abergelle (Tadesse et al., 2012) goat breeds. According to Yakubu et al. (2011), since LW and body measurement parameters vary with breed and environment, breed specific models need to be developed. Therefore, this study was aimed at developing models for predicting LW of Afar goats using body measurements based on data collected in Gulina woreda of Afar region in north eastern Ethiopia.

2. METHODOLOGY

2.1. Description of the study area

The field data was collected in Gulina woreda, Zone Four of Afar region. Gulina woreda covers a total land area of 1,228km^2. It is located at a distance of 674km from Addis Ababa, capital of Ethiopia. Kelwan is a small rural town located at geographic coordinates of 13°27$^{'}$36.00$^{''}$N and 39°27$^{'}$00.00$^{''}$E and it is the centre for Zone 4 and Gulina woreda. Figure 1 presents the location of the study area.

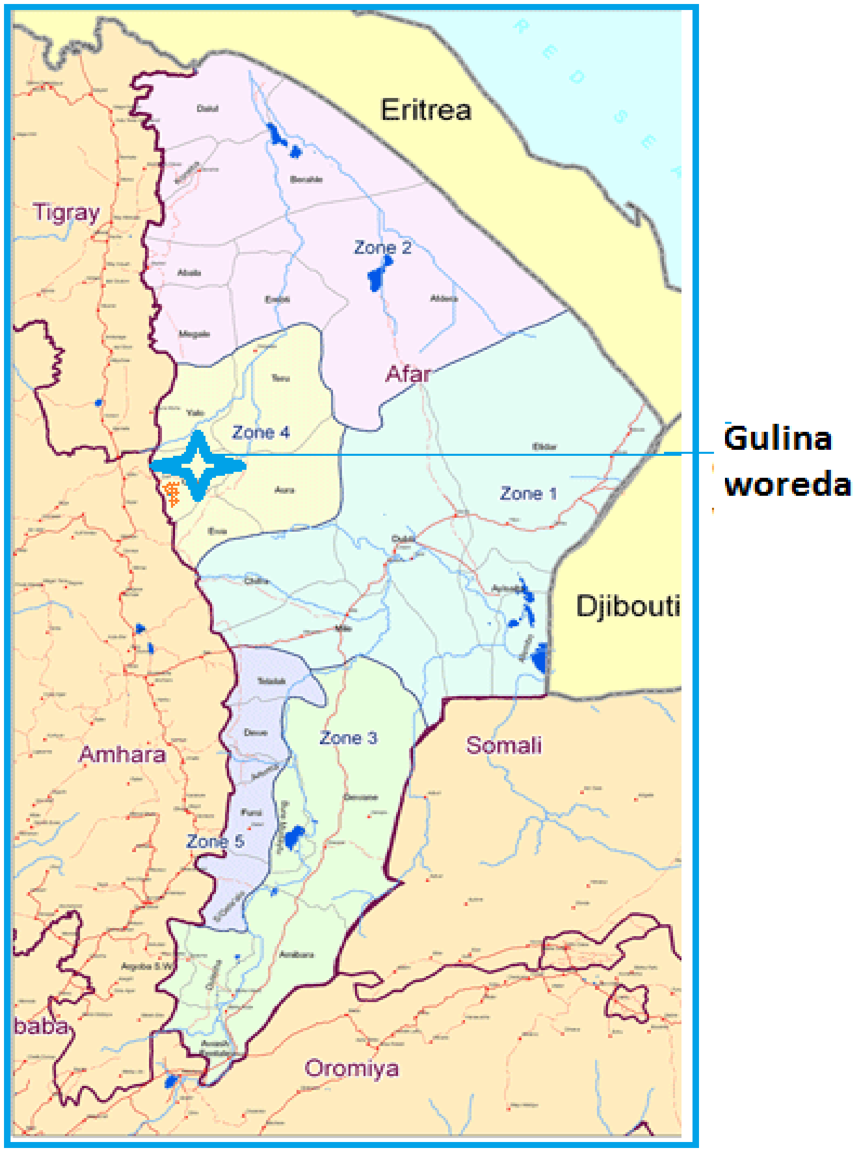

Figure 1. Map showing study area in Afar region of Ethiopia.
(Source:http://www.idp-uk.org/Resources/Maps/Administrative%20Regions/Afar-Region2.gif)

The livestock population in Gulina woreda was estimated at 11, 231 cattle; 11,079 sheep; 37,158 goats; 4,818 camels and 271 donkeys (BoPARD, 2008). Goats and sheep are managed together in a mixed flock under extensive pastoral management system but un-weaned kids and lambs were housed separately while goats within the age of 2 to 3½ years were the preferred animals for marketing in the study area (personal observation). The climate of the study area vary from arid to semi-arid with annual average rainfall of 590mm and monthly average temperature of 15-37.8°C (BoPARD, 2008). The vegetation cover of the study area consists mainly of sparse cover of low shrubs and closed thickets of bush such as *Acacia millifera, Acacia senegal, Acacia* *torrtilis, Prosopis juliflora, Commiphora* species and *Avena* species and associated grasses like *Aristida, Chloris, Entropagon, Panicum* and *Cynodon* species (BoPARD, 2008).

Verification of the developed models was performed based on the data on body measurements of randomly selected 173 bucks of Afar breed which were delivered for slaughtering at Abergelle International Export Slaughter house. Abergelle International Export Slaughter house is located at a distance of 9km North of Mekelle.

2.2. Sampling procedure and data collection

A multi-stage sampling procedure was employed for selecting the primary (kebeles) and secondary sampling units (pastoral encampments) taking into consideration the presence of sufficient goat flocks and the accessibility of the study sites. Out of 8 kebeles in Gulina woreda, 5 kebeles namely Derayetu, Wanasana Harigerbo, Galicoma, Kelwan and Mulina Asale were purposively selected. From each of the selected kebeles, 4 encampments were randomly selected and from the selected encampments 1-2 goat flocks were randomly selected. Therefore, a total of 39 goat flocks were targeted and from these this flocks 8-9 goats were selected on random basis based on the sex and age, therefore, a total of 318 goats (213 females and 105 males) of different age and sex are used in the present study (Table 1).

Table 1. Study goats by age and sex category.

Sex	***Age categories***				***Total***
	0PPI	***1PPI***	***2PPI***	***3PPI***	
F	30	25	80	78	213
M	25	20	30	30	105
Total	55	45	110	108	**318**

Key: *F: female; M: male; PPI: pairs of permanent incisor.*

Age grouping was based on eruption of permanent incisors as 0PPI (referring to goats with no pairs of permanent incisors); 1PPI (goats with one pair of permanent incisors); 2PPI (goats with two pairs of permanent incisors) whereas 3PPI consisted of goats with 3 and more pairs of permanent incisors according to Abegaz and Awgichew (2009). Data on LW and body measurement parameters were collected separately for each sex and age category. Data collection focused on recording the sex, age, LW, chest girth (CG), height at withers (HAW), body length (BL), rump height (RH); pelvic width (PW), ear length (EL) and neck circumference (NC). LW was measured using a hanging scale (capacity 50 kg).

Body measurements were taken using measuring tape to the nearest centimeter (cm). CG was measured as the distance around the animal measured directly behind the front legs; HAW was measured as the height of a standing goat perpendicular to the ground on a flat surface; RH was measured as a perpendicular distance from *Spina illiaca* to the ground; BL was measured as the distance between the base of neck (first thoracic vertebrae) to the base of the tail; PW was measured as distance between the two pelvic bones across the dorsum; EL was measured as the distance between the point of attachment of the ear to the head to the tip of the ear while NC was measured as circumference around the neck.

Data on LW and body measurements were taken early in the morning before the goats were let out of their enclosure for browsing, with the goats being kept comfortably and quietly at standing position on a flat surface. Only goats which were physically healthy and free of signs of disease were included in this study. Pregnant animals were excluded because pregnancy has effect on some morphometric parameters especially those of the thoracic and rump regions (Yakubu et al., 2011). In addition, there were very few castrated bucks in the study flocks hence castrated bucks were not part of the study. All measurements were taken by the same person to minimize human error.

2.3. Data analysis

The collected data on LW and body measurements were subjected to various statistical analyses using the computer software statistical analysis system (SAS, 2002). Mean (± SEM) for LW and body measurements were computed for each age and sex category. PROC GLM of SAS was used to note statistically significant differences in LW and body measurements for each sex by age category. The relationship between LW and body measurements and the relationship between body measurement parameters was established using Proc corr (Correlation procedure) of SAS (SAS, 2002) for each sex by age group. Forward selection regression procedure was employed to identify independent variables that significantly contributed to LW prediction models for each sex by age category. The regression analysis was conducted separately for male and female goats for each age group and for the pooled data by sex categories. In addition, body measurements which were insignificant were excluded to obtain the optimal model. The choice of the best fitted regression model was determined using coefficient of determination (Adj R^2), root mean square error (RMSE), conceptual predictive criterion [C(p)] and Akaike information criterion (AIC).

Collinearity diagnostics was performed using Variance Inflation Factor (VIF) where VIF > 10 taken as a cutoff point. The ability of the developed models to predict new observations was verified by taking body measurements of bucks purchased for slaughter at Abergelle International Export Slaughter house and checking the R^2 predicted. During data analysis the stopping rules employed were made by adjusting alpha (0.5) and F value.

The following statistical model was used:

$Y = \beta_0 + \beta_1X_1 + \beta_2 X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \varepsilon$

Where: Y = LW, the dependent variable,

β_0 = population constant common to all observations (intercept)

X_1-X_7 = represent the independent variables CG, BL, HAW, RH, PW, NC and EL.

β_1-β_7 = represent regression coefficients of the independent variables X_1 to X_7, respectively while ε is residual error. Statistically significant differences were declared at $P < 0.05$.

3. RESULTS

The LW of Afar goats for age groups 0PPI, 1PPI, 2PPI and 3PPI were 14.3 ± 0.5 kg, 20.4 ± 0.4 kg, 23.8 ± 0.3 kg and 23.7 ± 0.4 kg, respectively. For pooled data, the mean LW in female and male Afar goats was recorded as 20.0±0.3 kg and 22.4±0.4 kg, respectively. In this study based on data of all age and sex groups, mean CG, BL, HAW, RH, PW, NC, EL and LW were recorded as 64.6±0.4 cm, 60.1±0.3 cm, 60.6±0.3 cm, 63.2±0.3 cm, 11.8±0.1 cm, 25.8±0.2 cm, 12.1±0.1 cm and 21.6±0.3 kg, respectively. Significant differences in body measurement parameters and LW for each sex by age categories are summarized in table 2. This study has shown that at younger age (0PPI), only RH, NC and LW varied with sex. Except EL in age group 2PPI and RH in pooled data, all body measurement parameters and LW varied with sex in goats belonging to age group 2PPI and for pooled data consisting of all studied goats (Table 2). LW varied with sex in goats belonging to age group 2PPI and for pooled data consisting of all study goats (Table 2).

Table 3 is the summary of the results on the relationship between LW and body measurement parameters by age and sex categories. In mixed data of young goats (0PPI), LW was significantly and strongly correlated (r=0.80-0.90) with CG, BL, HAW and NC. In young (0PPI) female goats, the relationship between LW and body measurements is higher than their male contemporaries.

Table 2. Mean (±SEM) for body measurement parameters (cm) and LW (kg) by age and sex categories, Afar goats.

Age	***Sex***	***N***	***CG***	***BL***	***HAW***	***RH***	***PW***	***NC***	***EL***	***LW***
0PPI	F	30	51.2(0.6)	48.5(0.6)	49.7(0.7)	53.4(0.4)^{a}	9.5(0.3)	19.8(0.2)^{a}	12.5(0.1)	12.1(0.3)^{a}
	M	25	59.4(0.8)	56.2(0.9)	59.2(0.7)	59.7(1.9)^{b}	10.3(0.3)	25.2(0.6)^{b}	11.3(0.3)	16.9(0.6)^{b}
	M+F	55	54.9(0.7)	52.0(0.7)	54.0(0.8)	56.3(0.9)	9.8(0.2)	22.2(0.5)	11.9(0.2)	14.3(0.5)
1PPI	F	25	61.9(0.4)^{a}	57.8(0.4)^{a}	59.6(0.9)^{a}	61.8(0.4)^{a}	12.4(0.2)	24.8(0.3)^{a}	13.4(0.2)^{a}	20.2(0.2)^{a}
	M	20	61.9(1.2)^{b}	57.9(1.2)^{b}	61.0(1.2)^{b}	63.8(1.3)^{b}	10.5(0.3)	27.1(0.7)^{b}	11.7(0.3)^{b}	20.5(0.8)^{b}
	M+F	45	61.9(0.6)	57.8(0.6)	60.2(0.7)	62.7(0.6)	11.6(0.2)	25.8(0.4)	12.6(0.2)	20.4(0.4)
2PPI	F	80	68.3(0.3)^{a}	62.9(0.3)^{a}	62.5(0.2)^{a}	65.2(0.2)^{a}	12.4(0.1)^{a}	25.3(0.4)^{a}	11.9(0.2)	22.8(0.2)^{a}
	M	30	66.7(1.1)^{b}	61.6(1.0)^{b}	63.3(0.7)^{b}	65.9(0.8)^{b}	12.2(0.4)^{b}	30.2(0.7)^{b}	12.2(0.3)	24.2(0.7)^{b}
	M+F	110	67.9(0.4)	62.5(0.4)	62.8(0.2)	65.4(0.3)	12.4(0.1)	26.6(0.4)	12.0(0.2)	23.8(0.3)
3PPI	F	78	68.8(0.4)^{a}	63.3(0.3)^{a}	61.8(0.3)^{a}	64.5(0.3)^{a}	12.9(0.1)^{a}	26.2(0.2)^{a}	12.5(0.2)^{a}	19.6(0.2)^{a}
	M	30	63.5(0.8)^{b}	61.1(0.8)^{b}	62.2(0.5)^{b}	65.8(0.8)^{b}	11.0(0.3)^{b}	28.4(0.6)^{b}	11.3(0.2)^{b}	25.2(0.9)^{b}
	M+F	108	67.4(0.4)	62.7(0.3)	61.9(0.3)	64.9(0.3)	12.4(0.1)	26.8(0.2)	12.2(0.2)	23.7(0.4)
Pooled	F	213	65.3(0.5)^{a}	60.4(0.4)^{a}	60.1(0.4)^{a}	62.9(0.3)	12.2(0.1)^{a}	24.8(0.2)^{a}	12.4(0.1)^{a}	20.0(0.3)^{a}
	M	105	63.2(0.5)^{b}	59.5(0.5)^{b}	61.6(0.4)^{b}	64.0(0.6)	11.1(0.2)^{b}	27.9(0.4)^{b}	11.6(0.1)^{b}	22.4(0.4)^{b}
	M+F	318	64.6(0.4)	60.1(0.3)	60.6(0.3)	63.2(0.3)	11.8(0.1)	25.8(0.2)	12.1(0.1)	21.6(0.3)

Key: $^{a, b}$: Body measurement and LW values within each age group with different superscripts differ significantly ($p<0.05$);
SEM: standard error of the mean;
PPI: pairs of permanent incisors;
M: male; F: female; F+M: both female and male goats;
N: number of observations; CG: chest girth;
BL: body length; HAW: height at withers;
RH: rump height; PW: pelvic width;
NC: neck circumference; EL: ear length; LW: Live weight.

In pooled data consisting of all age and sex categories, significant and strong correlation (r=0.81-0.94) between LW and body measurements CG and BL was noted while significant and moderate correlation (r=0.60-0.65) between LW and body measurements HAW, RH and PW was recorded.

Table 4 depicts the regression equations developed for predicting LW of Afar goats, for male and female goats separately and for pooled data (female and male goats together). The choice of the best fitted regression model was determined using adjusted coefficient of determination (adj R^2), root mean square error (RMSE), conceptual predictive criterion [C(p)] and Akaike information criterion (AIC). Collinearity diagnostics was performed using Variance Inflation Factor (VIF) where VIF > 10 taken as a cutoff point. Lower values of AIC, c(p) and RMSE were used as indicators of best fitted model.

Table 3. Coefficient of correlation between LW and body measurements, Afar goats.

			Body measurement parameters						
Age	***Sex***	***N***	***CG***	***BL***	***HAW***	***RH***	***PW***	***NC***	***EL***
0PPI	M	25	0.76**	0.72**	0.33^{ns}	0.30^{ns}	0.84**	0.79**	0.24^{ns}
	F	30	0.90**	0.80**	0.97**	0.76**	0.51**	0.76**	0.80**
	M+F	55	0.90**	0.86**	0.80**	0.53**	0.60**	0.89*	-0.12^{ns}
1PPI	M	20	0.42^{ns}	0.47**	0.34^{ns}	0.33^{ns}	0.37^{ns}	0.65*	0.18^{ns}
	F	25	0.62**	-0.03^{ns}	-0.54**	-0.44*	0.52**	-0.16^{ns}	0.05^{ns}
	M+F	45	0.44**	0.40**	0.12^{ns}	0.24^{ns}	0.26^{ns}	0.50**	0.09^{ns}
2PPI	M	30	0.51*	0.63^{ns}	0.63^{ns}	0.51^{ns}	0.38^{ns}	0.38*	0.34^{ns}
	F	80	0.22^{ns}	0.83**	0.33**	0.88**	-0.41**	-0.26*	0.28**
	M+F	110	0.40*	0.72**	0.45**	0.62**	0.02^{ns}	0.11^{ns}	0.25**
3PPI	M	30	0.44**	0.22^{ns}	0.23^{ns}	0.23^{ns}	0.26^{ns}	0.35^{ns}	-0.20^{ns}
	F	78	0.65*	0.68**	0.30**	0.42**	0.23*	0.51**	0.18^{ns}
	M+F	108	0.65**	0.44**	0.13^{ns}	0.09^{ns}	0.53**	0.02^{ns}	0.20*
Pooled	M	105	0.59**	0.52**	0.45**	0.38**	0.50**	0.58**	0.22*
	F	213	0.90**	0.94**	0.81**	0.88**	0.62**	0.58**	0.02^{ns}
	M+F	318	0.82**	0.81**	0.65**	0.62**	0.60**	0.43**	0.11**

Key*: ns: non-significant; *: significant (P<0.05); **: highly significant (P<0.01); PPI: pairs of permanent incisors; N denotes number of observations; CG: chest girth; BL: body length; HAW: height at withers; RH: rump height; PW: pelvic width; NC: neck circumference; EL: ear length; M: male; F: female; F+M: both female and male goats.*

Table 4. LW prediction equations based on pooled data, Afar goats.

Sex	**Equations/models**	**Adj R^2**	**RMSE**	**AIC**	**C(p)**	**p-value**
F (N=213)	LW= -24.9+0.78BL	0.89	1.5	188.6	152.4	<.0001
	LW= -31.4+0.57BL+0.3RH	0.92	1.3	133.7	69.5	<.0001
M (N=105)	LW= -9.8+0.47CG	0.35	3.6	273.2	15.6	<.0001
	LW= -15.6+0.3CG+ 0.2BL	0.43	3.5	261.7	3.63	<.0001
M+F (318)	LW= -17.4+0.6CG	0.67	2.7	644.4	102.9	<.0001
	LW= -21.1+0.5BL + 0.6PW	0.70	2.6	618.8	70.2	<.0001

Key: *R^2: coefficient of determination; RMSE: root mean square error; AIC: Akaike information criterion, C(p): conceptual predictive criterion, F: female; M: female, F+M: both female and male goats, N: number of observations; LW: Live weight; BL: body length; RH: rump height; EL: ear length; HAW: height at withers; NC: neck circumference.*

Based on the pooled data, all the body parameters (CG, BL, HAW, RH, PW, NC and EL) scored VIF value within the range of 1.1 to 3.8 which is less than the cutoff point of 10 signifying that the body measurements considered in this study are not linearly correlated.

Model based on BL separately was able to explain 89% of the variation in LW in female Afar goats while in males models based on CG separately explained 35% of variation in LW. In the pooled data model based on CG alone was able to explain 67% of the variation in LW (Table 4).

Models based on two or more measurements were better in explaining the variation in live weight. In female goats, models based on BL and CG together explain the variation in LW much better than any other variables but BL and CG were significantly and strongly correlated (r=0.88) as a result BL was used in combination with RH and the model explained 92% of the variation in LW of female Afar goats. In male goats, BL and CG were weakly correlated (r=0.56), in this group models based on CG and BL were found the best two variable model and were able to explain 43% of the variation in LW. It was noticed that the developed models were more explanatory in females than male goats.

The ability of the developed models to predict new observations was verified by including 173 new measurements on BL and HAW obtained from bucks ready for slaughter at Abergelle International Export Slaughter house. The model explained 50% of the variability in predicting new observations, as compared to the approximately 51% of the variability in the original data explained by the least squares fit.

4. DISCUSSION

In this study, LW varied with sex where males were found to be heavier (22.4±0.4 kg) than females (20.0±0.3 kg). Consistent with the current study, bucks belonging to the Short Eared Somali (Gebreyesus et al., 2012) and Abergelle (Tadesse et al., 2012) goat breeds in Ethiopia and Beetal goats in Peshawar, Pakistan (Khan et al., 2006) were reported to be heavier than females. The mean LW of bucks of Afar goats recorded in this study was higher than Abergelle bucks (17.3 ± 4.2 kg) while the mean LW recorded for female Afar goats was comparable to female goats of Abergelle goat breed (18.7 ± 3.7 kg) recorded by Tadesse et al. (2012). However, Afar goat breed has been categorized as small breed (Mekasha et al., 2008) which may be explained by differences in nutrition, agro-ecology or environment and season.

This study on Afar goats has revealed that at younger age (0PPI), only RH, NC and LW varied with sex. With the exception of PW recorded in age group 1PPI, EL in age group 2PPI and RH in pooled data, the body measurement parameters and LW in age group 1PPI, 2PPI and pooled data varied with sex and higher values were recorded for male goats. Similar to the finding of this study, higher values were registered for body measurement parameters CG, BL and HAW in bucks of Abergelle goat breed, Ethiopia (Tadesse et al., 2012) and Beetal goats, Pakistan (Khan et al., 2006).

According to this study, the relationship between LW and body measurements was more remarkable in young (0PPI) goats and in pooled data consisting of all study goats. In young goats (0PPI), LW was significantly and strongly correlated (r=0.80-0.90) with CG, BL, HAW and NC. It was also noted that in young goats (0PPI), the relationship between LW and body measurements recorded was better in female goats than their male contemporaries. In the pooled data consisting of all study goats of different age and sex categories, significant and strong correlation (r=0.81-0.82) between LW and body measurements CG and BL was noted while significant and moderate correlation (r=0.60-0.65) was recorded between LW and body measurements HAW, RH and PW. Similar to the current study, it was reported that the correlations between LW and body measurements in pooled data from 0-12 months of age were higher than those at different age groups for Kanu Adi goats in India (Thiruvenkadan, 2005). Not consistent with the findings of this study, in the Short Eared Somali goat breed, it was reported that body parameters CG, BL, PW and HAW were significantly correlated with LW in age group 3PPI (Gebreyesus et al., 2012). According to Tadesse et al. (2012), LW has strong relationship with CG (r=0.73-0.89) compared to other body measurements such as BL (r=0.46-0.82) and HAW (r=0.53-0.83). Similar to what was observed in Afar goats, strong and significant correlation between LW and body measurements HAW and CG was noted at early age in the Short Eared Somali goat breed. According to Thiruvenkadan (2005), a comparatively lower relationship between LW and HAW was observed at different ages and both sexes associated mainly with the fact that height is due to growth of bones whose function of increase in height is probably not proportionate to increase in LW (Thiruvenkadan, 2005).

This study on Afar goats has revealed that the relationship between body measurements was more noticeable in young (0PPI) goats and in the pooled data consisting of all age and sex categories. In age group 0PPI, CG was significantly and strongly correlated (r=0.82-0.88) with body measurements BL, HAW and NC. There was significant and strong correlation (r=0.78-0.80) between BL and body measurements HAW and NC. In addition, HAW was significantly and strongly correlated with NC in age group 0PPI. The correlation between body measurements was very weak in the age group 1PPI, 2PPI and 3PPI.

In the pooled data consisting of all study Afar goats of different age and sex categories, CG was significantly and moderately correlated (r=0.71-0.79) with body measurements BL and HAW, BL was significantly and moderately correlated (r=0.70-0.74) with body measurements HAW and RH while HAW was significantly and moderately correlated (r=0.76) with RH. In Afar goats it was noticed that with advancing age, the correlation between body measurement parameters became inconsistent and there were also negative and weak correlations noticed (for example CG, BL, RH, PW and NC in bucks of age group 1PPI). However, Khan et al. (2006) noted increasing coefficient of correlation (r) value with advancing age in Beetal goat breed of Pakistan. Tadesse et al. (2012) reported a decreasing trend in the correlation between LW and body measurement parameters with advancing age in Abergelle goats indicating that better prediction of LW could be obtained at early age. HAW significantly explained the variation in LW (R^2=0.93) in young (0PPI) female goats, PW significantly explained the variation in LW (R^2=0.70) in young male (0PPI) goats and CG in both sexes (R^2=0.81). In young (0PPI) goats, irrespective of age, BL significantly explained the variation in LW in female goats (R^2=0.89).

For pooled data consisting of females of all age groups, BL significantly explained the variation in LW (R^2=0.89) whereas in male goats CG was noted more important (R^2=0.40) explaining the variation in LW. Other researchers (Thiruvenkadan, 2005; de Villiers et al., 2009; Yakubu et al., 2011; Tadesse et al., 2012; Matsebula et al., 2013) have also reported CG as an important body measurement for predicting LW. According to Thiruvenkadan (2005), CG is superior over other body measurements considering the high environmental sensitivity of CG and the higher association between LW and CG could also be attributed to the relatively larger contribution of CG which consists of bones, muscle and viscera. Tadesse et al. (2012) have reported BL as the other most useful body measurement parameters for predicting LW of all age and sex groups in Abergelle goat breed in north Ethiopia.

The finding of this study in Afar goats is in agreement with Thiruvenkadan (2005) who reported that LW prediction model based on CG was less reliable at >6-9 and >9-12 months age groups and in such age groups HAW and BL accounted for the greatest amount of variation in LW for male and female Kanu Adi goats, India (Thiruvenkadan, 2005). In the Short Eared Somali goat breed, only CG, BL and HAW were found to significantly contribute to the LW prediction model in female goats at age group of 2PPI (Gebreyesus et al., 2012). According to Yakubu et al. (2011), HAW and RH were found to best explain the variation in LW of kids belonging to non-descript goat, in north central Nigeria.

In the case of Afar goats, higher R^2 value was noted for LW prediction models developed for female goats and for goats of younger age. In line with the current study in Afar goats, Yakubu et al. (2011) reported that prediction of LW from linear body measurements seemed to be better in kids than adult goats and with advancing age R^2 declined. It was also reported that as age advances, R^2 for all characteristics decreased indicating that body measurements accurately predict body weight in the first 6 months of life than later age (>6-12 months) (Thiruvenkadan, 2005). Similar to the finding of this study, R^2 was highest in females (93.6%) in a regression model constructed using pooled data, within sexes, from 0-12 months of age compared to equations constructed at different age groups (Thiruvenkadan, 2005). Not consistent with the current study, it was reported that R^2 computed for the body measurements of Short Eared Somali goat were generally higher for male goats in the pooled data (91%) than any of the age groups including the pooled data for females (Gebreyesus et al., 2012). As opposed to this study on Afar goats, Gebreyesus et al. (2012) reported that LW could be predicted with better accuracy for male goats than for females of short eared Somali goat breed where R^2 value is the lowest (47%) of all in older age group (3PPI).

The current study has shown an increase in R^2 with increasing number of body measurements in the model. Consistent with this finding, Tadesse et al. (2012) and Gebreyseus et al. (2012) reported that R^2 value improved with increasing number of regressors in the prediction model. Furthermore, Thiruvenkadan (2005) noted that highest R^2 was obtained when all body measurements are included in the regression equations suggesting that LW could be estimated more accurately by a combination of two or more measurements than by one body measurement (CG) alone. However, it is worth noticing that taking such a huge number of body measurements would pose practical problems under Afar field condition due to higher labor and time needed for data collection. In addition, measurement of body measurements has cost implications and it would be difficult to consider too many parameters. This, in turn reduces the usefulness of such indirect methods used to predict LW.

5. CONCLUSION

Knowledge of LW is required for optimizing the management and marketing of goats. In this study models based on body measurements which are easy to record were developed to predict LW of Afar goats as a solution to lack of weight measuring scales and challenges often faced with hard task of direct weight determination. It is verified that the body measurements explained the variation in LW is better than others. Therefore, CG has been found as the most simple, easy to measure body measurement and can effectively used for developing model for predicting LW of Afar goats of all age and sex groups. Model based on combination of BL and PW is found as an alternative to predict LW of goats irrespective of age and sex.

6. ACKNOWLEDGEMENTS

I would like to acknowledge College of Veterinary Medicine, Mekelle University and Faculty of Veterinary Medicine and Agriculture of Addis Ababa University for funding this research. It is with great respect I acknowledge Dr. Yayneshet T. for his intellectual support since the beginning of my involvement into the Science of Animal Production. I am also very grateful to Dr. Matiwos Lakew working for Goal Ethiopia at field office based in Gulina woreda. My respect and thanks is also extended to pastoralists in Gulina woreda who were kind to allow me to take the long procedures during data collection, specifically I am grateful to Ato Warie Onte who has been with me all the way throughout the data collection period.

7. REFERENCE

Abegaz, S & Awgichew, K. 2009. Estimation of weight and age of sheep and goats. *In:* A.Yami., K. Awgichew., T.A. Gipson & R.C. Merkel (eds.). ESGPIP Technical Bulletin No 23. USAID, Prairie View A & M research Foundation, MoA and American Institute for goat research, Addis Ababa, Ethiopia, 11p.

Afolayan, R. A., Adeyinka, I. A & Lakpini, C. A. M. 2006. The estimation of live weight from body measurements inYankasa sheep. *Czech Journal of Animal Science*, **51**: 343-348.

Birteebi, P & Ozoje, M. O. 2012. Prediction of live body weight from linear body measurements of West African long-legged and West African dwarf sheep in Northern Ghana. *Online Journal of Animal and Feed Research*, **2 (5)**: 427-434.

BoPARD (Bureau of Pastoralists, Agricultural and Rural Development). 2008. Basic Agricultural data for the year 2007/8. Afar Regional State. Semera. Ethiopia, pp. 95-100.

CSA (Central Statistics Agency). 2011. Federal Democratic Republic of Ethiopia Central statistical Agency, Agricultural sample survey, Volume II: Report on Livestock and Livestock Characteristics in Ethiopia. Statistical Bulletin 505, Addis Ababa, Ethiopia. 190p.

de Villiers, J. F., Gcumisa, S. T & Gumede, S. A. 2009. Estimation of live body weight from the heart girth measurement in Kwa Zulu-Natal goats. *Applied Animal Husbandry and Rural*

Development, **1**:1-8 (Retrieved October 1, 2013 at www.sasas.co.za/aahrd).

Gebreyesus, G., Haile, A & 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 (4-6)**: 90-93.

Gizaw, S. 2008. Goat breeds of Ethiopia: A guide for identification and utilization. *In:* A. Yami,, A. Kassahun., T.A. Gipson & R.C. Merkel (eds.), ESGPIP (Ethiopia Sheep and Goat Productivity Improvement Program). Technical Bulletin No 27. USAID, Prairie View A&M research Foundation, MoA, and American Institute for goat research. Addis Ababa, Ethiopia, 9p.

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

Matsebula, M., Bhebhe, E., Mupangwa, J. F & Dlamini, B. J. 2013. Prediction of live weight from linear body measurements of indigenous goats of Swaziland. *Livestock Research for Rural Development*. Volume *25*, Article #140. Retrieved September 24, 2013, at http://www.lrrd.org/lrrd25/8/Mats25140.htm.

Mekasha, Y. 2007. Reproductive traits in Ethiopian male goats, with special reference on breed and nutrition. Doctoral thesis, ISSN 1652-6880, ISBN 978-91-576-7371-8, 56p.

Mekasha, Y., Tegegne, A., Abera, A & Rodriguez-Martinez, H. 2008. Body Size and Testicular Traits of Tropically–adapted Bucks Raised Under Extensive Husbandry in Ethiopia. *Reproduction in Domestic Animals*, **43(2)**:196-206 (doi:10.1111/ j.1439- 0531. 2007. 00877.x).

Otoikhian, C. S. O., Otoikhian, A. M., Akporhuarho, O. P., Oyefia, V. E & Isidahomen, C. E. 2008. Body measurement parameters as a function of assessing body weight in goats under on-farm research environment. *African Journal of General Agriculture*, **4(3)**: 135- 140 (Retrieved October 1, 2013, at http://www.asopah.org).

SAS (Statistical Analysis System). 2002. SAS Version 9.1.2. SAS Institute Inc., Cary, NC, USA.

Slippers, S. C., Letty, B. A & de Villiers, J. F. 2000. Prediction of the body weight of Nguni goats. *South African Journal of Animal Science*, **30** (Supplement 1), Short paper and poster abstracts: 38th Congress of the South African Society of Animal Science (Available at http://www.sasas.co.za/Sajas.html).

Tadesse, A., Gebremariam, T & Gangwar, S. K. 2012. Application of linear body measurements for predicting body weight of Abergelle goat breed in Tigray region, Northern-Ethiopia. *Global Journal of Bio Science and Biotechnology*, **1 (2)**: 314-319.

Thiruvenkadan, A. K. 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 # 7 (Retrieved October 3, 2013, at http://www.lrrd.org/lrrd17/7/thir17085.htm).

Yakubu, A., Ladokun, A. O & Adua, M. M. 2011. Bioprediction of Body Weight from Zoometrical Traits of Non-descript Goats using Linear and Non-Linear Models in North Central Nigeria. *Livestock Research for Rural Development*, Volume **23**, Article #130. (Retrieved September 4, 2013, at http://www.lrrd.org/lrrd23/6/yaku23130.htm).