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Prediction of Afar Goat Breed Live Body Weight to Facilitate Breed Improvement and Husbandry Practice

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ABSTRACT

This study was undertaken in Afar Regional state, Ethiopia with the aim of developing a body weight prediction model from linear measurements. Stratified random sampling was employed to select the study area and households. A total of 891 goats (823 female and 68 male) above six months of age were used for body measurements. Each measurement was sexed and aged using dentition. Body measurements were analyzed using the Generalized Linear Model of the Statistical computing R. Tukey's HSD post-hoc test was used to separate means if analysis of variance showed significance. Pearson's correlation coefficients were used to select variables that have a strong correlation with body weight. Then stepwise regression procedure of R was employed to identify a model. The overall mean body weight was 23.8 kg. Body measurements for males and females were (26.44 and 20.87 kg) for body weight, (64.8 and 59.5 cm) for chest girth, (63.1 and 58.9 cm) for body length, (59.6 and 55.4 cm) for height at wither and (13.3 and 12.4 cm) for pelvic width respectively. In all measurements, males were significantly ($P<0.01$, $P<0.05$) heavier than females. Most body measurements increased consistently as age advanced. Most of the linear parameters depicted positive and highly significant ($P<0.01$) correlation with body weight. The body weight of the Afar goat breed could be predicted with higher accuracy from chest girth (CG) and body length (BL) in pastoral areas where there is limited weighing scale to improve the breed, husbandry practice and weight based marketing.

1. INTRODUCTION

In Ethiopia, the diversified goat population kept by pastoral and agro-pastoral substantially contributes to the livelihood of the rural poor and the country's economy at large (Haile et al., 2019). Despite their diversified importance and large population size, productivity per unit of animal is very low due to traditional production system. Lack of appropriate breeding strategies, poor husbandry practice and poor understanding of the market system were indicated as the main reasons (Gebremedhin et al, 2015; Zewdie and Welday, 2015).

The majority of Ethiopian goat populations (about 70%) are located in the arid and semi – arid areas where they are kept in large flocks by pastoralists (FARM Africa, 1996). The type of goat breeds in these unfavorable environment are determined by the ability to survival under the prevailing fluctuating feed scarcity, disease challenges, low level of management and harsh climate (Laird, 2002). Genetic improvement is currently being centered on indigenous breeds because they have long been adapted to extreme harsh environmental conditions and might be more productive in their own environment than the exotic breeds (Rege, 2003).

To date, community-based breeding programs can be viewed as part and parcel of a comprehensive conservation based genetic improvement activity without any significant additional costs. Community-Based Breeding Programmes (CBBPs), which focus on indigenous stock and consider owners' needs, views, decisions and active participation, from inception through to implementation, have been identified as programmes of choice (Muller et al., 2015).

However, genetic improvement efforts are constrained by absence of performance and pedigree recording, illiteracy, poor infrastructure, diseases, lack of market linkage and so on (Haile et al., 2019). The mobile nature of pastoral in search of feed also makes it difficult to take performance recording by technicians. Additionally, the marketing system of small ruminants is also traditional – price is determined by buyers or middle men – which mostly makes pastoral disadvantageous. Live weight based pricing system have been tried by government of Ethiopia, but with little success (Gebremedhin et al, 2015). At smallholder level, affordability and accessibility of weighting scale was the limiting factor. Hence easily applicable alternative methods are needed.

Measurement and recording of live body weight is one of the key traits used as selection criteria of best goats, compare performance change due to management, to evaluate genetic progress as well as live weight pricing of animals. Therefore, this paper aims to develop context specific live weight estimation model for afar goat breed.

2. MATERIAL AND METHODS

Description of the Study Area

Afar National Regional State (ANRS) is one of the eleven states of Ethiopia. The Region is located in the lowland of Great Rift Valley between 8^0 45' to 14^0 27' latitude North and 39^o 51' to 42^0 23' longitude East and covers an area of 100,860 km^2. The Region has an estimated population of 1.9 million (CSA, 2019) of which 90% are pastorals whereas 10% represent agro-pastoral. About half of the Region (51.4%) has arid agro-climate which falls with an elevation ranging from 400 to 900 meters. Even to the worst, one – third (35.5%) of the Region is categorized as desert agro-climate due to its lower altitude which is below 400 meters above sea level. The annual temperatures vary from 18^oC to 45^oC. The rainfall ranges from 500mm in the semi-arid western escarpments to 150mm in the arid zones (Nigatu, 1994; Solomon, 2006). The study was conducted in Aysaita district, where there is less mixing of the goat population with neighboring breeds.

Sampling Method and Sample Size

Stratified sampling procedure was employed. The district was stratified into pastoral and agro pastoral production system. Afterward, two pastoral and one agro-pastoral peasant association were selected based on availability of goat flock. The samples size for physical description of a breed depends upon the precision required and the variability in the sample population. Coefficients of variation on body measurements of mature goats were observed to range between 10 and 30% (FARM Africa, 1996). For 5% statistical significance, 100 to 300 mature goats are required from representative site (Peters, 1985). Bearing this in mind, a total of 891 individual goats above six months of age were used for body measurements. About 610 and 281 heads of goat were sampled from 32 pastoral and 22 agropastoral households, respectively. On average 19 and 13 goats per household were measured from pastoral and agropastoral production systems respectively. A maximum of 30 and 20 goats were restricted from an individual household in pastoral and agropastoral system, correspondingly even if the household owe large flock size.

Data Collection

Data was generated by employing field measurements. The following body measurements: Chest Girth (CG), Body Length (BL), Height at Wither (HW), Pelvic Width (PW), Ear Length (EL), Horn Length (HL) and Scrotum Circumference (SC) were taken using tailors measuring tape while body weight was measured using 50 kg capacity suspended spring balance with 0.2 kg precision. The definition and way of body weight and linear measurements were described in Appendix Table 1. Body condition score (BCS) was assessed subjectively and scored using the 5 point scale (1=very thin, 2=thin, 3= average, 4=fat and 5=very fat/obese) for both sexes. BCS of an animal was scored by feeling the back bone with the thumb and the end of the short ribs with finger tips immediately behind the last ribs (McGregor, 2007; Girma, 2009). The detail description of scoring is indicated in Appendix Table 2.

All measurements were taken in the morning before the animals were fed. Each of the animals selected for measurement was sexed and aged according to Girma and Alemu (2008) using permanent teeth eruption. Thus, goat with fully grown milk teeth that started to spread out and zero pair of permanent incisor eruption (0PPI) representing 6 to 13 months of age and goats with erupted and growing first pair of permanent incisor (1PPI) representing 14 to 17 months of age. In the same way, 2PPI, 3PPI and 4PPI represent 18 to 23 months, 24 to 36 months and above 36 months of age, respectively.

Methods of Data Analysis

Quantitative traits (body weight and some linear body measurements) were analyzed using the Generalized Linear Model of the Statistical computing R version 4.1.2, 2021. Tukey's HSD post-hoc test was used to separate means if analysis of variance showed significance. The statistical Model 1 was used to analyze body weight and linear body measurements:

$$Y_{ijkl} = \mu + A_i + S_j + D_k + (AS)ij + (AD)ik + (SD)_{jk} + (ASD)ijk + e_{ijk} \qquad \text{Model 1}$$

Where: Y_{ijk} = the observed l in the i^{th} Production System (PS), j^{th} sex class and k^{th} age group;
μ = Overall mean;
A_i = the fixed effect of PS (i=1, 2: where 1= pastoral and 2= agropastoral);
S_j = Fixed effect of sex (j = 1, 2: where, 1= male and 2= female);
D_k = Fixed effect of age (k = 1, 2, 3, 4 and 5: where, 1= age group at 0PPI, 1PPI, 2PPI, 3PPI and 4PPI, respectively) and possible interactions.
e_{ijk} = Random error.

Pearson's correlation coefficients between body weight and other body measurements of the population for each sex and dentition categories were estimated to select variables that have a strong correlation with body weight. Then body weight was regressed on linear measurements and BCS for each sex and age group using stepwise regression procedure of R version 4.1.2, 2021 to identify a model. Each of the available predictors was evaluated with respect to how much R^2 would be increased by adding it to the model. Best fitted model was selected based on highest coefficient of determination R^2 and lowest Mallow's C_p value that is close to p+1, where p is the number of predictor variables in the model (Mallows, 1973). Model 2 and 3 were used to develop the best linear regression equation for female and male goats, respectively.

$$Yj = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + e_j \qquad \text{------------} \qquad \text{Model 2}$$

Where: Yj = the dependent variable body weight,
β0 = the intercept,

X1, X2, X3, X4, X5 and X6 are the independent variables such that body length, chest girth, height at wither, chest width, pelvic width and body condition score respectively.

$$Yj = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + \beta 7X7 + ej \qquad \text{Model 3}$$

This model is similar with that of female except that scrotal circumference included in the model as independent variable.

$\beta 1, \beta 2, \ldots, \beta 6$ is regression coefficient of the variables $X1, X2, \ldots, X6$
e_j = the residual error.

3. RESULT AND DISCUSSION

Live Body Weight and Linear Measurements

The body weight and linear measurements of sampled population were summarized in Table 1. Body weight and linear measurements varies among age, sex and to some extent the production systems. Availability of few breeding male for screening was because most of the male goats are culled at young age as mating control strategy for breed improvement (Misbah et al., 2015) as well as to increase production efficiency and minimize handling problem. The net effect of this act is availability of very few male animals. A similar limitation was faced by Fajemilehin and Salako (2008) who used smaller proportion of male (84 heads) to study the physical description of West African Dwarf (WAD) goat, Nigeria.

Table 1 Least square means and standard error (LSM ± SE) for main effects of dentition (PPI), sex and production system (PS) and sex by age interaction effect on body weight (kg) and linear measurements of Afar goat breed.

Effects & level	N	Body weight	CG	CW	BL	HW	PW	BCS	HL	EL	SC
Overall	891	23.8 ± 0.21	62.17 ± 0.23	7.00 ± 0.06	60.96 ± 0.25	57.5 ± 0.20	12.9 ± 0.04	2.3 ± 0.04	21.4 ± 0.28	12.7 ± 0.12	23.4 ± 0.42
R^2		0.50	0.54	0.24	0.41	0.36	0.33	0.18	0.63	0.06	0.44
C.V		14.04	5.5	14.04	6.17	5.15	9.75	33.6	20.27	11.24	12.24
Dentition		***	***	***	***	***	**	NS	***	***	***
0PPI	127	19.10 ± 0.31^{a}	56.3 ± 0.34^{a}	6.2 ± 0.10^{a}	56.1 ± 0.37^{a}	54.0 ± 0.29^{a}	11.3 ± 0.12^{a}	2.60 ± 0.07^{a}	14.8 ± 0.43^{a}	11.96 ± 0.15^{a}	19.9 ± 0.58^{a}
1PPI	87	21.43 ± 0.55^{b}	60.2 ± 0.40^{b}	6.8 ± 0.11^{b}	59.8 ± 0.44^{b}	56.2 ± 0.34^{b}	12.5 ± 0.15^{b}	2.51 ± 0.08^{a}	18.1 ± 0.50^{b}	12.91 ± 0.18^{b}	22.3 ± 0.80^{b}
2PPI	58	23.96 ± 0.45^{c}	62.7 ± 0.48^{c}	7.3 ± 0.14^{c}	60.4 ± 0.53^{c}	57.9 ± 0.41^{c}	13.1 ± 0.18^{c}	2.26 ± 0.09^{b}	21.7 ± 0.06^{c}	12.87 ± 0.22^{b}	24.0 ± 0.98^{bc}
3PPI	142	26.33 ± 0.32^{d}	65.2 ± 0.34^{d}	7.3 ± 0.10^{c}	63.3 ± 0.37^{d}	59.7 ± 0.29^{d}	13.4 ± 0.13^{c}	2.33 ± 0.04^{b}	23.6 ± 0.42^{d}	12.93 ± 0.15^{b}	25.1 ± 0.86^{c}
4 PPI	477	27.35 ± 0.25^{e}	66.5 ± 0.26^{e}	7.4 ± 0.07^{c}	64.83 ± 0.29^{e}	59.8 ± 0.23^{d}	13.9 ± 0.10^{d}	2.00 ± 0.05^{c}	25.9± 0.33^{e}	12.98 ± 0.12^{b}	26.0 ± 1.12^{c}
Sex		***	***	***	**	***	***	***	***	*	
Female	823	20.87 ± 0.15	59.5 ± 0.16	6.5 ± 0.05	58.9 ± 0.18	55.4 ± 0.14	12.4 ± 0.06	2.15 ± 0.03	15.4 ± 0.21	12.5 ± 0.07	NA
Male	68	26.44 ± 0.39	64.8 ± 0.42	7.5 ± 0.12	63.1 ± 0.46	59.6 ± 0.36	13.3 ± 0.15	2.51 ± 0.08	26.3 ± 0.52	13.0 ± 0.19	NA
PS		***	NS	***	NS	NS	NS	**	**	NS	NS
Agropastoral	281	24.12 ± 0.26	61.9 ± 0.28	6.7 ± 0.08	61.1 ± 0.31	57.5 ± 0.24	12.9 ± 0.10	2.46 ± 0.06	20.3 ± 0.29	12.7 ± 0.12	24.0 ± 0.66
Pastoral	610	23.19 ± 0.22	62.6 ± 0.24	7.3 ± 0.07	60.8 ± 0.26	57.6 ± 0.20	12.8 ± 0.09	2.21 ± 0.05	21.3 ± 0.35^{b}	12.7 ± 0.11	22.6 ± 0.46
Sex*age		***	***	NS	***	***	***	***	***	NS	
Femal 0PPI	105	16.8±0.30^{a}	54.5±0.32^{a}	5.9±0.0.10^{a}	54.6±0.36^{a}	52.4±0.28^{a}	11.0±0.12^{a}	2.46±0.07^{a}	10.7±0.38^{a}	11.7±0.14	NA
Femal 1PPI	75	19.1±0.35^{b}	58.1±0.38^{b}	6.5±0.12^{b}	58.1±0.42^{b}	54.4±0.33^{b}	12.1±0.14^{b}	2.31±0.08^{a}	13.1±0.44^{b}	12.6±0.17	NA
Femal 2PPI	50	20.5±0.43^{c}	60.4±0.47^{c}	7.1±0.14^{c}	57.9±0.52^{b}	55.7±0.41^{c}	12.6±0.17^{c}	1.96±0.09^{b}	16.2±0.54^{c}	12.7±0.21	NA
Femal 3PPI	128	23.0±0.27^{d}	62.4±0.29^{d}	6.9±0.09^{c}	61.2±0.32^{c}	57.4±0.25^{d}	12.9±0.11^{c}	2.09±0.06^{b}	17.1±0.33^{c}	12.7±0.13	NA
Femal 4PPI	465	24.3±0.14^{e}	63.9±0.15^{e}	7.0±0.05^{c}	62.6±0.17^{d}	57.6±0.13^{d}	13.4±0.06^{d}	1.72±0.03^{e}	20.0±0.18^{d}	12.8±0.07	NA
Male 0PPI	22	18.7±0.65^{bf}	55.9±0.71^{af}	6.4±0.21^{bd}	55.0±0.78^{ae}	54.1±0.61^{be}	11.0±0.26^{ae}	2.43±0.14^{abf}	14.4±0.79^{bce}	12.3±0.32	NA
Male 1PPI	12	20.7±0.89^{bcf}	60.8±0.96^{cdg}	7.4±0.29^{ce}	59.3±1.05^{bcf}	56.8±0.83^{cdf}	12.6±0.35^{bcf}	2.5±0.19^{abf}	19.4±1.07^{df}	13.6±0.45	NA
Male 2PPI	8	28.6±1.08^{g}	65.5±1.17^{eh}	7.6±0.36^{cef}	64.6±1.29^{dg}	61.0±1.02^{g}	13.5±0.43^{cdfg}	2.63±0.24^{abf}	25.8±1.32^{g}	13.0±0.71	NA
Male 3PPI	14	31.7±0.82^{h}	71.0±0.89^{i}	8.3±0.27^{f}	68.2±0.98^{h}	63.2±0.77^{gh}	13.9±0.33^{dg}	2.50±0.18^{abf}	37.1±1.03^{h}	13.0±0.38	NA
Male 4 PPI	12	34.4±0.89^{i}	73.9±0.96^{j}	8.3±0.29^{f}	70.8±1.05^{h}	65.0±0.83^{h}	16.3±0.35^{h}	2.58±0.19^{abf}	37.9±1.07^{h}	12.8±0.41	NA

^{a,b,c,d,e,f,g,h,i} means on the same column with different superscripts, within the specified class variable, are significantly different (p <0.05); Ns = non-significant; *P< 0.05; ** P< 0.01; CG = Chest Girth; CW = Chest width; BL= Body length; HW = height at Wither; PW = Pelvic Width; BCS = Body Condition Score; HL = Horn Length; EL = Ear Length; SC = Scrotal Circumference; 0PPI = 0 Pair of Permanent Incisors, 1PPI =1 Pair of permanent Incisors; 2 PPI = 2Pairs of Permanent Incisors; 3PPI = 3 Pairs of Permanent Incisors; 4PPI = 4 Pairs of Permanent Incisors; NA = Not Applicable.

Sex effect: In all traits considered, males showed significantly (P<0.001, P<0.05) higher measurements than female except ear length (EL) (P>0.05). The effect of sex in body weight and linear measurements in favor of males was in consonance with other works (Leng et al., 2010; Semakula et at., 2010; Grum et al, 2012; Tsegaye et al, 2013). Body weight and linear measurements revealed in this study both for mature males and females were similar to the observation of Nigatu (1994) for the same breed.

Age effects: Age has significant (P < 0.01) effect on body weight and linear measurements and there were consistent increases in the traits considered as the animals aged (Table 1). This is expected since the size and shape of the animal increase as the animal advance in age. The variation in weight and body measurements sharply reduced at later stages (e.g. 3PPI and 4PPI). This may be attributed to the attainment of the mature weight in which growth is at decreasing rate (Hifzan et al, 2015). Steven et al (2019) also stated that at maturity, linear body measurements are essentially a constant**,** thereby reflecting heritable size of the skeleton.

Interaction effect: The sex by age interaction has significant effect (p<0.01) for weight and body measurements (Table 1). The interaction effect of sex and age was also evident in other studies (Workneh, 1992; Tsegaye et al, 2013). In both sexes, body weight and measurements increased as age of the animal advances. In all parameters except BCS, females showed wider range of variation in measurements between age class 0PPI and 1PPI and a narrow variation was observed at later age groups. While male goats' shows accelerated growth through 0PPI to 2PPI years and slower growth rate was observed post age group of 2PPI. A similar growth trend was reported in other studies (Leng *et al*., 2010; Grum et al, 2012).

The growth trend in this study may suggest that the age between one and three years may be the age in which the animal shows the fastest growth rate. This is expected since animals, under normal conditions, grow fast when younger but grow slowly when they reach maturity (Hifzan et al 2015; Steven et al, 2019).

The live weight of males and females at age 2PPI were about 83.1% and 84.4% of that at age group 4PPI, respectively. This can suggests that, farmers could sell goats after age group 2PPI. However such decision cannot be solely made on biological parameters and the availability of feed and other cost associated with their husbandry would certainly play an important role in making such decision.

Correlation between live body weight and linear measurements

The correlation between body weight with body measurements in the pooled data was positive and significant (P< 0.01). The relationship of body weight over other variables with respect to sex and age category was presented in Table 2. Within females, body weight shows a positive and significant (P < 0.01, P < 0.05) relationship with body measurements across all age group. Chest girth (r=0.84) and body length (r=0.70) showed positive and strong association (P< 0.01) with body weight.

In the pooled data (0-4PPI) set of males, CG, BL, HW, PW, SC and HL show strong and positive correlation (r<0.01) with body weight. Negative and non-significant association of EL and body weight was found for the pooled data of 3PPI – 4PPI. In this study, scrotal circumference showed significant association (P<0.01) with live body weight in all age categories. Therefore, selection for scrotal circumference would lead to males with high potential for sperm production while indirectly improving body weight.

The pooled data of males showed higher 'r' value than pooled data of female for all variables except EL (r=0.07). This signifies the stronger association of body weight with linear measurements in male than female. Therefore, a separate regression equation for each sex would be preferable to estimation body weight from independent variables.

The higher association between live body weight and body measurements demonstrated the possibility of using simple body measurements that can be carried out in the field to predict body weight. For both males and females in all age categories, chest girth consistently gave higher correlation with body weight as compared with other body measurements. This is also evident in several studies (Fajemilehin and Salako, 2008; Leng *et al*., 2010; Grum et al, 2012; Tsegaye et al, 2013).

Table 2 Coefficients of correlation between body weight and body measurements within age and sex groups

Trait		Age group									Overall
		Male			Female						
		0-1PPI	2-4 PPI	0-4PPI	0PPI	1PPI	2PPI	3PPI	4PPI	0-4PPI	
CG	r	0.69**	0.81**	0.94**	0.75**	0.76**	0.66**	0.67**	0.71**	0.84**	0.86**
	N	34	34	68	105	75	50	128	465	823	891
CW	r	0.48**	0.16Ns	0.58**	0.46**	0.22NS	0.09NS	0.10NS	0.23**	0.37**	0.42**
	N	34	34	68	105	75	50	128	465	823	891
BL	r	0.59**	0.62**	0.88**	0.66**	0.42**	0.50**	0.56**	0.47**	0.70**	0.73**
	N	34	34	68	105	75	50	128	465	823	891
HW	r	0.66**	0.51**	0.87**	0.52**	0.49**	0.57**	0.48**	0.34**	0.61**	0.67**
	N	34	34	68	105	75	50	128	465	823	891
PW	r	0.57**	0.61**	0.83**	0.45**	0.53**	0.47**	0.34**	0.43**	0.62**	0.65**
	N	34	34	68	105	75	50	128	465	823	891
BCS	r	0.33NS	0.45**	0.27*	0.30**	0.57**	0.27NS	0.36**	0.40**	0.04Ns	0.04**
	N	34	34	68	105	75	50	128	465	823	891
HL	r	0.73Ns	0.61NS	0.91**	0.72**	0.33**	0.47**	0.52**	0.29**	0.64**	0.72**
	N	34	33	67	96	73	48	127	439	783	850
EL	r	0.40*	-0.3Ns	0.07NS	0.27**	0.09NS	0.31*	0.20*	0.02Ns	0.21**	0.20**
	N	32	32	64	102	72	47	123	443	787	851
SC	r	0.66**	0.53**	0.73**	NA	NA	NA	NA	NA	NA	0.73**
	N	34	27	61	NA	NA	NA	NA	NA	NA	61

r = coefficient of correlation; N= Number of observation; NS = non-significant; *P< 0.05; ** P< 0.01; CG = Chest Girth; CW = Chest width; BL= Body length; HW = height Wither; PW = Pelvic Width; BCS = Body Condition Score; HL = Horn Length; EL = Ear Length; SC = Scrotal Circumference; 0PPI = 0 Pair of Permanent Incisors, 1PPI =1 Pair of Permanent Incisors; 2PPI = 2 Pairs of Permanent Incisors; 3PPI = 3 Pairs of Permanent Incisors; 4PPI = 4 Pairs of Permanent Incisors, NA = Non-applicable.

Multiple regression analysis

Summary of multiple linear regression analysis and generated models for predicting body weight from body measurements for each sex at different age categories were presented in Table 3. In the entire model, chest girth was the single most important variable to produce the largest R^2. For the pooled data of females, chest girth (CG), body length (BL), height at wither (HW), pelvic width (PW) and body condition score (BCS) are the best multiple regressor (R^2 = 0.78 and Cp = 5.9) to estimate body weight. For the pooled data of male, four alternative model was identified with a slightly varied R^2 (0.89 – 0.92) and Mallow's Cp ranging from 22.2–4.8. Chest girth, BL, HW and BCS are the best regressor variables to predict body weight of male. Nevertheless, the remaining equations can also be used with reduced precision under different circumstance (time, cost and ease of application).

Under smallholder situation where there is limited access to weighting scale, the pooled data models (Yf = -23 + 0.73CG + 0.22BL and Ym = -30.2 + 0.87CG) can easily be used to estimate live weight of female and male Afar goat breed respectively for selection, mating and live weight based pricing purpose.

The pooled data of male shows higher coefficient of determination than the pooled data of female. A similar situation was also reported in other studies (Grum et al, 2012; Tsegaye et al, 2013). Therefore, using a separate equation for each sex is feasible and can substantially increase precision to estimation body weight.

Table 3: Prediction equations for body weight at different sex and age groups

Dentition	Equations	Intercept	β1	β2	β3	β4	β5	β6	R^2	Δ R^2	Cp
Female	CG	-19.2	0.66						0.56	0	38.7
0PPI	CG+BL	-23.7	0.49	0.25					0.64	0.07	16.9
	CG+BL+BCS	-25.3	0.49	0.23	1.10				0.69	0.05	3.04
1PPI	CG	-24.05	0.74						0.58	0	45.4
	CG+BCS	-21.50	0.64	1.5					0.73	0.14	7.4
	CG+BL+BCS	-25.0	0.58	0.12	1.5				0.74	0.02	5.0
2PPI	CG	-19.1	0.66						0.44	0	25.4
	CG+HW	-35.7	0.53	0.44					0.58	0.14	9.7
	CG+BL+HW	-42.3	0.42	0.23	0.43				0.62	0.05	5.8
	CG+BL+HW+PW	-43.2	0.34	0.23	0.42	0.53			0.64	0.03	3.5
3PPI	CG	-19.7	0.68						0.45	0	46.0
	CG+BCS	-19.6	0.64	1.2					0.52	0.07	26
	CG+BL+BCS	-25.1	0.49	0.25	1.2				0.58	0.06	9.1
	CG+BL+HW+BCS	-29.8	0.40	0.23	0.19	1.3			0.60	0.02	4.2
4PPI	CG	-16.5	0.64						0.51	0.0	159.7
	CG+BL	-15.9	0.59	1.4					0.59	0.08	59.6
	CG+BL+BCS	-22.6	0.53	0.18	1.3				0.625	0.04	16.2
	CG+BL+PW+BCS	-23.1	0.50	0.16	0.26	1.3			0.632	0.008	8.5
	CG+BL+HW+PW+BCS	-25.7	0.48	0.15	0.08	0.25	1.3		0.636	0.004	5.4
0-4PPI	CG	-22.9	0.73						0.71	0	262.7
	CG+BL	-27.4	0.59	0.22					0.74	0.03	135.6
	CG+BL+BCS	-30.7	0.60	0.23	0.93				0.769	0.03	36.0
	CG+BL+HW+BCS	-24.34	0.36	0.22	0.14	0.37			0.776	0.003	13.8
	CG+BL+HW+PW+BCS	-33.5	0.53	0.20	0.12	0.20	0.96		0.778	0.002	5.9
Male	CG	-30.2	0.87						0.89	0	22.2
(0- 4PPI)	CG+BCS	-33.3	0.85	1.71					0.907	0.02	11.8
	CG+ HW + BCS	-38.4	0.72	0.24	1.6				0.914	0.008	7.8
	CG+BL+HW+BCS	-39.8	0.56	0.18	0.23	1.7			0.921	0.006	4.8

BL= Body length; CG = Chest Girth; CW = Chest width WH = Wither height; PW = Pelvic Width; SC = Scrotal circumference; SL = Scrotal Length; BC = Body Condition Score; 0PPI = 0 Pair of Permanent Incisors, 1PPI =1 Pair of Permanent Incisors; 2 PPI = 2Pairs of Permanent Incisors; 3PPI = 3 Pairs of Permanent Incisors; 4PPI = 4 Pairs of Permanent Incisors

4. CONCLUSION

Most of the linear parameters depicted positive and highly significant (P<0.01) correlation with body weight. The regression analyses showed that body weight could be predicted from chest girth (CG) and body length (BL). The simplified model (weight of female = -23 + 0.73CG + 0.22BL and weight of male = -30.2 + 0.87CG) can be used to estimate body weight of female and male Afar goat breed with 74% and 89% coefficient of determination (R^2) respectively. This will assist pastorals in making good judgment for breeding, feeding, veterinary service and marketing in area where weighting scales are rarely available.

Conflict of Interest

The authors state that there is no conflict of interest with any financial, personal, or other relationships with other people or organizations in the manuscript.

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APPENDIX

Appendix Table 1 List of quantitative traits and method of measurements[a]

Parameter	Units	Descriptions
Body weight	Kg	Taken early in the morning using 50 kg spring balance
Body length	cm	The horizontal distance from the point of shoulder to the pin bone to the nearest centimeter.
Chest girth	cm	The circumferential measure taken around the chest just behind the front legs and withers to the nearest 0.5cm.
Height at wither	cm	The height from the bottom of the front foot to the highest point of the shoulder between the withers to the nearest centimeter.
Chest width	cm	The width of the chest between the briskets to the nearest centimeter.
Pelvic width	cm	The distance between the pelvic bones, across dorsum to the nearest centimeter.
Ear length	cm	The length of the ear on its exterior side from its root at the poll to the tip to the nearest centimeter.
Scrotal circumference	cm	The circumference of the testicles at the widest part to the nearest centimeter.
Horn length	cm	Length of the horn on its exterior side from its root at the poll to the tip.

[a]Adapted from Girma and Alemu (2008)

Appendix Table 2 Scales for body condition scoring[1]

Score	Features			Condition
	Spinous and transverse process of Lumbar region	Eye muscle area	Rib cage	
1	The spinous processes are prominent and sharp. The transverse process are also sharp, the fingers pass easily under the ends, and it is possible to feel between each process.	The eye muscle areas are shallow with no fat cover.	Ribs are clearly Visible	Very thin
2	The spinous processes feel prominent but smooth, and individual processes can be felt only as fine corrugations. The transverse processes are smooth and rounded, and it is possible to pass the fingers under the ends with a little pressure.	The eye muscle areas are of moderate depth, but have little fat cover.	Some ribs can be seen. There is a small amount of fat cover. Ribs are still felt.	Thin
3	The spinous processes are detected only as small elevations; they are smooth and rounded and individual bones can be felt only with pressure. The transverse processes are smooth and well covered, and firm pressure is required to feel over the ends.	The eye muscle areas are fully covered to end of spinal processes. Feels rounded and have a moderate degree of fat cover.	Ribs are barely seen; an even layer of fat covers them. Spaces between ribs are felt using pressure.	Moderate
4	The spinous processes can just be detected with pressure as a hard line between the fat covered eye muscle areas. The ends of the transverse processes cannot be felt.	The eye muscle areas are full, and have a thick covering of fat.	Ribs are not seen	Fat
5	The spinous processes can't be detected even with firm pressure, and there is a depression between the layers of fat in the position where the spinous processes would normally be felt. The transverse processes cannot be detected.	The eye muscle areas are very full with thick fat cover. There may be large deposits of fat over the rump and tail.	Ribs are no visible and are covered with excessive fat.	Very fat

[1]Adapted from McGregor (2007) and Girma (2009)

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