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Original Article

Phenotypic Characterization of Indigenous Goats in South Gondar Zone, Amhara Regional State, Ethiopia

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ABSTRACT

This study was conducted in South Gondar zone, Amhara regional state, Ethiopia with the objective of phenotypic characterization of indigenous goat population in South Gondar zone. The study was conducted based on visual observation and field measurements. The zone was stratified into highland, midland and lowland agro-ecology and then selected one district from each agro-ecology. Data for visual observation and body measurements were collected from a total of 603 goats (201 per agro-ecology) of both sexes which has one and above pair of permanent incisor (PPI). Observations on qualitative trait were analyzed by using frequency procedure of SPSS version 20 for male and female goat separately. Whereas, body weight and other linear body measurements were analyzed using the Generalized Linear Model (GLM) procedure of SAS Ver.9.3 (2014). Correlation between body weight and other linear body measurements as well as REG procedure to regress body weight from linear body measurement for male and female goats were computed by SAS Ver.9.3 (2014). Most qualitative traits observed in the study area were significantly different and the most dominant coat color pattern was plain in all agro-ecology. White with red was the most frequent observed coat color type in the population. Whereas, white was the most frequent observed coat color in lowland agro-ecology of the zone. Agro-ecology and age group had highly significant ($p<0.01$) effect on body weight and most of linear body measurements except horn length, rump length, cannon bone length and head length for agro-ecology. Sex of goats had significant effect ($p<0.05$) on body weight and most of the body measurements except ear length, canon bone length, head length, and rump length. Most quantitative traits showed significantly higher average values in the lowland, than the rest two (highland and midland) agro-ecologies and most quantitative trait of goat population for male were significantly higher than the female one. Body weight was significantly correlated with all continuous traits of both male and female goats but higher in heart girth. As a result, the stepwise regressions revealed that heart girth was the most important variable in the

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prediction of live body weight. Generally the difference and similarities of indigenous goat in morphometric trait and adaptability should be supported by further study on characterization at molecular level under their production environments.

Keywords: body weight**,** Indigenous Goat, Phenotypic Characterization, South Gondar Zone

INTRODUCTION

Ethiopia has the largest livestock population in Africa and has an estimated total number of 30.20 million goats which are kept in various production systems and different agro-ecological zones of highlands, sub-humid, semi-arid and arid environments (FARM Africa, 1996, Getnet, 2016 and CSA, 2017). They have a certain valuable genetic traits such as ability to perform better under low input condition and climatic stress, tolerance to infectious diseases and heat stresses (Kosgey and Okeyo, 2007). The average carcass weight of Ethiopian goats is 10kg, which is the second lowest in sub-Saharan Africa (Adane and Girma, 2008). Despite the wide distribution and large size of goat population in the country, the productivity per unit of animal and the contribution of this sector to national economy is relatively low (Ameha, 2008). According to Tesfaye (2009) and LMP (2015) lack of appropriate breeding strategies, poor nutrition and poor understanding of the production system are some of the factor that leads to reduce the production and productivity of an animal.

Genetic improvement is one way to increase the productivity of goat and Studies on characterization of goat is essential for planning improvement, documentation and identification of breed, sustainable utilization and conservation of a breed at local, regional, national and global levels (FAO, 2012). In the absence of baseline characterization, some breed populations and unique characteristics possessed by them may decline significantly, or be lost, before their value is recognized and measures taken to conserve them (FAO, 2007).

Two decades ago, the goat population in Ethiopia were phenotypically characterized and classified into 12 distinct major breed (FARM-Africa, 1996) and genetic/molecular characterization by using microsatellite marker analysis showed only eight goat types in Ethiopia (Tesfaye, 2004). However, the current molecular study on the domestic goats by Getnet (2016) does not support the former classifications of the indigenous goat populations. After detailed analysis of the goat population based on production systems, agro-ecologies, goat families and phylogenetic network analyses he classified the 12 Ethiopian goat populations in to six goat types.

In addition to this, various goat characterization studies have been executed in different area across Ethiopia (Tsegaye, 2009; Gebreyesus, 2010; Ahmed, 2013; Bekalu, 2014; Yaekob *et al.*, 2015 and Belay and Meseretu, 2017). However, South Gondar zone is less focused area on characterization of indigenous goat rather than two decade of FARM Africa (1996) work. In south Gondar zone, the total number of indigenous goat population is 514,746 and has a suitable environment for goat productivity (CSA, 2017). Indigenous goats in this area are used to provide meat, manure, skin and also a source of income generating for the producer. Despite its significance, research on these goat genetic resources has not been done so far in the last two decades. Information on phenotypic characterization of this goat population was very limited; so further studies were required for designing and developing genetic improvement programs of the most promising and widely used breeds and for conservation of genetic resources. Therefore, the objective of the study was carried out to undertake phenotypic characterization of indigenous goat population and to develop equation for prediction of body weight by using LBMs in South Gondar zone, Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

This study was conducted in three districts namely: -Farta, Este and Tach-gayint of south Gondar zone, Amhara regional state. South Gondar Zone is one of the eleven zones in Amhara National Regional State of Ethiopia.

Farta: it is one of the districts in South Gondar Zone of Amhara region. It is located between 11°32' to 12°03'N latitude and 37°31' to 38°43'E longitude. The district receives an average annual rain fall of 1250 -1599 mm and a mean annual temperature of 9^0-25^0C (Farta District OoARD, annual report). It represents the highland agro-ecology with an altitude range of 1920-4135 masl and the climate condition of this district is highland *(*56%), midland (41.5%) and lowland *(*2.5%). It is located about 97 km north-east of Bahir Dar, capital of the Amhara region and 666 km from Addis Ababa which is capital city of Ethiopia. There are 37 rural peasant associations and 2 (*Gasay* and *Kimir Dingay*) urban peasant associations in the district with an estimated area of 1077.77 square kilometers. The total number of livestock population in this district is about 213,188 cattle, 113978 sheep, 51556goats, 36072 equine, 132050 chicken and 17615 beehives (SGZARD, 2017). The major crops grown in the district were: teff, wheat, and barley, minor crop like pea, sorghum and maize. In addition to these, irrigated vegetables like potato, onion and cabbage was also produced in the area.

Este: -The second district, Este is one of the districts in South Gondar Zone of Amhara region. This district is located between 11° 37' N latitude and 38° 4'E longitude. The district receives an average annual rain fall of 900-1100 mm and the mean annual temperature of 8.3^0C-25^0C (ENMA, unpublished). It represents the midland agro-ecology with an altitude range of 1500-4000 masl and the climate condition of this district is highland *(19%)*, midland *(70%)* and lowland (11%). It is located 109.9 km North West of Bahir Dar city and 675.9 km from Addis Ababa which is capital city of Ethiopia. Mekane Yesus is the main town in the district. There are 36 rural and 3 urban peasant associations in the district with an estimated area of 1374.98 square kilometers. The total number livestock population in the district is about 190,853 Cattle, 141,985 sheep, 104,604 goats, 30,428 equines, 130,985 chicken and 14,137 beehives (SGZARD, 2017). The major crops grown in the district were: teff, wheat, barley, sorghum, maize, pea, chick pea and vegetables were also grown as major source of cash income and household consumption.

Tach Gayint: -The third district, Tach Gayint is one of the districts in south Gondar Zone of Amhara region. It is located between 11° 22' to 11° 42'N latitude and 28° 19' to 38° 43'E longitudes. The district receives an average annual rain fall of 900 - 1000 mm and the mean annual temperature ranges from 13^oc to 27^oc (ENMA, unpublished). It represents the lowland agro-ecology with an altitude range of 750-2800 masl and the climate condition of the district is highland (22.3%), midland (23%) and lowland (54.7). It is located 194.9 km North West of Bahir Dar city and 760.9 km from Addis Ababa. The major town in Tach Gayint is Arbi Gebeya. There are 15 rural and 1 urban peasants associations in the district with an estimated area of 825.03 square kilometers. The total number livestock population the district is about 78531Cattle, 51628 sheep, 62691goat, 58168equines, 25111chicken, and 9751beehives (SGZARD, 2017). The major crops grown in the district were: cereals such as teff, barley and wheat; pulses such as fava beans, field peas, haricot beans and chick peas; vegetables such as potatoes; bananas and hops (TGWAO, 2014).

Sample Size Determination and Sampling Techniques

Based on the information obtained from secondary data sources and discussion with south Gondar Zone Livestock and Fishery Resources Development Office expert, the districts in

the zone were stratified according to their agro-ecological variations. From each agro ecological zones, one sample district (Farta from highland, Este from midland, and Tach-gayint from lowland) was purposively selected based on relatively large goat population. From each district, three kebeles were purposively selected again based on relatively large goat population.

Then, from each kebeles, sample goats were taken by using simple random sampling method from each district. Pregnant female, castrated male and kids were avoided from the goat population to enhance accuracy for body weight and linear body measurements (LBMs). Dentition was used to determine the estimated age class of goats and goats which had one and above pair of permanent incisor (1PPI) was used for body measurements and qualitative trait descriptions.

The sample size of adult goat was determined by the formula given by Cochran's (1977) as recommended by FAO (FAO, 2012) for phenotypic characterization of livestock for simple random sampling.

$$n = \frac{Z^2 * (p)(q)}{e^2}$$

Where: n=sample size

Z=standard normal deviation (1.96 for 95% confidence interval

p=0.155 (estimated population variability, 15.5% the conservative population variability)

q=1-p i.e. (1-0.155) =0.845(84.5%)

e= (0.05) level of precision (sampling error).

$$\frac{1.96^2 * (0.155(1-0.155)}{0.05^2} = \frac{3.8416 * (0.130975)}{0.0025} = \frac{0.503154}{0.0025} = 201.2614 = 201$$

This (201) is only for one agro-ecology; the total sample size of goat population is **3*201=603**. A total of 603 goat populations were selected randomly from three selected agro-ecology. These 603 goats comprised of 67 goats per each selected kebeles (201 adult goats per each selected agro-ecology). Out of this 603 goats 10% (63) were bucks and 90% (540) were does as recommended by (FAO, 2012).

Method of Data Collection

Secondary data like climatic data (temperature and rainfall), and human and livestock demography were collected from the zone administrative office, the district office of livestock and fishery resources written documents.

Data (for quantitative and qualitative traits) was recorded based on breed morphological characteristics descriptor list of FAO (2012) for phenotypic characterization of goat. Data for heart girth (HG), body length (BL), height at wither (WH), rump height (RH), chest depth (CD), horn length (HL), ear length (EL), rump length (RL), rump width (RW), cannon bone length (CBL), cannon bone circumference (CBC) and head length (HDL) as well scrotum circumference only for male were collected using tailors measuring tape while body weight (BW) was measured using suspended spring balance.

Data were generated for qualitative traits (coat color pattern, coat color type, hair length, hair type, presence or absence of (horn, toggle, beard, ruff, and wattle), horn shape, horn orientation, ear orientation, head profile, back profile and rump profile) through visual observations.

Data Management and Statistical Analyses

All data gathered during the study period were coded and recorded in Microsoft Excel 2010. All the collected data was double-checked for any types of errors occurred during data collection and entry. Different types of statistical analysis were used depending upon the nature of the data.

Observations on qualitative traits were analyzed and summarized by using descriptive statistics for male and female goats separately using frequency procedure of SPSS version 20. Chi-square (x2) test was also applied to test ($p<0.05$) the statistical difference among categorical variables using agro-ecology as fixed effect.

A general linear model procedure (PROC GLM) of SAS Ver.9.3 (2014) was used for quantitative variables to detect statistical differences among sample goat populations. For adult animals, sex, age and agro-ecology were fitted as fixed effect while body weight and other linear body measurements were fitted as response variables. Least square means (LSM) with their corresponding standard error was calculated for each body trait over sex, age, agro-ecology, and the interaction of age by sex and sex by agro-ecology. The means of significant effect were compared by Tukey test.

The model employed for analyses of mature body weight and other linear body measurements of males and females, except scrotum circumference for female was as under:

$Y_{ijkl=} \mu + A_i + D_j + S_k + (DS)_{jk} + (SA)ki + e_{ijkl}$

Where:

Y_{ijkl} = the observation of body weight and LBMs excluding scrotum circumference for female in the i^{th} agro-ecology, j^{th} age group and k^{th} sex

μ = overall mean

A_i = the effect of i^{th} agro-ecology (i = highland, and midland lowland)

D_j= the effect of j^{th} age group (j = 1PPI, 2PPI, 3PPI and 4PPI)

S_k= the effect of k^{th} sex (k =male and female)

$(DS)_{jk}$=the interaction effect of j^{th} age group and k^{th} sex

(SA)ki = the interaction effect of k^{th} sex and i^{th} agro-ecology

e_{ijkl} = random residual error

Correlation coefficient was computed for each sex using Pearson correlation coefficient in order to determine the relationship between body weight and other linear body measurements. Stepwise regression procedure of SAS ver. 9.3(2014) were used to regress body weight for both male and female using PROC REG procedure of SAS in order to determine the best-fitted regression equation for the prediction of live body weight. The following model was used for the estimation of body weight from LBMs:

$$y=\beta_0+ \beta 1X_1+\beta 2 X_2 \ldots+\beta_{14} X_{14}+ e_j$$

Where:

y= the response variable (live body weight)

β_0 = the intercept

$X_1 \ldots, X_{14}$ are independent variables (all linear body measurements) for males and females except SC (for female $X_n = 13$)

$B_1 \ldots, \beta_{14}$, are regression coefficients of the variables $X_1 \ldots, X_{14}$ (for female $\beta_n = 13$)

ej =the residual random error

RESULT AND DISCUSSION

Qualitative traits of goat in study area

The phenotypic characterization of goat breed includes all the qualitative description and morphological measurements of the goat. The participatory descriptions of qualitative characters for both female and male goats found in highland, midland and lowland agro-ecologies are presented in Table 1. The qualitative traits observed in the study area were significantly different across all agro-ecology except hair type, horn, head profile, ruff, wattle, back profile and rump profile.

Coat Colour Pattern and Type

The most frequently observed coat color patterns in the study area were plain followed by patchy and spotted (55.9%, 22.9 % and 14.3% respectively) and this was in agreement with Belay and Meseretu (2017) who reported that the most frequent observed color patterns in all agro-ecology of Gamo-Gofa zone were plain (65.73%) followed by patchy (22.47 %) and spotted (11.8%). The dominant coat color pattern (51.7%, 50.7% and 65.2% in highland, midland and lowland, respectively) observed in the study area was plain which was in agreement with the report of Ahmed (2013) who reported that the most observed coat color pattern in all study districts was plain (75.49% in Guduru, 63.24% in Amuru and 55.88% in Horro) in Horro Guduru Wollega zone. On the contrary, Halima *et al.* (2012) reported that the most frequently observed coat color pattern in Ethiopian indigenous goat population were spotted (36.1 %) followed by patchy (32.4 %) and plain (30.4 %) of various colors.

The studied goat population has a diversified coat color type. Of the eight observed coat color, white with red (22.9%), White (22.7%) and red (16.1%) color were the most frequent observed coat colors. The dominant coat color types mostly observed in the study area were white with red, white and red (28.4, 20.9 and 15.4) in highland and (23.9, 17.4 and 12.9%) in midland whereas in lowland white, red and white with red (29.9, 19.9 and 16.4%) respectively. Generally, in south Gondar zone red with white coat color type was the most dominant coat color type in highland and midland where as in lowland agro-ecology of the study area white coat color type was the most dominant one. The overall most frequent coat color type in the study area (white with red 22.9%; white 22.7; and red 16.1%) was in disagreement with Hulunim (2014) who reported that white (36.27), white with black (21.24%) and white with light brown (20.21) were the most frequent coat color type of Bati, Borena and Short Eared Somali goat and Bekalu (2014) who reported that Brown/fawn (23.33%) and white (22.83%) coat color type was mostly observed in west Gojjam. In the present study gray, brown, black, white with black and red with black coat color type were also observed but in small proportion in highland, midland and lowland agro-ecology which indicated that goat populations found in the study area have a wide range of coat colors types. The representative coat color type of goat population across the three agro-ecologies showed in Figure 1.

Hair Length and Type

The length of hair was significantly different in agro-ecology while hair types of goat population were not significant different as presented Table 1. Majority of goat population in highland, midland and lowland agro-ecology of the study area had short hair accounting 53.7%, 67.7% and 86.1% respectively, which was in agreement with Ahmed (2013) and Alemu (2014) who reported that majority of goat population had short hair in all selected districts of Horro Guduru Wollega zone and Shabelle zone respectively. In a small proportion of goat population across three agro-ecologies were also observed medium hair followed by long hair with a proportion of (34.3%, 22.9% and, 8.0%) and (11.9%, 9.5% and 6.0%) in highland, midland and lowland respectively.

Regarding hair coat type as presented in table 1, majority of goat population (76.6%, 77.1% and 82.1) in highland, midland and lowland agro-ecology were smooth hair type with the overall 78.6%; which was in agreement with Alefe (2014) who reported that smooth hair type was the most dominant (99.48%) hair cot type of goat in Shabelle zone.

Sample goat in highland **Sample goat in midland** **Sample goat in lowland**

Figure 1: The representative coat color type of goat population across the three agro-ecologies

Horn Shape and Orientation

The majority of goat populations in the study area were found to be horned (98.5%, 98.0%, and 97.0% in highland, midland and lowland, respectively). The overall figures showed that 97.8% of goat populations were horned and the rest 2.2% of goat populations were spiral. In the study area different horn shapes (straight, curved and spiral) and orientations (Obliquely and backward) were observed. The majority of goat population had curved and straight in highland (58.1and 36.4%) and lowland (52.3 and 46.7%), where as in midland straight and curved (47.7 and 45.5%) horn shape was most frequently observed. Spiral horn shape was also observed across all agro-ecology of the study area in varied frequencies.

Two types of horn orientation (Obliquely and backward) were observed in the present study across all agro-ecologies. The backward horn orientation was more numerous in all three agro-ecologies. The overall results showed that 56.4% and 43.6% of goat had backward and oblique horn orientation. This result was comparable with the report of Bekalu (2014) who reported majority of sampled goat population in west Gojjam were horned (85.67%) with back ward horn orientation (65.5%).

Ear Orientation

In the present study three types of ear orientations (Erect, semi-pendulous and horizontal) were observed. However, semi-pendulous ear orientation followed by horizontal ear orientation were the most frequently observed ear orientation in midland (39.8 and 38.6%) and lowland (42.4 and 38.8%) respectively, whereas in highland horizontal followed by Semi-pendulous ear orientation was the most frequent with the proportion of 52.7 and 39.4%, respectively. A small proportion of goat had erect hair orientation in all three agro-ecologies. Even if ear orientation across the three agro-ecologies was different, the overall results showed that ear orientations were horizontal (43.4%) followed by semi-pendulous (37.3%) and erect (19.2%) in the study area. The current finding was in disagreement with the report of Tsigabu (2015) who reported that pendulous ear orientation was the most frequent observed in Nuer zone of Gambella people regional state.

Head Profile

In the present study three types of head profile (concave, straight and convex) were observed. However, concave head profile followed by straight head profile was the most frequently observed in highland (61.7 and 39.3%), midland (62.7 and 36.3%) and lowland (64.2 and 33.8%) which was in agreement with Farm Africa (1996) majority of Western Highland goat had concave facial profile. A small proportion of goat had convex head profile in the midland (1%) and lowland (1.5%) areas. In overall only 0.8% of goat population in the study area was convex head profile. The current finding was in disagreement with the report of Belay and Meseretu (2017) who reported that straight head profile followed by concave head profile was the most frequent observed in Gamo-Gofa Zone of South Western Ethiopia.

Toggle, Beard, Ruff and Wattle

In the present study, the goat population, across all agro-ecologies, showed presence of toggle (18.4%), beard (34.5%), ruff (10.6%) and wattle (9.5%). The remaining 81.6%, 65.5%, 89.4% and 90.5% of goat population across three agro-ecologies of the study area were absence of toggle, beard, ruff and wattle which was in agreement with Belete (2014) and Alubel (2015) who reported that majority of indigenous goat population in Bale were absence of toggle, beard and ruff.

Back and Rump Profile

In the study area different back profile (straight, slop up to the rump and dipped) and rump profile (flat and sloppy) were observed in sampled goat populations. The most population of sample goat was described with straight back profile (74.5%) and sloppy rump profile (76.6%), which was in agreement with Ahmed (2013) who reported that straight back profile and slopping rump profile was the most dominantly observed back and rump profile in Horro Guduru Wollega zone of Oromia region Ethiopia. Similarly Bekalu (2014) reported that the dominant back profile was straight back profile in west Gojjam zone of Amhara region.

Quantitative traits of goat in study area

Body weight and linear body measurements

The least square means ± SE of body weight (kg) and other linear body measurements of goat are presented in Table 2. The importance of body weight and other linear body measurements in breed improving strategies and improve the goat productivity is not doubted. In the study area, overall mean of HG, HW, BL, RH, CD, HL, EL, RW, RL, CBL, CBC, HL, BW and SC were 73.19±0.18cm, 67.30±0.18cm, 60.39±0.18cm, 69.32±0.21cm, 32.09±0.11cm, 12.91±0.18cm, 13.56±0.06cm, 14.74±0.09cm, 11.73±0.12cm, 12.36±0.04cm, 8.38±0.04 cm, 14.92±0.07cm, 28.82±0.17kg and 22.83±0.19cm, respectively. The current finding was comparable with the finding of Bekalu (2013), Yaekob *et al.*, (2015) and Belay and Meseretu (2017) indicates that the average body weight, chest girth, height at withers, body length and ear length were 28.03, 74.87 cm, 64.51 cm, 60.19 cm, 13.89 cm for western highland goat in west Gojjam, 26.7 kg, 73.11 cm, 66.65 cm, 58.20 cm, 12.5 cm for Woyto-Guji in Northern Omo, 26.29 kg, 71.17 cm, 64.16 cm, 58.68 cm, 16.16 cm for Woyto-Guji in Bench-Mage zone, respectively.

Table 1: qualitative traits of sampled goat population in the study area

Character and level	Highland						Midland						Lowland						Overall	
	Male		Female		Total		Male		Female		Total		Male		Female		Total			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Coat color pattern:																				
Plain	10	47.6	94	52.2	104	51.7	10	47.6	92	51.1	102	50.7	12	57.1	119	66.1	131	65.2	337	55.9
Patchy	8	38.1	57	31.7	65	32.3	6	28.6	57	31.7	63	31.3	6	28.6	46	25.6	52	25.9	180	29.9
Spotted	3	14.3	29	16.1	32	15.9	5	23.8	31	17.2	36	17.9	3	14.3	15	8.3	18	9.0	86	14.3
X^2value																			**12.537***	
Coat color type:																				
White	2	9.5	40	22.2	42	20.9	4	19.0	31	17.2	35	17.4	6	28.6	54	30.0	60	29.9	137	22.7
Red	4	19.0	27	15.0	31	15.4	2	9.5	24	13.3	26	12.9	4	19.0	36	20.0	40	19.9	97	16.1
Black	0	0.0	17	9.4	17	8.5	2	9.5	17	9.4	19	9.5	0	0.0	11	6.1	11	5.5	47	7.8
Brown	4	19.0	9	5.5	13	6.5	2	9.5	19	10.6	21	10.4	2	9.5	18	10.0	20	10.0	54	9.0
Gray	1	4.8	18	10.0	19	9.5	2	9.5	21	11.7	23	11.4	3	14.3	11	6.1	14	7.0	56	9.3
Red +black	1	4.8	12	6.7	13	6.5	2	9.5	10	5.6	12	6.0	0	0	5	2.8	5	2.5	30	5.0
Red +white	9	42.9	48	26.7	57	28.4	4	19.0	44	24.4	48	23.9	5	23.8	28	15.6	33	16.4	138	22.9
Black +white	0	0.0	9	5.0	9	4.5	3	14.3	14	7.8	17	8.5	1	4.8	17	9.4	18	9.0	44	7.3
X^2value																			**30.410***	
Hair length:																				
Short	9	42.9	99	55.0	108	53.7	12	57.1	124	68.9	136	67.7	16	76.2	157	87.2	173	86.1	417	69.2
Medium	7	33.3	62	34.4	69	34.3	5	3.8	41	22.8	46	22.9	3	14.3	13	7.2	16	8.0	131	21.7
Large	5	23.8	19	10.6	24	11.9	4	19.0	15	8.3	19	9.5	2	9.5	10	5.6	12	6.0	55	9.1
X^2value																			**40.406***	
Hair type:																				
Smooth	16	76.2	138	76.7	154	76.6	16	76.2	139	77.2	155	77.1	17	81.0	148	82.2	165	82.1	474	78.6
Glossy	5	23.8	42	23.3	47	23.4	5	23.8	41	22.8	46	22.9	4	19.0	32	17.8	36	17.9	129	21.4
X^2value																			**2.189^{NS}**	

Table 1(continued)

Character and level	Highland						Midland						Lowland						Overall	
	Male		Female		Total		Male		Female		Total		Male		Female		Total			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Horn:																				
Present	21	100	177	98.3	198	98.5	21	100	176	97.8	197	98.0	21	100	174	96.7	195	97.0	590	97.8
Absent	0	0.0	3	1.7	3	1.5	0	0.0	4	2.2	4	2.0	0	0.0	6	3.3	6	3.0	13	2.2
X^2 value																			**1.101^{NS}**	
Horn shape:																				
Straight	8	38.1	64	36.2	72	36.4	9	42.9	85	48.3	94	47.7	12	57.1	79	45.4	91	46.7	257	43.6
Curved	12	57.1	103	58.2	115	58.1	11	52.4	79	44.9	90	45.5	8	38.1	94	54.0	102	52.3	307	52.0
Spiral	1	4.8	10	5.6	11	5.6	1	4.8	12	6.8	13	6.6	1	4.8	1	0.6	2	1.0	26	4.4
X^2 value																			**14.287***	
Horn orientation:																				
Obliquely	13	61.9	80	45.20	93	47.0	9	42.9	80	45.5	89	45.2	12	57.1	63	36.2	75	38.5	257	43.6
Back- ward	8	38.1	97	54.80	105	53.0	12	57.1	96	54.5	108	54.8	9	42.9	111	63.8	120	61.0	333	56.4
X^2 value																			**3.283^{NS}**	
Ear orientation:																				
Erect	2	9.5	34	18.9	36	17.9	5	23.8	38	21.1	43	21.4	3	14.3	34	18.9	37	18.4	116	19.2
Pendul-ous	6	28.6	53	29.4	59	39.4	11	52.4	69	38.3	80	39.8	12	57.1	74	41.1	76	42.4	225	37.3
Horizon-tally	13	61.9	93	51.7	106	52.7	5	23.8	73	40.6	78	38.6	6	28.6	72	40.0	78	38.8	262	43.4
X^2 value																			**12.086***	
Head profile:																				
Straight	9	42.9	70	38.9	79	39.3	10	47.6	63	35.0	73	36.3	4	19.0	64	35.6	68	33.8	220	36.5
Concave	12	57.1	110	61.1	122	61.7	11	52.4	115	63.9	126	62.7	17	81.0	113	62.8	130	64.7	378	62.7
Convex	0	0.0	0	0.0	0	0.0	0	0.0	2	1.1	2	1.0	0	0.0	3	1.7	3	1.5	5	0.8
X^2 value																			**3.881^{NS}**	
Toggle:																				
Present	2	9.5	43	23.9	45	22.4	3	14.3	45	25.0	48	23.9	2	9.5	16	8.9	18	9.0	111	18.4
Absent	19	90.5	137	76.1	156	77.6	18	85.7	135	75.0	153	76.1	19	90.5	164	91.1	183	91.0	492	81.6
X^2 value																			**18.086***	

Table 1 (continued)

Character and level	Highland						Midland						Lowland						Overall	
	Male		Female		Total		Male		Female		Total		Male		Female		Total			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Beard:																				
Present	11	52.4	63	35.0	74	36.8	12	57.1	76	42.2	88	43.8	14	66.7	32	17.8	46	22.9	208	34.5
Absent	10	47.6	117	65.0	127	63.2	9	42.9	104	57.8	113	56.2	7	33.3	148	82.2	155	77.1	395	65.5
X^2 value																			**20.139***	
Ruff:																				
Present	12	57.1	8	4.4	20	10.0	13	61.9	7	3.9	20	10.0	14	66.7	10	5.6	24	11.9	64	10.6
Absent	9	42.9	172	95.6	181	90.0	8	38.1	173	96.1	181	90.0	7	33.3	170	94.4	177	88.1	539	89.4
X^2 value																			**0.559^{NS}**	
Wattle:																				
Present	6	28.6	15	8.3	21	10.4	4	19.0	12	6.7	16	8.0	6	28.6	14	7.8	20	10.0	57	9.5
Absent	15	71.4	165	91.7	180	89.6	17	81.0	168	93.3	185	92.0	15	71.4	166	92.2	181	90.0	546	90.5
X^2 value																			**0.814^{NS}**	
Back profile:																				
Straight	19	90.5	127	70.6	146	72.6	17	81.0	139	72.2	156	77.6	15	71.4	132	73.3	147	73.1	449	74.5
Slops up to rump	2	9.5	47	26.11	49	24.4	4	19.0	37	20.6	41	20.4	6	28.6	39	21.7	45	22.4	135	22.4
Dipped	0	0.0	6	3.3	6	3.0	0	0.0	4	2.2	4	2.0	0	0.0	9	5.0	9	4.5	19	3.2
X^2 value																			**3.116^{NS}**	
Rump profile:																				
Flat	5	23.8	38	21.1	43	21.4	6	28.6	42	23.3	48	23.9	4	19.0	46	25.6	50	24.9	141	23.4
Sloping	16	76.2	142	78.9	158	78.6	15	71.4	138	76.7	154	76.1	17	81.0	134	74.4	151	75.1	462	76.6
X^2 value																			**0.722^{NS}**	

Effect of Agro-ecology

The effects of agro-ecologies were highly significant ($P < 0.01$) for all quantitative measurements except horn length, rump length, cannon bone length and head length. The present result was in agreement with earlier workers (Solomon, 2014; Yaekob *et al.*, 2015 and Belay and Meseretu, 2017) who reported that the effects of agro-ecologies had significant effect on body measurements in indigenous goat types. However, the present result is in disagreement with the result of Bekalu (2014), Belete (2013) and Tsigabu (2015) where in body measurements were not affected by location. The lowland goat population showed a significant higher value for all quantitative traits, except horn length, rump width, canon bone circumference and head length, compared to goats' population in midland and highland. Generally lower values were observed in all linear measurements for highland agro-ecology compared to the other two agro-ecologies. This might be due to associated with the temperature difference in different agro-ecologies were lowland goat has higher feed conversion efficiency. On the contrary highland and midland goat's population spent more energy to generate heat to keep them warm, particularly during colder seasons and this was in line with the report of Belay and Meseretu (2017) who reported that goat populations sampled from lowland area were higher in their linear measurements than highland ones. On the contrary present finding were in disagreement with the report of Yaekob *et al.*, (2015) who reported that highland have higher value than the lowland goat population in Woyto-Guji goats. The possible reason for differing values of quantitative traits in the agro-ecologies may be the variation in management, quality/quantity of feeds, climatic conditions and other ecology related factor.

Effect of Sex

The result revealed that sex is an important source of variation for live body weight and linear body measurements at all age groups. In the study area sex had significant effect on body weight and other linear body measurements except ear length, canon bone length, head length, and rump length. In this study males had higher body weight and other linear body measurements ($p<0.05$) than the corresponding values in females which was in agreement with Farm Africa (1996), reported that most male goat had higher body weight and other linear body measurement than the corresponding value in female for western highland goat. This might partly due to hormonal difference, that is, release of androgen in male animals after the testes are well developed (Frandson and Elmer, 1981).

Effect of Age

Body weight and all body measurements were significantly affected ($p<0.01$) by age. The current finding was in line with Yaekob *et al.*, (2015) who reported that the effect of age was highly significant ($p<0.001$) on body weight and all other body measurements across three agro-ecology in Woyto-Guji goat. HG, HW, BL, RH, CD, HOL, EL, RW, RL, CBL, CBC, HL, BW and SC increased as the age increased from the youngest (1PPI) to the older (4PPI) age group which was in agreement with Tsigabu (2015) and Yaekob *et al.*, (2015) who reported that body weight and other linear body measurement increased with increasing age of goats; and Bekalu (2014) who reported that body weight and other linear body measurement except ear length increased from (1PPI) to (4PPI) age group. The size and shape of the animal increases until the animal reach its maturity and the effect of age on body weight and other linear body measurements were also observed in different goat breeds of Ethiopia (Yoseph, 2007). This increasing trend with increasing age was due to the growth of goats.

Effect of Sex by age interaction

The interactions between sex and age groups were also significant ($P < 0.05$) on heart girth, height at wither, rump height, chest depth, rump width, cannon bone circumference and live body weight of goat population. In each age group all the parameters considered, males showed significantly (at least $P<0.01$or $p<0.05$) higher measurements than females except, ear length, canon bone length, and head length. The different value of quantitative trait between male and female in different age class is due to hormonal difference between males and females. The value of body weight and other linear body measurements of goat's population increased as age group increased from the youngest 1PPI to the oldest 4PPI for both male and female goats. This was in agreement with Yaekob *et al.* (2015), Alubel (2015) and Bekalu (2014) who reported that the interaction of sex and age group was significant for body weight and all other linear body measurements on Central Highland and Abergelle goat and except ear length, horn length in west Gojjam respectively.

Effect of Sex by agro-ecology interaction

The interactions between sex and agro-ecology were also significant ($P < 0.05$) on some quantitative trait such as heart girth, height at wither, body length, rump height, chest depth, cannon bone circumference and live body weight of sampled goat population. In all agro-ecology body weight and other linear body measurements showed that males had significantly higher values than females except ear length. The different value of quantitative trait between male and female in different agro-ecology is due to hormonal difference between males and females, as explained above in the interaction sex by age group, management system and agro-ecologies difference. The value for all body measurement for both sex were higher in lowland than the rest two (midland and highland) agro-ecology of the study area except body length for male, cannon bone length for female, ear length, head length and chest depth for both sexes which had higher values in midland.

Correlation between Body Weight and other Linear Body Measurements

The phenotypic correlation coefficients (r_p) of studied goat population in the study area obtained between the live body weight and other linear body measurements for both sexes were presented in Table 3. For both male and female goat, the correlation coefficients between body weight and other linear body measurement were varied from moderately significant ($p<0.05$) to highly significant ($p<0.0001$). The heart girth followed by height at Wither, body length, rump height, chest depth, scrotum circumference and horn length with correlation value of 0.92, 0.91, 0.90, 0.90, 0.89, 0.87 and 0.73, respectively had high correlation with body weight for male goat. On the other hand the highest correlated trait with body weight was heart girth followed by height at wither, rump height, chest depth, body length and horn length for females with a correlation value of 0.85, 0.84, 0.83, 0.76, 0.59 and 0.55, respectively. The linear body measurements which have moderate correlation with body weight are (EL, RW, CBC and HDL) for male and (EL, HL, RW, RL, CBL, CB and HDL) for female. Heart girth had the highest correlation with body weight in both sexes, and this suggested that heart girth is the most reliable parameter for prediction of body weight for goat population in present study. The current finding is in agreement with the earlier study of Ahmed (2013), Belete (2013), Alefe (2014), Alubel (2014), Bekalu (2014), and Yaekob *et al.* (2015), who reported that heart girth had high correlation with body weight and this is the best parameter to estimate body weight of sample goat population on Woyto-Guji in Loma, Central Highland and Abergelle goat, indigenous goat in (Shabelle, West Gojjam, bale and Horro Gudruu Wollega), respectively.

Table 2: Least Square Means ± SE of Body Weight (Kg) and Other Linear Body Measurements (Cm) By Sex, Age, Agro-Ecology, Interaction of Age by Sex and Sex by Agro-Ecology

Effect and levels	N	HG	WH	BL	RH	CD	HOL	EL
		LSM±SE	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**
Overall	603	73.19±0.18	67.30±0.18	60.39±0.18	69.32±0.21	32.09±0.11	12.91±0.18	13.56±0.06
CV%		3.84	4.10	6.71	4.03	6.01	30.10	9.97
R^2		0.62	0.60	0.37	0.59	0.51	0.39	0.21
Agro ecology:		*	*	*	*	*	NS	*
Highland	201	72.73^{b}±0.4	66.85^{b}±0.36	60.57^{b}±0.53	68.86^{b}±0.37	32.79^{b}±0.25	13.20±0.47	$13.09±0.18^{c}$
Midland	201	74.01^{a}±0.3	68.17^{a}±0.32	61.25^{ab}±0.47	70.17^{a}±0.32	33.17^{a}±0.22	13.29±0.41	$13.44±0.16^{b}$
Lowland	201	75.08^{a}±0.3	68.90^{a}±0.32	62.35^{a}±0.47	70.95^{a}±0.33	33.44^{a}±0.23	12.96±0.42	$13.80±0.16^{a}$
Sex:		*	*	*	*	*	*	NS
Male	63	75.57^{a}±0.39	69.51^{a}±0.38	63.17^{a}±0.57	71.53^{a}±0.39	34.79^{a}±0.27	14.11^{a}±0.49	13.39±0.19
Female	540	72.32^{b}±0.12	66.44^{b}±0.12	59.61^{b}±0.18	68.46^{b}±0.12	31.48^{b}±0.09	12.19^{b}±0.16	13.51±0.06
Age:		*	*	*	*	*	*	*
1PPI	121	69.55^{d}±0.33	63.75^{d}±0.32	57.66^{c}±0.47	65.82^{d}±0.32	30.66^{d}±0.22	9.15^{c}±0.42	12.69^{c}±0.16
2PPI	142	72.53^{c}±0.35	66.74^{c}±0.35	59.63^{b}±0.51	68.74^{c}±0.35	31.72^{c}±0.24	11.68^{b}±0.45	13.20^{bc}±0.17
3PPI	144	75.80^{b}±0.43	69.78^{b}±0.42	63.21^{a}±0.62	71.80^{b}±0.43	34.25^{b}±0.29	15.33^{a}±0.54	13.67^{ab}±0.21
4PPI	196	77.88^{a}±0.51	71.61^{a}±0.50	65.06^{a}±0.74	73.662^{a}±0.51	35.89^{a}±0.35	16.43^{a}±0.65	14.20^{a}±0.25

Table 2(Continued)

Effect and levels	N	HG	WH	BL	RH	CD	HOL	EL
		LSM±SE	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**
Sex X age interaction:		*	*	NS	*	*	NS	NS
Male,1PPI	25	71.68^{cd}±0.58	65.88^{cd}±0.57	59.44±0.84	67.93^{cd}±0.58	32.38^{bc}±0.40	9.64±0.74	12.50±0.28
Female,1PPI	96	67.43^{e}±0.29	61.62^{e}±0.28	55.87±0.42	63.70^{e}±0.29	28.94^{e}±0.20	8.67±0.38	12.88±0.14
Male,2PPI	18	74.18^{bc}±0.66	68.41^{bc}±0.65	61.19±0.95	70.41^{bc}±0.66	32.74^{bc}±0.45	12.26±0.83	13.00±0.32
Female,2PPI	124	70.87^{d}±0.25	65.07^{d}±0.25	58.08±0.36	67.07^{d}±0.25	30.70^{d}±0.17	11.09±0.32	13.41±0.12
Male, 3PPI	12	76.73^{ab}±0.82	70.73^{ab}±0.81	64.92±1.19	72.73^{ab}±0.82	35.88^{a}±0.56	17.41±1.04	13.63±0.40
Female,3PPI	132	74.89^{b}±0.24	68.84^{bc}±0.24	61.49±0.35	70.87^{bc}±0.24	32.64^{c}±0.17	13.25±0.31	13.71±0.12
Male, 4PPI	8	79.67^{a}±1.01	73.01^{a}±0.99	67.12±1.46	75.03^{a}±1.00	38.15^{a}±0.69	17.14±1.27	14.38±0.49
Female,4PPI	188	76.08^{b}±0.20	70.22^{b}±0.20	63.00±0.29	72.21^{b}±0.20	33.64^{b}±0.14	15.73±0.26	14.02±0.10
Sex X Agro-ecology:		*	*	*	*	*	NS	NS
Male, highland	21	75.02^{ab}±0.71	68.38^{ab}±0.70	63.09^{a}±1.03	70.40^{ab}±0.71	34.58^{a}±0.49	13.47±0.90	13.18±0.35
Male, midland	21	75.14^{ab}±0.62	69.52^{a}±0.60	63.27^{a}±0.90	71.53^{a}±0.61	34.61^{a}±0.42	14.76±0.78	13.51±0.30
Male, lowland	21	76.55^{a}±0.62	70.62^{a}±0.61	63.14^{a}±0.90	72.65^{a}±0.62	35.17^{a}±0.43	14.10±0.79	13.45±0.30
Female,highland	180	70.45^{d}±0.21	65.32^{c}±0.21	58.04^{b}±0.31	67.32^{c}±0.21	30.99^{c}±0.15	12.93±0.27	13.01±0.10
Female, midland	180	72.88^{c}±0.22	66.82^{b}±0.21	59.23^{b}±0.31	68.82^{b}±0.22	31.74^{b}±0.15	11.82±0.28	13.37±0.10
Female, lowland	180	73.62^{bc}±0.21	67.17^{b}±0.21	61.55^{a}±0.31	69.25^{b}±0.21	31.70^{b}±0.15	11.82±0.28	14.15±0.10

Table 2 (Continued)

Effect and levels	N	RW	RL	CBL	CBC	HDL	BW	SC
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	603	14.74±0.09	11.73±0.12	12.36±0.04	8.38±0.04	14.92±0.07	28.82±0.17	22.83±0.19
CV%		11.34	23.96	6.78	9.28	9.61	9.42	5.34
R^2		0.27	0.14	0.18	0.26	0.28	0.58	0.83
Agro-ecology:		*	NS	NS	*	NS	*	*
Highland	201	15.97^{a}±0.22	11.43±0.37	12.33±0.11	8.22^{b}±0.10	14.92±0.19	28.71^{b}±0.36	23.80^{b}±0.41
Midland	201	14.56^{ab}±0.19	11.51±0.33	12.38±0.10	8.46^{b}±0.09	15.01±0.17	30.20^{a}±0.32	23.30^{a}±0.27
Lowland	201	15.33^{a}±0.20	12.17±0.33	12.35±0.10	8.95^{a}±0.09	14.71±0.17	30.72^{a}±0.32	24.35^{a}±0.28
Sex:		*	NS	NS	*	NS	*	
Male	63	15.40^{a}±0.23	11.87±0.39	12.41±0.12	8.79^{a}±0.11	15.00±0.20	31.70^{a}±0.38	22.82±0.19
Female	540	14.50^{b}±0.07	11.54±0.12	12.30±0.04	8.29^{b}±0.03	14.77±0.06	28.06^{b}±0.12	-
Age:		*	*	*	*	*	*	*
1PPI	121	13.75^{c}±0.19	10.48^{b}±0.33	11.80^{c}±0.10	8.00^{b}±0.09	13.74^{c}±0.17	25.62^{d}±0.32	20.45^{c}±0.26
2PPI	142	14.16^{c}±0.21	10.77^{b}±0.35	12.00^{c}±0.11	8.16^{b}±0.10	14.21c±0.18	28.23^{c}±0.34	22.49^{b}±0.29
3PPI	144	15.41^{b}±0.26	12.32^{a}±0.43	12.49^{b}±0.13	8.83^{a}±0.12	15.35^{b}±0.22	31.75^{b}±0.42	25.53^{a}±0.39
4PPI	196	16.48^{a}±0.31	13.24^{a}±0.51	13.08^{a}±0.15	9.18^{a}±0.14	16.22^{a}±0.26	33.93^{a}±0.50	26.81^{a}±0.51

Table 2 (Continued)

Effect and levels	N	RW	RL	CBL	CBC	HDL	BW	SC
		LSM±SE	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**
Sex X Age:		*	NS	NS	*	NS	*	
Male,1PPI	25	14.14^{bc}±0.35	10.58±0.59	11.78±0.17	8.10^{cd} ±0.16	13.73±0.30	27.21^{ef}±0.57	20.45^{c}±0.26
Female,1PPI	96	13.35^{c}±0.17	10.5±0.29	11.89±0.08	7.89 ^{d}±0.08	13.74±0.15	24.02^{f}±0.28	-
Male,2PPI	18	14.27^{bc}±0.39	10.6±0.66	11.89±0.20	8.26^{bcd}±0.18	14.13±0.34	29.40^{cde}±0.64	22.49^{b}±0.29
Female,2PPI	124	14.05^{c}±0.15	10.9±0.25	12.12±0.07	8.05^{d}±0.07	14.30±0.13	27.05^{e}±0.24	-
Male, 3PPI	12	15.97^{ab}±0.49	12.8±0.83	12.65±0.24	9.22^{a}±0.23	15.62±0.42	33.63^{ab}±0.80	25.53^{a}±0.39
Female, 3PPI	132	14.85^{b}±0.14	11.8±0.24	12.34±0.07	8.43^{c} ±0.07	15.08±0.12	29.87^{d}±0.24	-
Male, 4PPI	8	17.21^{a}±0.60	13.5±1.01	13.33±0.30	9.59^{a}±0.28	16.52±0.51	36.57^{a}±0.97	26.81^{a}±0.51
Female, 4PPI	188	15.75^{ab}±0.12	13.0±0.20	12.84±0.06	8.77^{ab}±0.06	15.92±0.10	31.29^{bc}±0.20	-
Sex X Agro-ecology:		NS	NS	NS	*	NS	*	*
Male, highland	21	15.56±0.42	11.55±0.72	12.37±0.21	8.26^{b}±0.19	14.97±0.36	31.40^{a}±0.69	23.80^{b}±0.41
Male, midland	21	15.12±0.37	11.72±0.62	12.43±0.18	8.76^{ab}±0.17	15.14±0.31	31.35^{a}±0.60	23.30^{a}±0.27
Male, lowland	21	15.52±0.37	12.35±0.63	12.43±0.19	9.35^{a}±0.17	14.89±0.32	32.36^{a}±0.60	24.35^{a}±0.28
Fem, highland	180	14.38±0.13	11.31±0.21	12.29±0.06	8.17^{c}±0.06	14.86±0.11	26.03^{c}±0.21	-
Female, midland	180	13.99±0.13	11.30±0.22	12.32±0.06	8.15^{c}±0.06	14.89±0.11	29.06^{b}±0.21	-
Female, lowland	180	15.13±0.13	11.99±0.21	12.28±0.06	8.55^{bc}±0.06	14.53±0.11	29.09^{b}±0.21	-

a,b,c,d,e,f and g means on the same column with different superscripts within the specified age group, sex, agro-ecology and interaction of age by sex and sex by agro-ecology are significantly different (P<0.05); HG= Heart Girth; BL=Body Length; WH= Wither height; RH= Rump Height; CD=Chest Depth; HOL=horn length, EL= Ear Length; RW=rump width, RL= Rump Length; HL=head length, SC=scrotum circumference, BW =body weight 1PPI = 1 Pair of Permanent Incisors; 2PPI = 2 Pair of Permanent Incisors; 3PPI = 3 Pairs of Permanent Incisors; 4PPI = 4 Pairs of Permanent Incisors.

Table 3: Correlation Coefficients Among Body Weight And Linear Measurements Goat (Values above the Diagonal for Males And Below The Diagonal for Females) (N=63 for Male; N=540 for Females)

	HG	HW	BL	CD	HL	EL	RH	RW	RL	CBL	CBC	HDL	BW	SC
HG		0.93*	0.80*	0.84*	0.70*	0.49*	0.93*	0.47*	0.61*	0.55*	0.50*	0.50*	0.92*	0.82*
HW	0.97*		0.81*	0.80*	0.69*	0.53*	0.99*	0.48*	0.60*	0.51*	0.57*	0.52*	0.91*	0.79*
BL	0.61*	0.60*		0.81*	0.64*	0.78*	0.80*	0.37*	0.51*	0.49*	0.55*	0.48*	0.90*	0.83*
CD	0.83*	0.83*	0.57*		0.67*	0.40*	0.80*	0.45*	0.58*	0.63*	0.52*	0.47*	0.89*	0.76*
HL	0.57*	0.60*	0.38*	0.58*		0.48*	0.68*	0.60*	0.68*	0.50*	0.61*	0.63*	0.73*	0.64*
EL	0.38*	0.36*	0.25*	0.32*	0.23*		0.53*	0.67*	0.58*	0.32*	0.42*	0.60*	0.52*	0.55*
RH	0.97*	0.99*	0.60*	0.83*	0.60*	0.36*		0.48*	0.60*	0.51*	0.57*	0.52*	0.90*	0.78*
RW	0.55*	0.57*	0.38*	0.55*	0.56*	0.38*	0.56*		0.81*	0.58*	0.54*	0.78*	0.52*	0.51*
RL	0.33*	0.55*	0.25*	0.28*	0.32*	0.20*	0.34*	0.41*		0.62*	0.63*	0.84*	0.66*	0.62*
CBL	0.40*	0.44*	0.26*	0.38*	0.37*	0.18*	0.44*	0.42*	0.26*		0.61*	0.63*	0.60*	0.50*
CBC	0.45*	0.46*	0.35*	0.42*	0.38*	0.28*	0.47*	0.38*	0.35*	0.46*		0.56*	0.57*	0.54*
HDL	0.53*	0.56*	0.32*	0.57*	0.55*	0.26*	0.55*	0.61*	0.31*	0.48*	0.43*		0.56*	0.55*
BW	0.85*	0.84*	0.59*	0.76*	0.55*	0.36*	0.83*	0.52*	0.30*	0.35*	0.40*	0.46*		0.87*

* Significant at ($p<0.05$ and $p<0.0001$) level; HG= Heart Girth, BL=Body Length, WH= Wither Height, RH= Rump Height, CD=Chest Depth, HL=Horn length, EL= Ear Length, RW = Rump Width, RL=Rump Length, CBL=Cannon Bone Length, CBC=Cannon Bone Circumference, HDL= Head Length, BW=Body weight and SC = Scrotal Circumference;

Table 4: Multiple regression analysis of live body weight on different body measurements of female and male goats in the study area

Models	Parameters										
	Intercept	β1	β2	β3	β4	β5	β6	β7	R^2	C(p)	RMSE
Model for female											
HG	-27.12	0.76							0.71	33.23	4.88
HG+CD	-26.21	0.63	0.27						0.72	16.99	4.73
HG+CD+BL	-26.87	0.60	0.07	0.24					0.72	9.76	4.66
HG+CD+BL+HL	-25.16	0.58	0.07	0.20	0.07				0.73	5.67	4.61
HG+CD+BL+HL+EL	-25.66	0.57	0.07	0.21	0.06	0.11			0.73	4.91	4.60
HG+CD+BL+HL+EL+HW	-25.91	0.45	0.14	0.07	0.19	0.06	0.12		0.73	4.40	4.58
HG+CD+BL+HL+EL+HW+HDL	-25.42	0.44	0.15	0.07	0.21	0.07	0.12	-0.11	0.73	4.22	4.57
Model for male											
HG	-45.30	1.01							0.85	109.53	2.06
HG+BL	-46.62	0.62	0.49						0.92	32.47	1.11
HG+BL+CD	-42.03	0.48	0.39	0.36					0.93	18.95	0.93
HG+BL+CD +RW	-41.67	0.48	0.40	0.31	0.20				0.94	12.13	0.84
HG+BL+CD+RW+SC	-37.41	0.40	0.34	0.32	0.16	0.17			0.95	10.50	0.80
HG+BL+CD+RW+SC+HW	-37.09	0.25	0.19	0.30	0.34	0.12	0.18		0.95	8.90	0.77
HG+BL+CD+RW+SC +HW +RH	-31.24	0.25	2.51	0.25	0.39	-2.32	0.11	0.19	0.95	4.42	0.70

HG = Heart girth; CD = Chest Depth; BL = Body length; HL=Horn Length; EL=Ear Length; WH = Wither Height; HDL= Head Length; RW=Rump width, SC=scrotum circumference RH = Rump Height; R2 = coefficient of determination, C (P) = the mallow's parameters, MSE = Mean square error

Prediction of Body Weight of Goats from Other Linear Body Measurements

The results of multiple linear regression models for predicting the body weight of goats from other linear body measurements is presented in Table 4. The knowledge of live weight of animals is important in both livestock production and marketing practices and though the use of conventional weighing scales is the best way of determining live weight of an animal. Yet proper weight measurements are often difficult in villages due to lack of weighing scales. Thus in situations where no equipment for physical weighing of small ruminants is available, it is advisable to predict the body weight on the basis of body measurements using suitable prediction equations (Kassahun and Solomon, 2008). Multiple linear regression analysis was carried out to predict live body weight of an animal. The regression of body weight on independent variables, which have higher correlation with body weight, was done to set adequate model for the prediction of body weight separately for male and female. The result of stepwise multiple regression analysis showed that the most important variable to predict body weight was heart girth than the other variables in both sexes for does (71%) and bucks (85%).This is in agreement with the earlier results of Belay and Meseretu (2017), Yaekob *et al*., (2015), Alubel (2015), Bekalu (2014), Hulunim (2014), Ahmed (2013), and Belete (2013), as heart girth was selected first for prediction of live body weight of animals. The accuracy of functions used to predict live weight or growth characteristics from live animal measurements have enormous contribution on the improvement of livestock production and productivity Tesfaye (2008).

Only seven quantitative variables (HG, BL, CD, RW, SC, HW and RH) and (HG, CD, BL, HL, EL, HW and HDL) explained a total variability of 85% and 71% in males and females, respectively. However, the addition of BL (for male) and CD (for female) to chest girth in the first step improved the R2 value by 0.07 and 0.01 and decreased the MSE by 0.95 and 0.15 respectively. The inclusion of CD and RW (for male) and BL (for female) improve the R^2 by 0.01 and decreased the mean square error by 0.08 and 0.09 (for male) and 0.05 (for female). However the inclusion of other parameters did not improve the total variability of the dependent variable. This showed that heart girth (Model I) was the most reliable variable in predicting body weight than other LBMs both for male and female goats at farmer's level.

Stepwise regression procedure was carried out to generate models (equations) for prediction of body weight of both male and female goats separately from linear measurements. The regression equation for body weight was estimated as $Y= - 27.12 + 0.76X$ (where X stands for HG), with R value of 0.71 for female and $Y= - 45.12 + 1.01X$ (where X stands for HG), with R value of 0.85 for male goat in the present study. This finding showed that an increase of one cm of HG resulted in an increase of 0.76 and 1.01 kg of live body weight in female and male goats, respectively.

Even though the increment of $R^2$was small in each steps in the model, combination of more than one variable clearly indicated that weight could be estimated more accurately by combination of two or more variable. This may be decreasing the values of C (P), MSE which will ultimately increase the efficiency of the model. However, according to Grum (2010) and Tesfaye (2008), considering more variables under extensive management conditions will be unpractical due to cost and accuracy problems. So, live body weight estimation using heart girth alone would be better under extensive management conditions.

CONCLUSION AND RECOMMENDATIONS

The current study was aimed to generate information on physical characteristics of indigenous goat type that help to design important breeding program in South Gondar Zone of Amhara National Regional State. The most dominant coat color pattern was plain, but patchy and spotted were also present in some extent. White dominant on red and red were the

most frequent coat colors in highland and midland goat population in the study area while in lowland area white dominant on red and white coat color was the most frequent one. The body weight and most other linear body measurement result showed that the studied population in lowland was generally better than highland and midland goat population. The least square means for the effect of sex had significant effect ($P<0.05$) on all quantitative variables except ear length, canon bone length, and rump length. Male goats were consistently higher than females in all significantly affected variables except for horn length. The lowland goat population showed a significant higher value for all quantitative traits, except horn length, rump width, canon bone circumference and head length, compared to goats' population in midland and highland. The most important variable for predicting body weight was chest girth in both sexes (71%) for does and (85%) for bucks. The goat population in the study area showed the phenotypic variation. However, this phenotypic characterization is not enough to show this variation. Therefore, the difference of goat population in morphometric trait should be supported by further study on characterization at molecular level under their production environment.

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