Morphometric Characterization of Indigenous Goats in East Gojjam Zone, Amhara Region, Ethiopia

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Abstract
This study was conducted in HuletEjuEnesie, GonchaSisoEnesie and EnbseSarMidir districts of East Gojjam Zone with the aim to Morphometric characterize indigenous goat populations. A total of 600 goats were sampled randomly for phenotypic characterization. The most dominant coat color pattern in the sampled populations wasplain and patchy with the most frequently observed coat color type being light red, white with red and white. Sex of animal had significant effect on all of the body measurements, except ear length, chest depth, and rump length and width. EnbseSarMidir district had significantly higher body measurement values than other districts. Dentition had significant differences on body weight and most of the linear body measurements. Correlations among body weight and linear body measurements were positive for both sexes. The result of the multiple regression analysis showed that heart girth explained more variation than any other linear body measurements in both does (71%) and bucks (82%). The prediction of body weight could be based on regression equation BW = -37.93 + 0.92CG for female sample population and BW = -44.47 + 1.02CG for male sample goat population. To sustainably utilize these goat population the production constrains should be solved and selective community-based breeding strategies should be designed and implemented.

Keywords: Body weight, Indigenous, Linear Body Measurement, Morphometric Characterization.

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Introduction

In Ethiopia, more than 85% of the human population depends on agriculture for their livelihoods (Solomon, 2014) and usually keep livestock as pastoralists or in mixed crop livestock systems. Livestock are an important section of agriculture in Ethiopia and provides milk, meat, draught power, transport, manure, hides, skins (Funk et al., 2012) and it has served as a source of income for the country (Feki, 2013).

Goats (Capra hircus) are an integral part of economic and social life especially in developing countries. Goats also can have a role in tradition, social status, social payments, rituals and ceremonies, bride price, insurance, status display, dispute compensation and as a mobile bank (Berhanu et al., 2012; Arineitwe and Ndyomugyeni, 2013).

According to CSA (2017), the number of goats reported in the country is estimated to be about 30.2 million, of which about 70.61% are females and 29.39% are males. Phenotypic characteristics are important in breed identification local genetic resources as it depends on the knowledge of the variation of morphological traits, which play very fundamental role in classification of livestock based on size and shape (Ferra et al., 2010; Agga et al., 2010; Leng et al., 2010).

The research done so far on phenotypic characterization indicated that there are about 14 goat types in Ethiopia and Eritrea (FARM Africa, 1996). In addition, there are different studies conducted in Ethiopia, Ahmed (2013) in Horro Guduru Wollega zone Oromia region, Belete (2013) in Bale zone Oromia region, Netsanet (2014) in Meta-Robi district Oromia region and Konso district in Southern Nations, Nationalities and People’s region, Bekalu (2014) in West Gojam zone Amhara region, Alubel (2015) in north Gondar zone of Amhara region and Diba (2017) in Guji zone of Oromia region carried out to characterize the indigenous goat found in Ethiopia. However, characterization has not been done so far particularly for indigenous goats found in East Gojjam zone. FARM Africa (1996) based on the physical description study named these populations as western highland goats. According to FAO (2007) changes in population type and structure need to be documented regularly for all breeds at intervals of about five years for cattle, buffalo, sheep and goats. Goats are the major income source for farmers in East Gojjam zone. In addition, large goat populations are found in the study area. The agro ecology of the area is also suitable for goat production. Therefore, this study objective was to characterize indigenous goat populations in the study area.

Materials and Methods

Description of the Study Area

This study was conducted in three districts of east Gojjam zone (Hulet Eju Enesie, Goncha Siso Enesie and Enbse Sar Midir) in East Gojjam zone of Amhara regional state, Ethiopia. It is 298 km from Addis Ababa and 265 km
from the capital city Bahir Dar. The area consists of different livestock composition. According to CSA (2016/2017), the study site has 2,071,364 Cattle, 1,403,264 Sheep, 451,290 Goat, and 99,949 Horse, 425,397 Donkey, 23,999 Mules, 1,245,284 Poultry, and 181,093 Bee hives.

Sampling Techniques and Sample Size Determination

Sampling techniques
A multi-stage sampling technique was employed for the selection of sample households and indigenous goats for this study. For sampling goat population, castrated goats, pregnant doe, kids, buck kids and doe kids were not included in the sample goat population to increase accuracy for quantitative traits and to represent the adult goat population. Subsequently, sample goats were taken by using simple random sampling method.

Sample size determination for goats
The sample size of indigenous goats was determined by the formula given by Cochran’s (1977), totally 600 indigenous goats were used for collecting data about qualitative and quantitative traits. For physical description and quantitative traits measurement a total of 60 mature male and 540 mature female goats were used. Based on FAO (2012), from the total sample size 90% of goats were female and the remaining 10% of goats was male.

Data Types and Methods of Data Collection

Secondary sources: secondary data was collected from the respective district office of livestock and Fishery resource to complement the production system along with the climatic data, agero ecology data, geographical location, and livestock demography.

Morphometric characterization of indigenous goats
The standard breed descriptor list developed for goat by FAO (2012) was closely followed in selecting qualitative and quantitative traits. Data for qualitative variables like coat color pattern, coat color type, hair type, hair length, head profile, ear orientation, presence or absence of toggle, rump profile, back profile, beard, wattle, horn presence or absence, horn shape, horn orientation, muzzle and ruff were recorded by visual observation of the animal goat. Quantitative trait like body weight, body length, chest girth, wither height, rump height, chest depth, cannon bone length, cannon bone circumference, pelvic width, rump width, head length, horn length, ear length were measured using plastic measuring tape. For males scrotal circumference was also measured. Body weight was measured using spring balance having 50 kg capacity.

Each animal was identified by its sex, location and dentition. Goat’s age classification was made using dentition. Adult goat were classified into four age group; 1PPI (one pair of permanent incisor), 2PPI (two pair of permanent incisor), 3PPI three pair of permanent incisor and ≥4PPI (four pair of permanent incisor).

Data Management and Analysis

All data gathered during the study period were coded and recorded in Microsoft Excel 2007. Then statistical data analysis used dependeds upon the nature of the data. All data were analyzed by SAS version 9.3 (2014), and SPSS version 20.

Data collected through qualitative data from individual observations were analyzed by SPSS version 20 and chi-square test was carried out to assess the statically significance among categorical variables using district as a fixed effect.

Quantitative data was analyzed using Statistical Analysis System (SAS Version 9.3). A general linear model procedure (PROC GLM) of the Statistical Analysis System (SAS 9.3) was used for quantitative variables to detect statistical differences among sample goat’s populations. Sex, location and age group of the goats were fixed variables while body weight and linear body measurements were fitted as response variables least square means with their corresponding standard errors were calculated for each body trait over sex, age and location to test statically deference by Tukey test.

The model employed for analyses of body weight and other linear body measurements except Scrotum circumference was:

\[ Y_{ijkl} = \mu + A_i + S_j + D_k + A_i S_j + e_{ijkl} \]

Where: \( Y_{ijkl} \) is the observed \( k \) body weight or linear body measurements) in the \( i^{th} \) age group & \( j^{th} \) Sex, \( \mu \) = Overall mean, \( A_i \) = the effect of \( i^{th} \) age group (\( i = 1, 2, 3, 4 \)), \( S_j \) = the effect of \( j^{th} \) Sex (\( j = 1 \) and 2) \( D_k \) = the effect of \( k^{th} \) district (Hulet Eju Enesie, Goncha Siso Enesie and Enbse Sar Midir) \( A_i S_j \) = age by sex interaction and \( e_{ijkl} \) random residual error.

Live body weight and other body measurements including heart girth, body length, height at wither, rump height, chest depth, rump width, Pelvic Width, horn length, cannon bone circumference, cannon bone length, Rump Height, Rump Length, Head Length, and Ear Length were considered both for male and female goats. In addition, Scrotum circumference was included for male.

Correlations of live body weight with different body measurement under consideration were computed for
each sex using Pearson correlation coefficient. Stepwise regression procedure of SAS (9.3) was used to estimate 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. Best fitting models were selected based on coefficient of determination ($R^2$), mean square error, and the mallows C parameters C (p), the following models were used for the estimation of body weight from LBMs.

The following models were used for the estimation of body weight from LBMs.

**For male:**

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \epsilon$$

Where: $Y =$ the response variable (body weight) $\beta_0 =$ the intercept $X_1, X_2, \ldots, X_n =$ are independent variables (height at wither, rump height, body length, chest depth, heart girth, rump length, rump width, pelvic width, cannon bone length, cannon bone circumference, ear length, Horn length, pelvic width, and scrotal circumference) $\beta_1, \ldots, \beta_n =$ regression coefficients of the variables $X_1, \ldots, X_n$ $\epsilon =$ random error

**For female:**

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \epsilon$$

Where: $Y =$ the dependent variable body weight; $\beta_0 =$ the intercept; $X_1, \ldots, X_n =$ are independent variables (height at wither, rump height, body length, chest depth, heart girth, rump length, rump width, pelvic width, cannon bone length, cannon bone circumference, ear length, horn length, and rump length); $\beta_1, \ldots, \beta_n =$ regression coefficients of the variable $X_1, \ldots, X_n$ $\epsilon =$ random error

**Result and Discussion**

**Morphometric Characterization of Indigenous Goats**

**Qualitative traits**

Qualitative traits of indigenous goat population in the study area are presented in Table 1. In the study area, the main dominant coat color type was light red (25.3%). The current variation in coat color type of indigenous goats found in the study area was different from the previous findings of FARM-Africa (1996), who reported the coat color type of western highland breed as white (42%). Similar to this finding, in Abergelle goat red dominant coat color was observed, which accounted for 30.98% (Alubel, 2015) and followed by red with white (21.3%), white (22.2%), dark red (9.5%), brown (5.7%), black with white (5.5%), grey (5%), black (3.5%) and black and red (2.0%) coat color type were observed in the study area.

In all study areas, majority of the goat populations had no skin pigmentation (95.8%). Smooth hair coat type was predominant in the study area, which accounted for 71.3%, whereas, glossy hair coat type were 28.7% of the sampled goat population. Majority of the sampled goats had short hair (77.0%).

About the overall goat in all study area (95%) of goats in the study area had horn, In contrast to this in Gurawa district occurrence of polled goat was higher than horned one (Mahilet, 2012). Straight horn shape was the most frequently observed in the study area (51.1%) followed by curved (31.9%), lyre/u shaped (11.2%) and spiral (5.8%). According to Belay and Meseretu (2017) the goats in GamoGoffa zone have predominantly straight horn shape (78.09%) which was higher than what we observed in the current study. The overall horn orientation from the sampled goats was backward (86.1%) and upward (13.9%). The most dominant ear orientation was horizontal (76.0%) followed by dropped (13.0%) and lateral (11.0%) were observed in the study area.

In contrast to this finding, Hulunim (2014) reported the majority of Bati and Borena goats were characterized by lateral/sideway ear orientation accounting a total of 59.9 and 78.9%, respectively.

Overall sampled goats had straight head profile (72.0%), concave (21.8%) and slightly concaves (6.2%), this is difference with FARM-Africa (1996) reported, as a concave facial profile (100%) in Western Highland goat. The present finding similar with the report of Yaekob (2015) in woytoGuji goat (80.6%) have straight head profile.

Majority of goats in the study area do not have to ggles (80.2%) and beard (76.8%). About (71.3%) of goats in the study area has no ruff. In the study area 68.0% of sampled goats had straight back profile. Sloping rump profiles of goat types were frequently observed (96.2%), whereas flat rump profile was observed only in 3.8% of the sampled goat population.

The chi-square test of categorical variables in HuletEjuEnesie, GonchaSisoEnesie and EnbseSarMidir sample goats population indicated that among the variables considered in this study coat color pattern, coat color type, horn shape, hair length, back profile, skin pigmentation, toggle and ruff were significantly different ($P<0.05$) across location. The most observed coat color pattern in all the study districts was plain/uniform (52.5% in HuletEjuEnesie, 55.5% in GonchaSisoEnesie and 48.0% in EnbseSarMidir). In the study area, the main dominant coat color type was light red (25.3%). The current variation in coat color type of indigenous goats found in the study area was different from the previous findings of FARM-Africa (1996), who reported the coat color type of western highland breed as white (42%).

Highest plain coat color pattern were recorded in GonchaSisoEnesie and lowest recorded in EnbseSarMidir. On the other hand, patchy coat color pattern was frequently observed in EnbseSarMidir (36.0%) and GonchaSisoEnesie (35.6%) district than in HuletEjuEnesie district (31.1%).
The dominant coat color types in HuleteJuuEnesie district were white (42.0%) and red and white (14.0%) whereas in GongaSisoEnesie district, the dominant coat color types were light Red (33%) and Red + white (22%). In EnbsesarMidir district, light red (33%) and red + white (28.0%) were frequently occurred coat color types.

In EnbsesarMidir district highest number of goats had predominantly short hair (85.5%) than GongaSisoEnesie (97.4.0%) and Enbsesar Midir (71.1%.) district.

In EnbsesarMidir higher pigmented than HuleteJuuEnesie and GongaSisoEnesie. The highest proportion of goat populations had horn in GongaSisoEnesie 99% than Hulete JuuEnesie (93.9%) and EnbsesarMidir (97.8%). In HuleteJuuEnesie, 53.3% of goats had straighthorn shape and also in GongaSisoEnesie straight horn shape but in EnbsesarMidirdistinctcurved horn shape was (50.5%).

The presence of ruff higher in HuleteJuu Enesie (34.5%) than in GongaSisoEnesie (30.5%) and in Enbsesar Midir (21%). In Hulet Juu Enesie (22.2%) higher in toggle presence than GongaSiso Enesie (15.3%) and Enbsesar Midir (15.5%).

Table 1. Qualitative traits of goats in the study area by sex and district

| Qualitative Trait | Hulete Juu Enesie | Gonga Siso Enesie | Enbsesar Midir | Overall |
|-------------------|-------------------|--------------------|----------------|---------|
| **Coat color pattern** |                   |                    |                |         |
| Plain             | 94(52.2)          | 11(55.0)           | 101(56.1)      | 31(55.2) |
| Patchy            | 49(27.2)          | 4(20.0)            | 56(31.1)       | 18(30.4) |
| Spotted           | 37(20.6)          | 5(25.0)            | 23(12.8)       | 10(16.8) |
| **X**value        |                   |                    |                |         |
| Brown             | 10(5.60)          | 1(5.0)             | 0(0.0)         | 3(4.5)   |
| **Coat color**    |                   |                    |                |         |
| Grey              | 12(6.7)           | 2(10.0)            | 5(2.8)         | 9(5.0)   |
| Dark red          | 18(10.0)          | 1(5.0)             | 17(9.4)        | 5(7.8)   |
| Light red         | 19(10.6)          | 2(1.0)             | 20(11.0)       | 5(10.0)  |
| Red + white       | 25(13.9)          | 3(15.0)            | 38(21.1)       | 12(21.3) |
| **X**value        |                   |                    |                |         |
| Brown             | 10(5.60)          | 1(5.0)             | 0(0.0)         | 3(4.5)   |
| **Hair coat type**|                   |                    |                |         |
| Smooth hair       | 49(27.2)          | 12(60.0)           | 53(29.4)       | 8(40.0)  |
| Glossy            | 131(72.8)         | 8(40.0)            | 127(70.6)      | 130(72.8)|
| **X**value        |                   |                    |                |         |
| Swart             | 131(72.8)         | 12(60.0)           | 137(71.1)      | 145(85.0)|
| Medium            | 83(21.1)          | 6(20.0)            | 33(18.3)       | 17(10.7) |
| Long              | 16(6.1)           | 2(10.0)            | 19(10.5)       | 2(10.0)  |
| **X**value        |                   |                    |                |         |
| Horned            | 109(59.3)         | 9(45.0)            | 169(93.9)      | 196(97.8)|
| Abseint           | 12(6.7)           | 1(5.0)             | 11(6.1)        | 2(10.0)  |
| **X**value        |                   |                    |                |         |
| Curved            | 49(27.3)          | 6(26.3)            | 34(20.0)       | 8(9.1)   |
| Spiral            | 6(4.1)            | 1(5.0)             | 4(2.8)         | 2(10.0)  |
| **X**value        |                   |                    |                |         |
| Backward          | 15(79.2)          | 4(20.0)            | 25(15.6)       | 11(9.5)  |
| Uphard            | 13(72)            | 1(5.0)             | 16(9.1)        | 1(9.5)   |
| **X**value        |                   |                    |                |         |
| Deeping           | 21(11.7)          | 3(15.0)            | 28(15.6)       | 18(10.0) |
| Lateral           | 27(14.4)          | 4(20.0)            | 36(20.0)       | 21(10.0)|
| Croduced horizontal| 133(73.9)        | 13(65.0)           | 120(67.0)      | 15(75.0) |
| **X**value        |                   |                    |                |         |
| Straight          | 155(75.0)         | 16(80.0)           | 130(72.2)      | 124(68.9)|
| Concave           | 25(16.1)          | 2(10.0)            | 40(22.2)       | 15(75.0) |
| Convex            | 16(6.9)           | 1(5.0)             | 10(5.6)        | 6(3.3)   |
| **Facial profile**|                   |                    |                |         |
| Slightly concave  |                  |                    |                |         |
| **X**value        |                   |                    |                |         |
| Board             | 44(24.4)          | 7(35.0)            | 35(19.4)       | 42(23.3) |
| Present           | 136(75.6)         | 16(65.0)           | 145(80.6)      | 138(76.7)|
| **X**value        |                   |                    |                |         |
| Ruff              | 59(32.8)          | 10(50.0)           | 57(31.7)       | 30(15.0) |
| Present           | 121(67.2)         | 10(50.0)           | 123(68.3)      | 142(75.0)|
| **X**value        |                   |                    |                |         |
| Slaps up to rump  | 55(3.6)           | 6(30.0)            | 76(42.2)       | 39(21.7) |
| Slaps up to the   | 125(69.4)         | 14(70.0)           | 102(56.7)      | 137(72.2)|
| back profile      |                   |                    |                |         |
| **X**value        |                   |                    |                |         |
| Rump proile       |                   |                    |                |         |
| Sloping           | 173(96.1)         | 170(95.0)          | 172(95.6)      | 177(98.3)|
| Flat              | 7(3.9)            | 3(15)              | 8(4.4)         | 3(17)    |
| **X**value        |                   |                    |                |         |
| Togglle           | 53(28.4)          | 3(15.0)            | 37(20.6)       | 2(10.1)  |
| Present           | 127(70.6)         | 17(85.0)           | 143(79.4)      | 105(58.9)|
| **X**value        |                   |                    |                |         |
| Wattle            | 147(8.5)          | 2(10)              | 22(12.2)       | 17(9.4)  |
| Absent            | 166(92.3)         | 18(90)             | 158(88.8)      | 163(86.0)|

N = Number of goat exhibiting a particular qualitative character; X² = Pearson chi-square; *significant difference at p < 0.05; NS = Non-Significan
Figure 1. Adult indigenous breeding doe (left) and Buck (right) in Hulet Eju Enesie district

Figure 2. Adult indigenous breeding doe (left) and buck (right) in Goncha Siso Enesie district

Figure 3. Adult indigenous breeding doe (left) and buck (right) in Enbse Sar Midir district

Quantitative traits of indigenous goats

Body weight and linear body measurements are the most important characters, which help to identify the breeds of goat population. The body weight and linear body measurements of indigenous goat in the study area are presented in Table 2.

In the study area overall mean of body weight, body length, chest girth, height at withers, pelvic width, rump height, rump length, rump width, head length, ear length, horn length, chest depth, canone bone circumference, canone bone length and scrotum circumference were 29.05 kg, 61.94 cm, 72.16 cm, 66.77 cm, 9.30 cm, 68.89 cm, 14.62 cm, 15.64 cm, 14.45 cm, 14.33 cm, 10.57 cm, 29.28 cm, 8.46 cm, 12.29 cm, and 22.73 cm, respectively. The
Result was comparable with Ahmed (2013); Bekalu, (2014) and Diba (2017) indicates that the Average body weight, body length, chest girth, height at withers and ear length were 28.7 kg, 56.9 cm, 70.8 cm, 67.2 cm and 14.9 cm for western highland goat in Horro Gudru Welega, 28.03 kg, 60.19cm, 74.87cm, 64.51 cm, and 13.89 cm for western highland goat in west gojjam, 29.7 kg, 63.2 cm, 73.4 cm, 67, 3 and 17 cm for Woyito Guji goat in Guji zone oromia region, respectively.

**Location effect:** Location had significant difference (P<0.05) for all quantitative traits except horn length and cannon bone circumference. Lower values were observed in all linear body measurements for Hulet Eju Enesie compared to Enbse Sar Midir and Goncha Siso Enesie districts except scrotum circumference and horn length Table 2. The results of this study revealed that body weight was higher for Enbse Sar Midir (31.15BW) than Hulet Eju Enesie (27.67BW) and Goncha Siso Enesie (29.67BW) districts. This might be explained by different factors such as nutrition, shortage of grazing areas in the site could be implicated, farming system is depend on extensive grazing without supplementation, the incidence of disease, the size and productivity of the grazing land can be taken as the main factors affecting livestock productivity in the study area. Similar to this finding differences in genetic makeup of the animal, availability of feed resource base (in terms of quantity and quality), availability of natural grazing field and the management conditions the animals (Cam et al., 2010).

**The effect of Sex:** Sex is an important source of variation for live body weight and linear body measurements at all age groups. In all three districts sex had significant effect (P<0.05) on body weight, body length, chest girth, height at wither, rump height, cannon bone circumference, head length, cannon bone length, horn length and pelvic width, whereas chest depth, ear length, rump length and rump width were not affected by sex. Male goats were having higher values than female the sex related differences might be partly a function of the sex differential hormonal effect on growth. In addition to that, the differentials obtained in the morphological traits of the sexes could be attributed to sexual dimorphism (Semakula, 2010). They also suggested that males might have a longer season of mass gain each year throughout their lives, while females divert annual resources into reproduction, rather than body mass.

**Age effect:** All body measurements increased as age group increased from 1PPI to ≥4PPI. In the current study body weight (BW) had significant difference (P<0.05) in all age (dentition) groups and the same was true for all linear body measurements. The body weight of goats at ≥4PPI was 33.49±0.43 kg, which is lower than 36.4±0.8 kg reported for indigenous goats in Horro Guduru Wollega (Ahmed, 2013). The linear body measurements increased as animal advances with age (1PPI to ≥4PPI). Increased with increase in dentition class up to the four Dentition and then after it starts to decline or remains as it is. The size and shape of the animal increases until the animal reaches its optimum growth point or until maturity (Yoseph, 2007).

**The interaction effect of Sex and age:** The interaction of sex and age group was significant (p<0.05) for body weight, Body length, chest girth, rumpwidth, pelvic width and rumpheight, wither height. The interaction effect Sex and age significantly different (p>0.05) were not observed in ear length, rump length, chest depth, cannon bone circumference, head length, cannon bone length and horn length. Contrary to this, Alefe (2014) reported that the interaction of sex and age group was significant difference (p<0.05) all liner body measurements. In each age group males were having higher values. The value of body weight for female goat in age group 1PPI, 2PPI, 3PPI and ≥ 4PPI were kg, 23.11 kg, 26.51 kg, 29.85 kg and 32.06 kg, respectively and the values for males in the same age groups were 26.88 kg, 29.25 kg, 31.00 kg and 35.00 kg, respectively. Higher body weight of males than that of females at all ages is attributed to aggressive behavior of males during feeding and sucking and male sex hormone, which has an anabolic effect. In all age groups and measurements, male goats performed greater than female goats. This finding was in agreement with short eared Somali goats and Hararghe Highland goats, where values for male goats were found greater than their female counter parts in all age group and all measurements (Grum, 2010; Mahilet, 2012) but in contrast with the report of Alade et al. (2008); Sowande et al. (2009); Samakula et al. (2010); and Okbeku et al. (2011) were female have higher body weight and other body measurements than male counterpart.
Table 2. (Least square mean ± SE) body weight (kg) and other linear body measurements by sex, age and location.

| Effect Level | CG | BH | WI | RH | PI | BL | RL | RW | SC | BL | CG | HW | BW |
|--------------|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Male Overall | 74.6±0.4 | 65.3±0.4 | 67.9±0.3 | 70.2±0.3 | 67.9±0.3 | 75.7±0.2 | 71.8±0.3 | 70.9±0.3 | 69.2±0.3 | 69.9±0.3 | 75.8±0.2 | 73.4±0.2 | 69.8±0.3 |
| SE | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| *P<0.05 Correlation between Body Weight and LBMs

The Pearson's correlation coefficient between body weight and linear body measurements for male and female are calculated and presented in Table 3. The presence of strong correlation coefficients recorded between body weight and some of the linear body measurement, suggests that either of these LBMs variables or their combination could provide a good estimate for predicting body weight of indigenous goats in the study area. Body weight had positive and significant (P<0.05) correlation with all continuous traits of both male and female goats.

In this study, strong, positive and significant correlation between body weight and chest girth suggests that this variable could provide a good estimate in predicting live body weight for the population. In males positive and highly strong association were found between body weight and chest girth (r=0.90), wither height and body length (r=0.90), chest depth (0.70). The highest association between chest girth and body weight were observed for male and female goat population. This finding was in agreement with 

The correlation coefficients between body weight and all parameters for males and females in the current study were lower than Shabelle goats which was reported by Alefe (2014).

**Correlation between Body Weight and LBMs**

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The correlation coefficients between body weight and all parameters for males and females in the current study were lower than Shabelle goats which was reported by Alefe (2014).
Prediction of Body Weight from LBM

Multiple linear regression models for predicting the body weight of goats from linear body measurements are presented in Table 4. Using measurements obtained readily and offered accurate prediction of body weight might be considered as a framework for recording system in rural areas (Farhad et al., 2013). Regression analysis is commonly used in animal research to describe quantitative relationships between a response variable and one or more explanatory variables such as body weight and body measurements (chest girth, chest depth, body length and height at wither) especially when there is no access to weighing equipment (Cankaya, 2008).

The small sample size of male goat in this study may decrease the accuracy of the result if separate sex groups are used. Comparable R² values were obtained for all relationships existing between BW and other LBM for both female and male sample goat population. All body measurements were fitted into the model and through elimination procedures, in this study, the optimum model was identified. Chest girth, body length, height at wither, rump width and rump height were the best fitted model for male goat, whereas chest girth, body length, height at withers, rump height, cannon bone circumference and rump width were the best fitted model for female goats.

However, predictions of body weight from combinations of LBM with additional variables in the model was not strong strengthening the preceding argument that heart girth alone served as a best predictor of body weight under field condition. Measuring chest girth with tape is easy, cheap and rapid. Thus, body weight prediction from heart girth alone would be a practical option under field conditions.

Thus, prediction of body weight could be based on regression equation \( y = 37.93 + 0.92 x \) for female sample population and \( y = -44.47 + 1.02 x \) for male sample goat population where, \( y \) and \( x \) are body weight and chest girth, respectively.

In the current study chest girth (CG) was the best predictor variable, which explains more variation than any other linear body measurements in both sexes. This was in agreement with the results of, Grum (2010), Halima et al. (2012), Mahilet (2012), Ahmed (2013), Belete (2013), Biruh (2013), Bekalu (2014) and Hulunim (2014) as heart girth was selected first for prediction of live body weight of animals.

Table 3. Coefficient of correlations between body weight and linear body measurements (Above diagonal for male and below diagonal for female)

|     | CG  | BL  | WH  | HR  | CD  | CBL | CBC | RW  | HL  | BW  | SC  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| CG  | 1.00* | 0.85* | 0.82* | 0.81* | 0.68* | 0.45* | 0.33* | 0.48* | 0.48* | 0.90* | 0.58* |
| BL  | 0.81* | 1.00* | 0.83* | 0.82* | 0.68* | 0.30* | 0.36* | 0.39* | 0.87* | 0.61* | 0.90* |
| WH  | 0.83* | 0.82* | 1.00* | 0.92* | 0.65* | 0.22NS | 0.30* | 0.29* | 0.39* | 0.87* | 0.59* |
| HR  | 0.84* | 0.81* | 0.98* | 1.00* | 0.58* | 0.30* | 0.35* | 0.36* | 0.39* | 0.82* | 0.57* |
| CD  | 0.72* | 0.66* | 0.70* | 0.71* | 1.00* | 0.39* | 0.40* | 0.51* | 0.36* | 0.70* | 0.47* |
| CBL | 0.42* | 0.48* | 0.41* | 0.40* | 0.37* | 1.00* | 0.23NS | 0.55* | 0.45* | 0.40* | 0.18NS |
| CBC | 0.39* | 0.35* | 0.36* | 0.37* | 0.34* | 0.21* | 1.00* | 0.18* | 0.42* | 0.30* | 0.25* |
| RW  | 0.47* | 0.48* | 0.50* | 0.48* | 0.40* | 0.30* | 0.26* | 1.00* | 0.45* | 0.46* | 0.37* |
| HL  | 0.47* | 0.44* | 0.46* | 0.46* | 0.43* | 0.31* | 0.28* | 0.28* | 1.00* | 0.43* | 0.35* |
| BW  | 0.85* | 0.80* | 0.81* | 0.80* | 0.69* | 0.43* | 0.37* | 0.48* | 0.45* | 1.00* | 0.61* |

NS= non-significant (P>0.05); * significant at 0.05 level; BL=Body Length; HG= Heart Girth; WH=Wither Height; RH=Rump Height; RW=Rump Width; RL=Chest Depth; PW=Pelvic Width; SW=Shoulder Width; HL=Head Length; CBL=Cannon Bone Length; CBC=Cannon Bone Height; Hol=Horn Length; EL= Ear Length; BW=Body Weight; SC=Scrotal Circumference
Table 4. Multiple regression analysis of live weight on different body measurements for male and female goats in the study area

| Parameters | R² | CP | A-R² | MSE |
|------------|----|----|------|-----|
| CG         | 0.45 | 0.27 | 0.32 | 0.26 |
| CG+ BL     | 0.65 | 0.36 | 0.31 | 0.27 |
| CG+ BL+ WH | 0.45 | 0.24 | 0.31 | 0.27 |
| CG+ BL+ WH+ CD | 0.45 | 0.27 | 0.45 | 0.27 |
| CG+ BL+ WH+ HR+ CD | 0.45 | 0.27 | 0.45 | 0.27 |
| CG+ BL+ WH+ HR+ CD+ RW | 0.45 | 0.27 | 0.45 | 0.27 |
| CG+ BL+ WH+ HR+ CD+ CBC+ RW | 0.45 | 0.27 | 0.45 | 0.27 |

For male goats

| Parameters | R² | CP | A-R² | MSE |
|------------|----|----|------|-----|
| CG         | 0.45 | 0.27 | 0.32 | 0.26 |
| CG+ BL     | 0.65 | 0.36 | 0.31 | 0.27 |
| CG+ BL+ WH | 0.45 | 0.24 | 0.31 | 0.27 |
| CG+ BL+ WH+ CD | 0.45 | 0.27 | 0.45 | 0.27 |
| CG+ BL+ WH+ HR+ CD | 0.45 | 0.27 | 0.45 | 0.27 |
| CG+ BL+ WH+ HR+ CD+ RW | 0.45 | 0.27 | 0.45 | 0.27 |
| CG+ BL+ WH+ HR+ CD+ CBC+ RW | 0.45 | 0.27 | 0.45 | 0.27 |

Conclusions and Recommendation

Goats were characterized as having dominantly plain coat color pattern, light red coat color type, smooth hair coat type, short hair length, sloping rump profile. The most dominant ear form carried horizontal. The most frequently observed horn orientation was backward followed by upward.

The least square means for the effect of sex was significant (p<0.05) on majority quantitative variables except CD, EL, RL and RW. Male goats were higher than females in all variables except ear length. District had significant effect (p<0.05) on all quantitative variables except horn length and cannon bone circumference. Body weight and all LBMs were significantly affected (p<0.05) by age group.

Positive and significant correlations between LBMs and body weight were observed. Multiple regression equations were developed for predicting live body weight from LBMs. Chest girth was selected first, which explain more variation than any other linear body measurements in both does (71%) and bucks (82%). The prediction of body weight and all LBMs were significantly affected (p<0.05) by age group.

The main conclusions to be drawn from this study is that Goats in the study area play a significant role for farmers as source of home consumption and income generation throughout the year. In all study area goats have shown inferior performance in body weight and other linear body measurements as compared to the previous evaluation. One of the main conclusions to be drawn from this study is that Goats in the study area play a significant role for farmers as source of home consumption and income generation throughout the year. In all study area goats have shown inferior performance in body weight and other linear body measurements as compared to the previous characterization. The east gojjam goats needs further study to quantify the productive and reproductive performance of the indigenous breeds through monitoring, and also need molecular characterization for differentiate from other breeds.

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