# Application of Morphometric Traits and Body Indices in Assessing the Type and Function of Local Goats Reared in Two Districts of Gamo-Gofa Zone, South Ethiopia

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## *ABSTRACT*

*The present study was conducted with the objectives of applying the morphometric traits and their indices in assessing the type and function of indigenous goats reared in Arbaminch-Zuria (AMZ) and Mirab-Abaya (MA) districts of Gamo-Gofa zone. For this study, 151 bucks and 464 does were scored for morphometric measurements from which fourteen body indices were calculated. The results indicated that the AMZ bucks had higher ($p<0.05$) wither height (WH), chest girth (CG), rump width (RW) and head width (HW) values than those of MA. Conversely, chest depth (CD), rump length (RL), head length (HL) and ear length (EL) of MA bucks were higher ($p<0.05$) than those of AMZ. The body weight (BW), body length (BL), CG, RW and HW values were higher ($p<0.05$) in does of AMZ than those of MA. However, does in MA had higher ($p<0.05$) wither height (WH), CD, RL and EL values than those of AMZ. Except at 0PPI, goats in MA had higher ($p<0.05$) CD, RL and EL values than those of AMZ at all age ranges. Goats in AMZ at 2PPI and above had higher ($p<0.05$) BL, CG, RW and HW values than those of MA. Goats in AMZ were heavier ($p<0.05$) than those of MA at 1PPI and 3PPI. Irrespective of 1PPI, goats in AMZ had higher ($p<0.05$) CG than those of MA and their RW was higher ($p<0.05$) than those of MA at all age ranges. The BW of bucks was strongly ($p<0.001$) and positively correlated with BL, WH, CG and HL. In does, a positive and moderate ($p<0.01$) correlation of BW was observed with BL, CG, RW and HL. Rump width was identified as suitable predictor of BW in does at 3PPI ($R^2 = 93.9$). Wither height and CG were the best predictor of BW in bucks at 2PPI ($R^2 = 99.6$). At 3PPI, CG was a single predictor of bucks' BW ($R^2 = 94.8$). Goats in AMZ had higher values than those of MA for cephalic index, thoracic development, pelvic index, transversal pelvic, length index, area index compact index, conformation index, foreleg index and weight. Conversely, goats in MA had higher values in relative depth of thorax, longitudinal pelvic and proportionality than those of AMZ. In conclusion, morphometric traits and their indices suggested that goats reared in AMZ can be classified as a medium-sized and long-shaped body frame, with a marked orientation for meat production, while goats in MA were characterized as medium-sized animal whose morphology corresponds to dairy type*

**Key words*:*** Arbaminch-Zuria; indigenous goat; Mirab-Abaya; morphometric traits; zoometric indices

## INTRODUCTION

Small ruminant in general and goat production in particular, significantly contribute to the national and household economy and is considered as the most important agricultural activity in Ethiopia. According to CSA (2018), Ethiopia has 32.74 million heads of goats of which 70.5% are females and about 29.5% are males and almost all of them (99.97%) are pure indigenous. The country is home to genetically diverse goat populations that are widely distributed across all agro-ecologies (Hassen *et al.*, 2012). According to FAOSTAT (2016), Ethiopia stands third in Africa and sixth in the world accounting for 9% and 3% of the African and global goat population, respectively. According to DAGRIS (2007), there are four families and 13 different indigenous goat types in Ethiopia based on their phenotypic characterization. However, recent genetic characterization studies revealed only the presence of seven different breed types in the country (Mekuriaw, 2016). However, such reports may not necessarily be comprehensive as some remote parts of the country that have the potential for goat production might have not been broadly represented.

Phenotypic characterization of farm animal genetic resources is the process of identifying distinct breeds or populations by describing their external and production characteristics in a given production environment. Morphological measurements have been traditionally used for characterization of local sheep and goat breeds by many researchers (Hassen *et al*., 2012; Melesse *et al*., 2013; Lorato *et al*., 2015) as well as to predict carcass characteristics (Agamy *et al*., 2015). Production performances, especially the function of meat production can be also assessed from morphometric traits such as chest girth, body length, chest width, rump width and chest depth, which are more closely associated with bone or muscle development. Furthermore, the information generated by characterization studies is essential for planning the management of animal genetic resources at local, national, regional and global levels (FAO, 2012).

To identify the type and function of goat breed, morphometric indices could be calculated from linear body measurements. Morphometric indices are relationships among linear body measurements that are used to describe the proportions and general size of animals. These indices are a combination of several linear body measurements that are used to assess the type, weight, and function of the breeds of animals and further enhance the ability of breeders to select potential breeding stock in the existing production system (Chacón *et al*., 2011). Such indices provide tested empirical values which are limited in the use of single measurements and calculated from morphometric traits (Chacón *et al*., 2011; Khargharia *et al*., 2015; Barragán, 2017). These authors suggested that indices that are produced from morphometric measurements that are more closely associated with bone growth such as foreleg length, height slope, and length index are more appropriate for assessment of type.

Gamo-Gofa zone is characterized by diverse agro-ecological locations where goats play increasingly significant role for communities that rear them. There is a long tradition of goat production and huge goat resources in the zone, particularly in the studied districts. Despite having huge benefits for the society of the zone, studies on goat's physical traits and documented information on phenotypic characterization and structural indices of goat in the studied area is lacking. Thus, this study was conducted to apply the morphometric traits and their structural indices in the assessment of type and function in local goats reared in two potential districts of Gamo-Gofa Zone.

## MATERIALS AND METHODS

### Description of Study Areas

The study was conducted in Arbaminch-Zuria (AMZ) and Mirab-Abaya (MA) districts that are found in Gamo-Gofa zone, southern Ethiopia. The AMZ district has an elevation that ranges from 1200 m a.s.l at the northern end to 1320 m a.s.l at the southern end. According to the Arbaminch Meteorological Station, the area receives bimodal rainfall of 830 mm per annum. The mean minimum, mean maximum and average temperatures are 15.1, 29.9 and 22.5$^{o}$C, respectively. The MA district has an altitude of 1193 m a.s.l and is characterized by bimodal rainy seasons as well receiving an average annual rainfall of 800-1200 mm. The average annual temperature ranges from 25 to 32 $^{0}$C. The two districts are characterized by mixed livestock-crop farming system.

### Sampling and Data Collection Procedures

#### *Morphometric characterization*

A multistage sampling procedure was used to select representative samples from the study zone. From 15 districts, two districts were selected purposively based on their potential in goat population. Three kebeles (Peasant Associations; smallest administrative unit) were then randomly selected from each district. Accordingly, Wozeka, Elgo and Dargo kebeles were selected from AMZ district and Yaike, Fetele and Faragosa kebeles from MA. Two hundred households that possess a minimum of five goats

and above were purposely identified from all kebeles from which 120 households were randomly selected from both districts.

Morphometric traits were taken from 151 males and 464 females following the phenotypic descriptor list of FAO (2012). Kids and pregnant animals were excluded from the measurement to avoid under and over estimation, respectively. All measurements were taken early in the morning to avoid the effect of feeding and watering on the animal's body size and when they are on normal standing position. The linear traits were taken using plastic tape and caliper, while body weight was measured using suspended weighing scale with 50 kg capacity of 0.2 kg precision. Body weight (BW), body length (BL), height at wither (WH), chest girth (CG), Chest depth (CD), rump length (RL), rump width (RW), head length (HL), head width (HW) and ear length (EL) were assessed. To avoid genetic similarity, less than or equal to 4 goats per household were used. Each animal was identified by its sex, dentition, and sampling site. Dentition together with the information obtained from the owner was used to classify the goats by their age group. Accordingly, goats were classified as 0PPI (no pair of permanent incisor), 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) by representing 0-1 year, 1-2 years, 2-3 years, 3-4 years and 4-5 years old, respectively (FAO, 2012).

***Calculation of body indices***

To assess the type and function of indigenous goat population in the study area, five structural (ethnological) and nine functional indices were calculated from the morphometric traits according to the method of Chacón *et al*. (2011), Khargharia *et al*. (2015) and Barragán (2017).

**Statistical Analysis**

All morphometric data were analyzed using GLM procedure of SAS (SAS, 2012; ver. 9.4) by fitting district, sex and age as main effects. Means were separated by using Duncan's Multiple Range Test. The stepwise multiple regression procedure was used to obtain models for estimation of body weight from the morphometric traits. Model used for the analysis of body weight and linear body measurements traits:

$y_{ijk} = \mu + A_i + S_j + D_k + e_{ijk}$

$y_{ijk}$ = the observation of measured variables

$\mu$ = overall mean

$A_i$ = the effect due to $i^{th}$ age group (i = 0PPI, 1PPI, 2PPI, 3PPI, 4PPI)

$S_j$= the effect due to $j^{th}$ sex (j = female and male)

$D_k$= the effect due to $k^{th}$ district (k = AMZ and MA)

$e_{ijk}$ = random residual error

Pearson's correlation coefficients were performed between body weight and linear body measurements for the population with in all age groups and both sexes. The body weight of the animals within age groups and sex was predicted using stepwise multiple regression procedure with the following model:

$Y_j = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots \beta_9 X_9 + e_j$

$Y_j$ = the response variable (body weight)

$\alpha$ = the intercept

$X_1 \ldots, X_9$= the explanatory variables (BL, WH, CG, …)

$\beta_1 \ldots, \beta_9$= regression coefficients of the variables $X_1 \ldots, X_9$

$e_j$= random error

# RESULTS

**Morphometric Traits**

The average value of body weight (BW) and morphometric traits of bucks and does in AMZ and MA are presented in Table1.The AMZ bucks had higher ($p<0.05$) wither height (WH), chest girth (CG), rump width (RW) and head width (HW) than those of MA. Conversely, bucks of MA showed higher ($p<0.05$) chest depth (CD), rump length (RL), head length (HL) and ear length (EL) than those of AMZ. Values of BW, body length (BL), CG, RW and HW in AMZ does were higher ($p<0.05$) than those of MA. However, MA females had higher ($p<0.05$) WH, chest depth (CD), RL and EL values than those of AMZ. The overall mean values indicated that AMZ goats were superior ($p<0.05$) in BW, BL, CG, RW and HW than those of MA. Conversely, MA goats were better ($p<0.05$) in CD, RL and EL traits than those of AMZ.

Average morphometric traits of local goats at different age groups reared in both districts has been presented in Table 2. Except at 0PPI, the CD, RL and EL values of MA goats were higher ($p<0.05$) than those of AMZ. AMZ goats at 2PPI and above had higher ($p<0.05$) BL, CG, RW and HW values than those of MA. The AMZ goats were heavier ($p<0.05$) than those of MA at 1PPI and 3PPI. The AMZ goats had higher ($p<0.05$) CG than those of MA in all age ranges (irrespective of goats at 1PPI). The RW in AMZ goats at all age ranges was higher ($p<0.05$) than those of MA. Body weight and WH consistently increased with the age of goats in both districts. The CG in AMZ goats and the BL in MA linearly increased with the age of the animals. However, the increase of both morphometric traits with age was inconsistent among goats of both districts.

**Phenotypic correlations**

The Pearson correlation coefficients of body weight with morphometric traits in does and bucks are presented in Table 3. Among quantitative traits measured on bucks, BW was strongly ($p<0.001$) and positively correlated with BL, WH, CG and HL. A strong and positive ($p<0.001$) association of WH was also observed with CG and HL in bucks. The BL of bucks was moderately and positively ($p<0.01$) correlated with WH and HL. The RL in bucks also showed a positive correlation ($p<0.01$) with RW and HL.

In does, a moderate and positive ($p<0.01$) correlation of BW was observed with BL, CG, RW and HL. Body weight of does was also positively correlated ($p<0.05$) with WH and HW. A strong and positive association ($p<0.001$) of RW with HL and HW was recorded in does. The CD in does was also strongly and positively associated with RL. The association of BL of does with CG, RW, HL and HW was positive while it was negative with CD and RL. Similarly, CG correlated negatively with CD while its correlation with RW and HW was positive.

Table 1. Average values of morphometric traits of male and female goats reared in Arbaminch-Zuria and Mirab-Abaya districts (does N = 464; bucks N = 151)

| Sex | district | Body weight | Body length | Height at wither | Chest girth | Chest depth | Rump length | Rump width | Head length | Head width | Ear length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Male | AMZ | 30.9 | 57.1 | 62.2 [a] | 72.1 [a] | 41.3 [b] | 16.3 [b] | 16.3[a] | 18.4 [b] | 16.9 [a] | 12.9 [b] |
| | MA | 29.7 | 57.3 | 59.4 [b] | 65.9 [b] | 48.3 [a] | 17.6[a] | 14.9 [b] | 19.0 [a] | 14.7 [b] | 14.0 [a] |
| Female | AMZ | 30.4[a] | 68.6 [a] | 58.5 [b] | 69.8 [a] | 42.2 [b] | 15.7 [b] | 16.4 [a] | 18.9 | 15.1[a] | 12.4 [b] |
| | MA | 29.1[b] | 60.4 [b] | 61.0 [a] | 66.6 [b] | 46.5 [a] | 17.6 [a] | 15.2 [b] | 18.7 | 13.5 [b] | 14.5 [a] |
| Overall mean | AMZ | 30.9 [a] | 62.9 [a] | 60.5 | 71.0 [a] | 41.7 [b] | 16.0 [b] | 16.3 [a] | 18.6 | 16.1[a] | 12.7 [b] |
| | MA | 29.0 [b] | 58.9 [b] | 60.2 | 66.0 [b] | 47.4 [a] | 17.6[a] | 15.1 [b] | 18.9 | 14.1 [b] | 14.3 [a] |
| S.E.M | | 0.394 | 2.691 | 0.824 | 1.443 | 1.682 | 0.478 | 0.381 | 0.132 | 0.704 | 0.484 |

[a,b] Means between districts within sex group bearing different superscript letters are significant at p<0.05
AMZ = Arbaminch-Zuria; MA = Mirab-Abaya; S.E.M = standard error of the mean

Table 2. Average morphometric traits of local goats at different age groups reared in Arbaminch-Zuria and Mirab-Abaya districts

| Age | district | Body weight | Body length | Height at wither | Chest girth | Chest depth | Rump length | Rump width | Head length | Head width | Ear length |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0PPI | AMZ | 25.5 | 53.8 | 56.2 | 67.0 [a] | 41.5 | 16.2 | 15.6 [a] | 17.6 | 16.1 | 12.9 |
| (N = 33) | MA | 24.4 | 53.7 | 55.2 | 61.6 [b] | 47.6 | 16.8 | 14.5 [b] | 16.9 | 15.3 | 12.3 |
| 1PPI | AMZ | 28.7[a] | 63.2 [a] | 58.8 | 68.8 | 41.8 [b] | 16.2 [b] | 16.2 [a] | 18.4 | 16.7 [a] | 12.8 [b] |
| (N = 58) | MA | 27.0[b] | 55.1 [b] | 60.2 | 66.9 | 47.3 [a] | 17.3 [a] | 14.4 [b] | 18.5 | 14.5 [b] | 14.0 [a] |
| 2PPI | AMZ | 30.0 | 62.3 [a] | 61.4 | 70.5 [a] | 41.8 [b] | 15.5 [b] | 16.8 [a] | 18.6 | 16.0 [a] | 12.7 [b] |
| (N = 115) | MA | 28.4 | 57.8 [b] | 59.8 | 63.9 [b] | 46.4 [a] | 17.5 [a] | 15.5 [b] | 19.0 | 13.9 [b] | 13.9 [a] |
| 3PPI | AMZ | 31.8 [a] | 69.1 [a] | 61.9 | 72.7 [a] | 43.7 [b] | 16.6 [b] | 17.2 [a] | 19.4 | 16.1 [a] | 12.4 [b] |
| (N = 206) | MA | 29.5 [b] | 60.8 [b] | 60.7 | 66.1 [b] | 47.4 [a] | 17.6 [a] | 15.0 [b] | 19.2 | 13.4 [b] | 14.4 [a] |
| 4PPI | AMZ | 31.9 | 66.4 [a] | 61.3 | 73.9 [a] | 40.0 [b] | 14.7 [b] | 16.4 [a] | 18.8 [b] | 14.8 [a] | 12.7 [b] |
| (N = 198) | MA | 31.1 | 61.1 [b] | 61.9 | 69.2 [b] | 46.6 [a] | 17.8 [a] | 15.3 [b] | 19.3 [a] | 13.1 [b] | 14.8 [a] |
| S.E.M | | 0.813 | 1.657 | 0.743 | 1.196 | 0.933 | 0.315 | 0.299 | 0.250 | 0.395 | 0.284 |

[a,b] Means between districts within age groups with different superscript letters are significant at p<0.05
1PPI = one pair of permanent incisor; 2PPI = two pairs of permanent incisor; 3PPI = three pairs of permanent incisor; 4PPI = four pairs of permanent incisor; AMZ = Arbaminch-Zuria; MA = Mirab-Abaya; S.E.M = standard error of the mean

Table 3. Phenotypic correlations of body weight with morphometric traits in does (above diagonal) and bucks (below diagonal)

| | BW | BL | WH | CG | CD | RL | RW | HL | HW |
|---|---|---|---|---|---|---|---|---|---|
| BW | - | 0.52** | 0.47* | 0.57** | -0.13 | -0.13 | 0.55** | 0.55** | 0.39* |
| BL | 0.79*** | - | 0.02 | 0.52** | -0.47* | -0.49* | 0.45* | 0.32* | 0.43* |
| HW | 0.83*** | 0.55** | - | 0.31 | 0.27 | 0.43* | 0.32 | 0.45* | 0.12 |
| CG | 0.72*** | 0.40* | 0.80*** | - | -0.44* | -0.33 | 0.55** | 0.34 | 0.44* |
| CD | 0.12 | 0.28 | -0.13 | -0.25 | - | 0.83*** | 0.05 | 0.22 | 0.01 |
| RL | 0.06 | 0.18 | 0.13 | -0.12 | 0.49* | - | 0.17 | 0.32 | 0.08 |
| RW | 0.21 | 0.27 | 0.24 | 0.26 | 0.18 | 0.58** | - | 0.72*** | 0.86*** |
| HL | 0.69*** | 0.60** | 0.70*** | 0.18* | 0.30 | 0.50** | 0.25 | - | 0.37 |
| HW | -0.02 | -0.17 | 0.09 | 0.20 | 0.13 | 0.24 | 0.61** | -0.10 | - |

*P<0.05; **P<0.01; ***P<0.001; BW = body weight; BL = body length; WH = height at wither; CG = chest girth; CD = chest depth; RL = rump length; RW = rump width; HL = head length; HW = head width

**Prediction of body weight from morphometric traits**

The regression models used for the prediction of BW from different morphometric traits of age and sex of sampled goats are presented in Table 4. Stepwise multiple linear regression analysis was used to predict BW from morphometric traits, which had a positive and significant correlation with BW. All variables were fitted into the model and through stepwise elimination procedures, the optimum model was identified. The best fitted prediction models (explanatory variables) were further selected with smaller C (P) and higher $R^2$ values and simplicity of measurement under field condition were also considered.

At 1PPI and 2PPI, the results of the multiple regression analysis revealed that WH was the single important variable in the prediction of BW in does. At 3PPI, RW was identified as best predictor of BW ($R^2$ = 93.9; P<0.007) in does. However, when data were pooled, CG appeared to be the best predictor of BW in does although the prediction model was not so strong ($R^2$ = 35.5; P<0.002).

At the 2PPI, WH alone appeared to be the best predictor of BW in bucks ($R^2$ = 88.9; P<0.01). The prediction became more accurate ($R^2$ = 99.6; P<0.01) when WH is combined with CG in the regression model. At the 3PPI, CG was found as suitable single predictor of bucks' BW ($R^2$ = 94.8; P<0.001). The prediction power of CG slightly increased when RL was included in the regression model ($R^2$ = 99.2; P<0.001). The RL was identified as a single and suitable predictor of BW in bucks at 4PPI ($R^2$ = 85.0; P>0.084). When all data were pooled, WH appeared to be the best predictor of BW in bucks ($R^2$ = 68.6; P<0.0001). However, the prediction power of WH considerably improved when BL was included in the regression model ($R^2$ = 84.6; P<0.001). The prediction power of both variables (WH and BL) slightly increased when CG was included in the model.

Table 4. Linear regression equations for estimation of live weight from linear body measurements and their determination coefficient

| Sex | Age | Prediction equations | $R^2$ | P-value |
|---|---|---|---|---|
| Does | 1PPI | 17.2 + 0.731*HW | 66.6 | 0.028 |
| | 2PPI | 16.0 + 0.907*HW | 47.0 | 0.080 |
| | 3PPI | 13.5 + 1.016*RW | 93.9 | 0.007 |
| | All ages | 4.60 + 0.358*CG | 35.5 | 0.002 |
| | (data pooled) | -8.49 + 0.278*CG + 0.988*HL | 49.3 | 0.0006 |
| Bucks | 2PPI | -26.3 + 0.911*WH | 88.9 | 0.005 |
| | | -15 + 0.812*WH - 0.261*RL | 98.3 | 0.002 |
| | | -12.1 + 0.707*WH + 0.044CG | 99.6 | 0.006 |
| | 3PPI | 4.55 + 0.399*CG | 94.8 | 0.001 |
| | | 1.418 + 0.353*CG + 0.409*RL | 99.2 | 0.0007 |
| | | -1.704 + 0.368*CG + 0.294*RW + 0.204*HL | 99.9 | 0.0015 |
| | 4PPI | - 111 + 9.56*RL (due to small number) | 85.0 | 0.084 |
| | All ages | -25.0+0.905*WH | 68.6 | <0.0001 |
| | (data pooled) | -42.7+0.619BL+0.614*WH | 84.6 | <0.0001 |
| | | -42.2+0.637BL + 0.419WH + 0.149CG | 86.2 | <0.0001 |

BW = body weight; BL = body length; WH = wither height; CG = chest girth; HL = head length; HW = head width; RL = rump length; RW = rump width

Table 5. Calculated structural and functional indices from morphometric traits of goat types reared in the studied districts

| Body indices | Arbaminch-Zuria | Mirab-Abaya | Overall mean | SD | CV (%) |
|---|---|---|---|---|---|
| Cephalic index | 86.6 | 75.0 | 80.7 | 8.20 | 10.2 |
| Body index (corporal index) | 87.5 | 87.9 | 87.7 | 0.28 | 0.32 |
| Thoracic development index | 1.17 | 1.10 | 1.14 | 0.05 | 4.36 |
| Relative depth of thorax | 68.9 | 79.0 | 73.9 | 7.14 | 9.66 |
| Pelvic index | 102 | 86.0 | 93.0 | 11.3 | 12.0 |
| Transversal pelvic index | 26.9 | 25.2 | 26.1 | 1.20 | 4.61 |
| Longitudinal pelvic index | 26.4 | 29.3 | 27.9 | 2.05 | 7.36 |
| Proportionality | 97.4 | 103 | 100 | 3.96 | 3.95 |
| Relative body or length index | 1.03 | 0.97 | 1.00 | 0.04 | 4.24 |
| Area index | 3757 | 3480 | 3618 | 196 | 5.41 |
| Compact index | 5.01 | 4.78 | 4.90 | 0.16 | 3.32 |
| Conformation index | 83.3 | 72.6 | 77.9 | 7.57 | 9.71 |
| Fore leg index | 18.8 | 12.6 | 15.7 | 4.38 | 27.9 |
| Weight | 44.7 | 35.9 | 40.2 | 6.22 | 15.4 |

SD = standard deviation; CV= coefficient of variation

# DISCUSSION

**Morphometric traits**

Body weight of MA does (29.1 kg) was similar with that of South African goats reared in semi-arid agro-ecology reported by Selolo *et al*. (2015). The overall mean of BW observed in AMZ goats was also in line with that of Hassen *et al*. (2012) who reported an average value of 31.1 kg for six Ethiopian indigenous goat breeds. Consistent with the current findings, Gatew *et al*. (2015) further reported 30.6 kg of BW for short-eared Somali goats. The BW of goats from both districts in the current study was also comparable to that of Central Highland goat populations; but was lower than Woyto-Guji goats reported by Zergaw *et al*. (2016). On the other hand, Chiemela *et al*. (2015) and Tsegaye *et al*. (2013) reported lower BW for Central Highland in south Wollo and Hararghe highland local goat populations, respectively. Conversely, Gatew *et al*. (2015) reported 41.3 and 40.4 kg BW for Bati and Borena male goat populations, respectively which are considerably higher than observed

in the current study. Similarly, higher BW of Horro-Guduru goats than recorded in AMZ and MA goats of the current study were also reported by Seid *et al*. (2016). These variations could be associated with genetic potential of the local goat types reared in various parts of the country, season when the measurements were taken, type of management provided by the owners, sex and age of animals. Proportion of male to female in the reported flocks could also contribute to such variations as body weight of goats is mainly affected by the sex of animals due to sexual dimorphism.

Consistent with the current results for AMZ goats, Hassen *et al*. (2012) reported similar CG for Bati and Abergelle goat populations. The CG reported by Tsegaye *et al*. (2013) and Chiemela *et al*. (2015) was in good agreement with that of MA goats. Gatew *et al*. (2015) also reported CG values for short-eared Somali goats that are comparable with those of MA. Moreover, the CG values reported for Indian Assam Hill goats by Khargharia *et al*. (2015) and those of Central Highland goats reported by Zergaw *et al*. (2016) were in line with that of AMZ bucks. Furthermore, the CG of Horro-Guduru goats reported by Seid *et al*. (2016) was similar with that of AMZ does while it was higher than recorded in MA goat populations. Similarly, the CG of MA bucks was consistent with the findings of Okpeku *et al*. (2011) for Nigerian Red Sokoto goats. On the other hand, Tsegaye *et al*. (2013) and Chiemela *et al*. (2015) reported lower CG for Hararghe highland and Central Highland goats in south Wollo, respectively while higher values were reported by Hassen *et al*. (2012) for Gumuz, Agew and Begiamedir goat populations than observed in AMZ goats. Moreover, Gatew *et al*. (2015) reported higher CG for Bati and Borena goats than observed in the current study. Chacón *et al*. (2011) reported much higher CG value (76.9 cm) for Cuban Creole goats than observed in the current study for goats of both districts. Such differences might be attributed to the genetic makeup, management (housing, feeding, exposure to parasite load, etc.) and production environments due to location of various goat breeds.

The BL of AMZ goats was consistent with the findings of Hassen *et al*. (2012) (for Bati and Abergelle goats) and Gatew *et al*. (2015) (for Bati and Borena goats). Body length values reported by Gatew *et al*. (2015) for small-eared Somali goats were also in good agreement with those of MA. Moreover, the BL values reported by Selolo *et al*. (2015) for does reared in South African semi-arid agro-ecology were comparable to that of MA (60.9 vs. 60.4 cm). Zergaw *et al*. (2016) also reported 57.4 cm BL for Woyto-Guji goats which is consistent with that of bucks reared in both districts. Conversely, Traore *et al*. (2008) reported lower BL for Sudan female goats than that of observed in the current study. Higher BL was also reported by Seid *et al*. (2016) for Horro-Guduru goats than observed in the bucks reared in both study districts. These variations in BL might be associated with differences in the genetic makeup of goats, type of management practiced by the smallholder farmers, season and environmental conditions in which goats have been raised.

In the current study, WH for AMZ and MA does was 58.5 and 61.0 cm, respectively, which was in line with the findings of Selolo *et al*. (2015) reported for South African female goats reared in semi-arid agro-ecological zones and Okpeku *et al*. (2011) for Nigerian Red Sokoto goats. The WH in MA does was found to be similar with that of Traore *et al*. (2008) for the Sudanese goats reared in the Sahel area and Okpeku *et al*. (2011) for Nigerian Red Sokoto goats and Chacón *et al*. (2011) for Cuban Creole goats. The WH reported by Chiemela *et al*. (2015) and Tsegaye *et al*. (2013) for Ethiopian local goat populations were also comparable with that of AMZ and MA goats. The WH of Woyto-Guji goats reported by Zergaw *et al*. (2016) were comparable to that of AMZ bucks and MA does. However, the same authors reported higher WH for Central Highland goats than any of the goats assessed in the current study. Similarly, the WH of Horro-Guduru goat reported by Seid *et al*. (2016) was higher than the current findings in both districts. Dekhili *et al*. (2013) also reported 66.9 cm WH for Algerian goats which was much higher than observed in the current study. The observed variations in WH among the current finding and in the literature for local goat populations might be

attributed to the existence of goats with variable genetic potentials which could be considered as a viable resource in the genetic improvement program of the existing indigenous goat populations.

The EL of Cuban Creole goats reported by Chacón *et al*. (2011) was similar with that of AMZ goats while it was lower than those of MA. Similarly, the EL reported by Zergaw *et al*. (2016) for Woyto-Guji goats was in good agreement with that of AMZ while it was lower than recorded in MA goats. The EL of MA goats was found to be similar to that of Central Highland goats as reported by Zergaw *et al*. (2016). Conversely, Dekhili *et al*. (2013) reported 18.5 cm ear length for Algerian goats which was much higher than observed for local goats of both districts in the current study. Such variations could be explained due to differences in the genetic makeup and adaptation potentials of the goat breeds to specific environmental conditions such as desert areas that are characterized by extreme ambient temperatures.

The BW of Hararghe highland goats at 2PPI reported by Tsegaye *et al*. (2013) was consistent with that of MA goats while it was lower than observed in those of AMZ. Goats of AMZ at 3PPI had similar BW with those of Hararghe highland goats at similar age as reported by Tsegaye *et al*. (2013). Moreover, the BW of MA at 2PPI and AMZ goats at 3PPI was consistent with the findings of Seid *et al*. (2016) for Horro-Guduru goats at similar age ranges. Moreover, the WH of Horro-Guduru goats at 1PPI and 3PPI was in good agreement with that of AMZ goats at similar ages. The WH of goats recorded until 2PPI in both districts was also similar with that of Hararghe highland goats reported by Tsegaye *et al*. (2013) for similar age range. The CG reported by the same authors for Hararghe highland goats at 1PPI was also consistent with that of AMZ goats of the same age. Similarly, the CG of AMZ and MA goat populations at 1PPI was comparable with that of Horro-Guduru goats reported by Seid *et al*. (2016) for the same age range. The same authors also reported CG values at 2PPI, 3PPI and 4PPI, which are comparable to AMZ goats of the same age ranges. The CG and WH values in MA goat populations at all PPI age ranges were inferior to those of Horro-Guduru goats reported by the same authors. The size of CG is considered as indicator of carcass yield potential and thus it can be speculated that the AMZ and Horro-Guduru goats are more suitable for meat production while the MA goats may fit for milk production. Such speculations are further evidenced by the fact that goats in AMZ had higher BW, BL, CG, RW and HW than those of MA, which suggests that they might be more suitable for meat production rather than milk production. On the other hand, the observed higher values for CD, RL and EL in goats reared in MA may suggest their suitability as a dairy goat type.

**Correlation of morphometric traits and prediction of body weight**

From the current findings, a higher relationship between body weight and linear measurements was observed in bucks than in the females. The higher association of BW with WH was possibly due to a relatively larger contribution of the wither area to body weight which consists of bones, muscles and the viscera organs. The association of BW with WH for bucks in the current study is in good agreement with that of Gatew *et al*. (2015) for Borena and short-eared Somali bucks, while it was higher than reported for Bati male goats. Okpeku *et al*. (2011) reported a high and positive correlation of BW with WH for the Nigerian WAD goats which is in good agreement with the current findings for bucks. Khargharia *et al*. (2015) also reported correlation of BW with BL (r = 0.86), RL (r = 0.70) and CG (r = 0.79) for Indian Assam Hill goats which are comparable to those observed for both sexes in the current study. The correlation of BW with BL in bucks of the current study was comparable with that of Borena bucks; but was higher than reported by Gatew *et al*. (2015) for short-eared Somali and Bati bucks. The positive correlation of morphometric traits indicated which trait could be further used for selection criteria. Moreover, the high phenotypic correlations observed between BW and morphometric traits suggests that these traits are under the same genetic influence and thus, selection for linear body measurement traits will favor the selection for body weight.

The strong positive and significant correlation of BW with BL, CG and WH suggested that either or the combination of these morphometric traits could be used to estimate BW of goats in the fields in the absence of a weighing scale. The regression model could not assess the prediction of body weight from morphometric traits in goats of 0PPI age category which might be due to age factor that they are still growing and their body has not yet been fully developed. Rump width was identified as the single important variable in the prediction of BW in does at 3PPI, which accounts for about 94% of the variations. The size of rump width is essential for does to accommodate the fetus during pregnancy and for efficient delivery during parturition. In males at 2PPI, WH accounts for about 90% of the variations in predicting the BW. The Model F statistic was highly significant ($F = 228.92$, $p<0.0001$), indicating that the model accounts for a higher portion of variation in the data. Even though, the magnitude of improvement varied in age groups, the inclusion of their respective linear measurements with WH and CG for bucks improved the accuracy of the prediction model ($R^2$) in all cases.

The result of stepwise regression analysis revealed that WH and CG in bucks were more consistent in predicting BW than others at 2PPI and 3PPI. This is in good agreement with the reports of various scholars in different parts of Ethiopia (Lorato *et al*., 2015; Seid *et al*., 2016; Hagos *et al*., 2016). The result of the multiple regression analysis for bucks at 3PPI indicated that the addition of other morphometric traits to the CG did not result in a significant increase in $R^2$, but it considerably improved the accuracy of prediction by decreasing the error source even though the quantity of increment was too small. Consequently, at farmers' management level where weighing scales may not be available using more than one trait may be impractical to measure by making the applicability less reliable. Moreover, adding more variables under farmers' management level will not be possible due to lack of technical skills and might increase errors. Therefore, CG alone could be used to predict body weight in bucks of 3PPI age category. The WH was found to be important variable to predict body weight of bucks in all age categories by accounting 68.8% of the variations.

**Zoometric indices**

Morphology of an animal expresses a strong relationship with productive potential, since it contains the structure which supports the biological functionality of the animal (Alpak *et al*., 2009). To the authors' knowledge, there is limited information in the literature reporting on the morphometric indices of local goat populations in Ethiopia. Moreover, reports dealing with structural and functional indices of goats in tropical and sub-tropical production environments are still scanty. As a result, it was difficult to make proper and plausible comparisons of the current findings with those of previous published works.

The cephalic index (CpI) refers to the harmony of the head, classifying it as brachycephalic, mesocephalic, or dolichocephalic (Arredondo-Ruiz *et al*., 2013). In the current study, CpI of MA goats was much smaller than those of AMZ (75.0 ver. 86.6). This is due to the fact that the head length of MA goats was much larger than the width and they can be thus classified as dolichocephalous. However, AMZ goats could be classified as mesocephalous. Body index (BI) indicates the relative capacity of the animal format (Latorre *et al*., 2011). Based on the results of BI, goats in both districts could be classified as mediolineous (⌑85 and ≤89). The BI values in the current study are much similar to those reported by Chacón *et al*. (2011), Khargharia *et al*. (2015) and Chiemela *et al* (2016) for various types of local goat populations. The respective weight index of goat populations in AMZ and MA was 44.7 and 35.9 kg, which correspondingly classify them as medium or eumetric type.

Thoracic development (TD) is important in terms of fitness, good respiratory system, particularly in those goats adapted to higher altitudes. In the current study, AMZ goats had higher TD value than those of MA indicating a better thoracic capacity enabling them to survive in relatively

high altitude terrains. The observations are consistent with those of Chiemela *et al*. (2016), who reported a TD value of 1.08 for Central Highland female goats in south Wollo; but were slightly lower than that of Chacón *et al*. (2011) for Cuban Creole goats (1.17) and Khargharia *et al*. (2015) for India Assam Hill goats (1.32).

Relative depth of thorax index (DTI) indicates a relationship between chest depth and wither-height and serves as an indirect measure of leg length, whereby higher indices for this trait corresponds to animals with longer legs (Chacón *et al*., 2011). According to these authors, animals with higher DTI values have a higher moving capacity, being more adapted to plains and long treks with bodies further from the ground to avoid heat radiation. In the current study, MA goats had a higher DTI (79.0 ver. 68.9), which suggests that they are characterized by long legs and their body is far from the ground. This has been clearly reflected in female goats of MA which had a significantly higher wither height value than those of AMZ. Moreover, the higher DTI observed in MA goats could suggest classifying them towards dairy phenotype. Chiemela *et al*. (2016) and Chacón *et al*. (2011) reported DTI of 43.8 for Central Highland goats in south Wollo and 47.7 for adult Cuban Creole goats, respectively, which is far lower from the current findings. Because of the small value in DTI, the Cuban Creole goats were characterized as short-legged with their body being much closer to the ground (Chacón *et al*., 2011).

The pelvic index (PI) is a racial diagnostic index which is used to determine the proportionality of the hindquarters and thus, could be related to the reproductive capacity of female goats (Cerqueira *et al*., 2011). According to the current result of PI, the rump of the MA goats had a convex curve ($p \leq 100$), with a predominance of the rump length over the width. However, pelvic index of AMZ goats was 102 indicating a balance between rump length and its width. Khargharia *et al*. (2015) reported PI values that are lower than observed in AMZ but higher than MA goats. Chacón *et al*., (2011) reported much lower (76.0) PI for Cuban Creole goats while Chiemela *et al*. (2016) reported much higher (123) values for Central Highland goats in south Wollo than observed in the current findings. Such variations might be due to differences in age and sex of goats when the morphometric measurements were taken. There is also a possibility of making errors while taking such measurements in the field.

Transversal pelvic (TPI) and longitudinal pelvic (LPI) indices are commonly used to estimate the meat aptitude of a given animal populations by relating the width and length of the rump to the height at withers (Barragán, 2017). A TPI largely exceeding 33 and LPI not exceeding 37 are suitable indicators of meat type. In the current study, the LPI values for both AMZ and MA goats showed lower values and thus, tended toward the meat phenotype. The observed TPI and LPI values are also comparable with those reported by Chacón *et al*. (2011) for Cuban Creole goats. According to Chiemela *et al*. (2016), the LPI of Central Highland goat in south Wollo was 17.0, which was much lower than observed in the current study. Lower LPI values could also be correlated to animals with a high incidence of dystocia (Chacón *et al*., 2011 and Chiemela *et al*., 2016). The LPI values reported by Khargharia *et al*. (2015) were comparable to those of recorded in AM goats (24.9 vs. 26.4), while those reported by Chacón *et al*. (2011) were much similar with that of MA goats.

Proportionality index (PrI) relates the body height to the body length and denotes the shape of a given animal populations (Barragán, 2017). A PrI value less than 1.00 (predominance of body length over body height) indicates that the breed's body tends to be rectangular which is a characteristic of meat type, while a value greater than 1.00 denotes that the shape of the animal tends to be square, which is a characteristic of dairy type (Bravo and Sepúlveda, 2010; Barragán, 2017). In the current study, the AMZ goats showed smaller PrI (0.97), which is a characteristic of meat type while those of MA demonstrated higher value (1.03) with almost a square shape relating them to a dairy type. PrI value (0.93) reported by Chacón *et al*. (2011) for Cuban Creole goats were comparable to those of

AMZ goats; but was much lower than those of MA. The PrI of Central Highland goats in south Wollo (1.08) reported by Chiemela *et al*. (2016) was comparable to that of MA goats.

The relative body or length index (LI) in the current study was 1.03 and 0.97 for AMZ and MA goats, respectively, which is in good agreement with that of Salako (2006) who reported 1.01 and 0.93 values for WAD and Yankasa sheep, respectively. The LI in the current study was also comparable to the findings of Chacón *et al*. (2011) and Chiemela *et al*. (2016), while it was slightly lower than reported by Khargharia *et al*. (2015). The respective LI values of AMZ and MA goats were comparable to those of Boer and Central Highland goats in south Wollo reported by Chiemela *et al*. (2016). The LI in the current study has confirmed that, relative to height, the AMZ goats are longer bodied than those of MA, which suggest that the carcass yield of the former is expected to be higher than those of the latter.

The area index (AI) values indicated that AMZ goats have larger body surface than those of MA. Animals with larger body surface area relative to their body mass have a better ability to withstand heat stress effectively by dissipating the excess heat load from their body surface by means of sensible and insensible heat dissipation mechanisms. The AI of the Indian Assam Hill goat reported by Khargharia *et al*. (2015) was somehow closer to that of MA goats but was much lower than that of AMZ.

The compact index (CI) value of AMZ goat populations was 5.01 and thus they can be classified as meat type animals validating previous indices. Chiemela *et al*. (2016) reported lower CI values (3.91) for Central Highland goats in south Wollo, while slightly higher values (5.20) were reported for adult Cuban Creole goats by Chacón *et al*. (2011) than observed in AMZ goats but was much higher than those of MA. Khargharia *et al*. (2015) reported 5.63 CI for Indian Assam Hill goats, which is higher than observed in the current study.

The overall body shape of an animal is referred as a conformation. The greater the conformation (baron) index, the more vigorous the breed would be. Accordingly, the AMZ goats are expected to be much vigorous with healthier physical appearance than those of the MA. The observed baron index values for both AMZ and MA goats were lower than reported for other goat breeds (Chacón *et al*., 2011; Khargharia *et al*. (2015). Goats of AMZ had comparable conformation index with that of Boer goats (83.3 vs. 82.7) reared in Central Highland of Ethiopia, while those of MA showed similar values with local goats of Central Highland goats in South Wollo (70.0 vs. 72.6) as reported by Chiemela *et al*. (2016). It is indeed interesting to note that the AMZ goats demonstrated closer similarities in many structural and functional indices with that of Boer goats reared in Central Highland of Ethiopia, while those of MA showed comparable values with Central Highland goats in south Wollo.

## CONCLUSIONS

Bucks of AMZ were better in WH, CG, RW and HW than those of MA, while they were inferior in CD, RL, HL and EL. Does reared in AMZ had higher BW, BL, CG, RW and HW than those of MA. In general, goats of AMZ were better in BW, BL, CG, RW and HW than those of MA, while the latter demonstrated higher CD, RL and EL values than the former. The BW of does in all age groups could be predicted by using CG while that of bucks with WH. The estimated morphometric indices suggested classification of AMZ goats as a medium-sized and long-shaped body frame, with a marked orientation for meat production along with signs of adaptation to its environment. Conversely, MA goats were oriented as medium-sized whose morphology corresponds to dairy type. The milk production of MA goats could be thus studied to identify their potential within the existing production system.

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