Characterization of indigenous goat populations by applying morphometrical traits and structural indices

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ABSTRACT

Aim: The principal objective of this study was to undertake morphometric characterization of indigenous goat populations reared in three districts of Jimma zone, western Ethiopia.

Method and Materials: Morphometrical data were collected from 660 adult goats raised in Nono Benja (NB), Omo Nada (ON) and Limu Sika (LS) districts of Jimma zone. The regression analysis was used to predict body weight from the measured data for both sexes separately. Based on linear body measurements, 15 structural indices were calculated.

Results: Except head length, all morphometrical traits were affected ($p<0.05$) by district. Accordingly, goats reared in NB district had higher ($p<0.05$) morphometrical values than those kept in ON and LS districts. Similarly, goats raised in NB district had higher values ($p<0.05$) for all quantitative traits than those of ON district. All quantitative traits increased ($p<0.01$) with the age of the goats. In both female and male goat populations, chest girth (CG), body length, and height at wither showed strong and positive correlations ($p<0.001$) with live body weight. The result of stepwise regression analysis revealed that CG was more consistent in predicting body weight in both sexes than the other quantitative traits. According to the values of the dactyl thorax index, longitudinal pelvic index and compact index, the general body conformation of these goat types matched up with the intermediary meat type.

Conclusion: Chest girth was found to be more consistent in predicting body weight of goats in both sexes. The calculated structural and functional indices suggest that goats in the study area could be classified as medium (intermediary) meat type animals.

Keywords: Characterization; indigenous goats; Jimma zone; morphometrical traits; structural indices.

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Introduction

Ethiopia is home to genetically diverse goat populations that are widely distributed across all agro-ecologies (Halima et al., 2012). The country has 32.74 million heads of goats of which 70.5% are females and 29.5% are males and almost all of them are indigenous (CSA, 2018). 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. Small ruminant in general and goat production in particular, contribute significantly to the national and household economy and it's most important agricultural activity in Ethiopia. Goats have wide acceptance and recognition worldwide because of their multiple benefits to human.

Goats contribute significantly to the livelihood of resource-poor farmers in Ethiopia. They fulfill various functions such as generating cash income, accumulating capital, and fulfilling cultural obligations (Gebreyesus et al., 2012). The small body size, broad feeding habits, adaptation to unfavorable environmental conditions and their short reproductive cycle provide goats with a comparative advantage over other species to suit the circumstances of especially resource-poor livestock keepers. The indigenous goat types are widely distributed and are found in all administrative regions of the country. The majority of the goat population is found in large flocks in the arid and semi-arid lowlands. Goats in the highlands are widely distributed in the mixed crop-livestock production systems with very small flock size, with an increasing trend in all agro-ecologies (Dereje et al., 2019).

Ethiopian indigenous goats are genetically less productive when compared to temperate breeds. Even though there are large populations of goats, their productivity and contribution to the country’s national economy is far below as compared with improved type of exotic goat breeds (Tesfaye et al., 2012; Yemane, 2019). One possible contributing factor for low productivity of local goats could be attributed to their poor genetic potential along with poor husbandry practices due to the absence of a clear breeding strategy to improve their production potential (Melesse et al., 2013a, 2016).

According to FAO (2012), four strategic view points for Animal Genetic Resource management have been developed under the theme of the Global Plan of Action in which animals breed characterization was one of them. The characterization of local genetic resource based on morphological trait plays a very fundamental role in the classification of animals based on size and shape to better understand their phenotypic potential to be able to develop a viable breeding strategy for their genetic improvement (Melesse et al., 2013b). Characterization of local animal genetic resources in their existing production system is a prerequisite for their sustainable management and utilization (FAO, 2012).

According to previous preliminary phenotypic characterization studies conducted by FARM-Africa (1996) and DAGRIS (2007), there are four families and 13 different indigenous goat types in Ethiopia. Genetic characterization studies revealed the existence of eight different goat types in the country (Tesfaye, 2004). Recently, Getinet (2016) regrouped the Ethiopian goat populations into seven categories based on a molecular characterization study. However, all these studies have focused on specific locations leaving most of the country’s goat populations undescribed.

Morphometrical measurements have been used to estimate the characteristics of several breeds of animals, and could provide information on the suitability of animals for selection (Okpeku et al., 2011; Melesse et al., 2013b, Dereje et al., 2019). Studies conducted by various scholars have reported the existence of phenotypic variations among Ethiopian goat populations between and within these goat ecotypes (Halima et al., 2012; Yakob et al., 2015; Hulunim et al., 2015; Dereje et al., 2019). To identify the type and function of goat breeds, structural indices from linear body measurement could be also calculated. Structural indices are the combinations of several linear measurements that could offer estimation of an animal's conformation when compared to individual measurements alone. Structural indices also provide tested empirical values, which are limited in the use of single measurements (Salako, 2006; Chacón et al., 2011).

Jimma zone was characterized by diverse agro-ecological zones where goats play increasingly significant role for communities that keep them. Despite having huge benefits for the society, studies on goat’s physical traits and documented information on morphological characterization and structural indices of goat in the studied area is lacking and was very few till yet. Thus, characterizing these goat populations based on their morphometrical characteristics is very essential to design management and utilization strategies. Therefore, this study was conducted to morphometrically characterize the indigenous goat populations reared in three districts of Jimma zone that have been known for their goat production potentials.

Materials and Methods

The study was conducted in three districts (Limu Seka, Nono Benja, and Omo Nada) of Jimma zone, Oromia Regional State of Ethiopia. Jimma zone is geographically situated between 35^0-37^0 E longitudes and 7^0- 8^0 N latitude at an elevation ranging from 880 to 3360 m.a.s. level.

Sampling and data collection procedures

Multi-stage sampling techniques were applied to select representative districts and Kebeles (smallest administrative unit of the country) for the study. At the first stage, out of the twenty districts, three districts (Limu Seka, Omo Nada and Nono Benja) were purposively selected based on their goat population potential in consultation with agricultural experts of the Zone and districts. In the second stage of sampling, four, three and two Kebeles were purposively selected from Limu Seka, Omo Nada and Nono Benja districts, respectively. Moreover, care was taken to select representative sample size by considering goat flock size of at least two female and one male goat per household and willingness of households to participate in the study. In third stage, the number of households from each selected Kebeles was determined according to the proportionate sampling technique. The sample size of 210 households was determined according to the Arsham (2007) using the following formula: $N = 0.25/SE^2$; where: N = sample size, SE = standard error (0.0345) with 95% confidence level and selected by systematic random sampling technique from households those keep at least three matured goats. Accordingly, 294, 146 and 220 adult goats were selected from Limu Seka, Nono Benja, and Omo Nada districts, respectively of which 240 were males while the rest 420 were females.

Morphometric traits

All physical measurements were recorded on the prepared format and each animal was identified by its sex, dentition, and district in which pregnant does and castrated bucks were excluded from sampling. All measurements were taken in the morning to avoid the effect of feeding and watering on the animal's live weight. Moreover, to avoid genetic similarity, less than or equal to 4 goats per household were used. Dentition together with the information obtained from the goats' owner was used to classify them by their age group. Accordingly, goats were classified as 0PPI (no pair of permanent incisor), 1PPI (one pair of permanent incisors), 2PPI (two pair of permanent incisors), 3PPI (three pair of permanent incisors) and 4PPI (four pair of permanent incisors) by representing 0-1 year, 1-2 years, 2-3 years, 3-4 years and 4-5 years old, respectively (Wilson, 1991; FAO, 2012).

Linear body measurements were taken using measuring tape while live body weight of animals was measured by using suspended weighing scale with 50 kg capacity of 0.2 kg precision. Fifteen morphometrical traits were measured following the phenotypic descriptor list of FAO (2012), which included body weight (BW), body length (BL), wither height (WH), chest girth (CG), chest depth (CD), rump width (RW), rump length (RL), height at rump (HR), shoulder width (SW), head width (HW), head length (HL), ear length (EL), horn length (HoL), fore cannon length (FCL), and circumference (FCC). Each animal was identified by its sex, dentition, and sampling site.

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

μ = 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 = Limu Seka, Nono Benja, and Omo Nada)

e_{ijk} = random residual error

Pearson's correlation coefficients were performed between body weight and linear body measurement traits for each sex separately. The body weight of the animals was then predicted by including those traits that showed high correlation with body weight 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)

α = 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

Calculation of body indices

To assess the type and function of indigenous goat population in the study area, six structural (ethnological) and 9 functional indices were calculated from the morphometric traits according to the method of Chacón et al. (2011), Khargharia et al. (2015) and Barragán (2017).

Results

The average values of body weight and linear body measurement traits of indigenous goat in the study area by district, sex and age are presented (Table 1). Information on the quantitative traits of animals is a useful tool in the selection program. Except head length, all morphometrical traits have been significantly affected by district. Accordingly, except for SW, RW, and FCC, goats reared in Nono Benja district had significantly higher morphometrical values than those kept in Omo Nada and Limu Sika districts. Similarly, goats raised in Nono Benja district had higher values ($p<0.05$) for all quantitative traits than those of Omo Nada. Sex had also a significant effect on all measured quantitative traits in which male goats

Table 1. Average values of morphometrical traits of local goat populations reared in three districts of Jimma zone as affected by sex and age

Factors	N	LBW	BL	WH	CG	CD	SW	HR	RL	RW	HW	HL	FCL	FCC	EL	HoL
District		<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.003	0.130	0.019	<.001	<.001	<.01
LS	294	25.4^{b}	56.0^{b}	61.2^{b}	66.8^{b}	27.8^{c}	14.9^{a}	63.7^{b}	13.2^{b}	13.3^{a}	10.4^{b}	18.4	12.8^{ab}	7.18^{a}	13.9^{b}	10.2^{b}
NB	146	26.2^{a}	57.1^{a}	62.7^{a}	68.0^{a}	28.4^{a}	14.8^{a}	65.2^{a}	13.3^{a}	13.1^{b}	10.6^{a}	18.3^{a}	12.8^{a}	7.01^{b}	14.3^{a}	11.8^{a}
ON	220	24.4^{c}	55.3^{c}	60.2^{c}	65.7^{c}	28.2^{b}	14.6^{b}	62.6^{c}	12.9^{c}	12.6^{c}	10.4^{b}	18.3^{a}	12.7^{b}	6.95^{b}	13.5^{c}	9.58^{c}
Sex		<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.002	<.01
Male	240	26.8	56.9	62.2	68.0	28.9	15.3	64.6	13.4	13.4	10.7	18.2	12.9	7.45	13.9	10.6
Female	420	24.3	55.5	60.6	66.0	27.6	14.4	63.1	12.9	12.8	10.3	18.3	12.6	6.83	13.7	10.2
Age		<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
0PPI	119	14.8^{e}	48.6^{e}	53.4	57.4^{e}	23.8^{e}	12.0	55.4^{e}	11.1^{e}	11.1^{e}	9.23^{e}	15.7^{e}	11.5^{e}	6.23^{e}	12.7^{e}	5.8^{e}
1PPI	152	22.0^{d}	53.7^{d}	58.4^{d}	63.3^{d}	26.7^{d}	14.0^{d}	60.6^{d}	12.5^{d}	12.4^{d}	10.0^{d}	17.5^{d}	12.4^{d}	6.82^{d}	13.3^{d}	9.4^{d}
2PPI	145	26.1^{c}	56.8^{c}	62.0^{c}	68.1^{c}	28.5^{c}	15.1^{c}	64.9^{c}	13.3^{c}	13.2^{c}	10.4^{c}	18.6^{c}	12.9^{c}	6.98^{c}	13.7^{c}	10.9^{c}
3PPI	130	30.6^{b}	59.9^{b}	65.4^{b}	71.3^{b}	30.3^{b}	16.0^{b}	68.2^{b}	14.1^{b}	14.0^{b}	11.2^{b}	19.9^{b}	13.4^{b}	7.50^{b}	14.6^{b}	12.5^{b}
4PPI	114	33.3^{a}	61.4^{a}	67.2^{a}	74.0^{a}	31.2^{a}	16.6^{a}	69.6^{a}	14.7^{a}	14.6^{a}	11.5^{a}	20.3^{a}	13.7^{a}	7.86^{a}	15.0^{a}	13.4^{a}

^{a,b,c,d,e} Means with different superscript letters within the same column and class are significantly different ($p<0.05$)
LS = Limu Seka; NB = Nono Benja; ON = Omo Nada; LBW = live body weight; BL= body length; WH = wither height; CG = chest girth; CD = chest depth; SW= shoulder width; HR = height at rump; RL= rump length; RW = rump width; HW = head width; HL = head length; FCL= fore cannon length; FCC= fore cannon circumference; EL= ear length; HoL= horn length

Table 2. The Pearson correlation coefficients between body weight and linear body measurement traits (values above diagonal are for females and below diagonal are for males)

	BW	BL	WH	CG	CD	SW	HR	RL	RW	HW	HL	FCL	FCC	EL
BW		0.94^{***}	0.94^{***}	0.95^{***}	0.93^{***}	0.923^{***}	0.94^{***}	0.92^{***}	0.93^{***}	0.83^{***}	0.86^{***}	0.85^{***}	0.80^{***}	0.66^{***}
BL	0.93^{***}		0.95^{***}	0.93^{***}	0.89^{***}	0.88^{***}	0.94^{***}	0.89^{***}	0.89^{***}	0.81^{***}	0.84^{***}	0.83^{***}	0.78^{***}	0.66^{***}
WH	0.92^{***}	0.94^{***}		0.95^{***}	0.88^{***}	0.88^{***}	0.97^{***}	0.89^{***}	0.89^{***}	0.80^{***}	0.84^{***}	0.83^{***}	0.78^{***}	0.67^{***}
CG	0.94^{***}	0.91^{***}	0.90^{***}		0.89^{***}	0.89^{***}	0.95^{***}	0.89^{***}	0.90^{***}	0.79^{***}	0.85^{***}	0.83^{***}	0.78^{***}	0.66^{***}
CD	0.92^{***}	0.87^{***}	0.87^{***}	0.89^{***}		0.89^{***}	0.90^{***}	0.90^{***}	0.88^{***}	0.80^{***}	0.85^{***}	0.82^{***}	0.76^{***}	0.59^{***}
SW	0.92^{***}	0.87^{***}	0.87^{***}	0.88^{***}	0.88^{***}		0.89^{***}	0.89^{***}	0.87^{***}	0.77^{***}	0.84^{***}	0.82^{***}	0.74^{***}	0.60^{***}
HR	0.92^{***}	0.91^{***}	0.94^{***}	0.93^{***}	0.86^{***}	0.88^{***}		0.86^{***}	0.90^{***}	0.79^{***}	0.83^{***}	0.83^{***}	0.78^{***}	0.66^{***}
RL	0.91^{***}	0.85^{***}	0.84^{***}	0.88^{***}	0.85^{***}	0.86^{***}	0.90^{***}		0.91^{***}	0.80^{***}	0.80^{***}	0.82^{***}	0.75^{***}	0.64^{***}
RW	0.91^{***}	0.85^{***}	0.84^{***}	0.87^{***}	0.83^{***}	0.87^{***}	0.86^{***}	0.91^{***}		0.82^{***}	0.82^{***}	0.82^{***}	0.77^{***}	0.65^{***}
HW	0.86^{***}	0.80^{***}	0.78^{***}	0.82^{***}	0.80^{***}	0.79^{***}	0.81^{***}	0.77^{***}	0.80^{***}		0.73^{***}	0.74^{***}	0.70^{***}	0.62^{***}
HL	0.87^{***}	0.81^{***}	0.81^{***}	0.84^{***}	0.85^{***}	0.82^{***}	0.85^{***}	0.85^{***}	0.84^{***}	0.80^{***}		0.77^{***}	0.71^{***}	0.58^{***}
FCL	0.82^{***}	0.79^{***}	0.77^{***}	0.80^{***}	0.76^{***}	0.75^{***}	0.78^{***}	0.75^{***}	0.76^{***}	0.72^{***}	0.73^{***}		0.75^{***}	0.50^{***}
FCC	0.76^{***}	0.69^{***}	0.69^{***}	0.72^{***}	0.68^{***}	0.71^{***}	0.69^{***}	0.70^{***}	0.74^{***}	0.71^{***}	0.72^{***}	0.67^{***}		0.48^{***}
EL	0.61^{***}	0.59^{***}	0.58^{***}	0.59^{***}	0.54^{***}	0.55^{***}	0.59^{***}	0.57^{***}	0.59^{***}	0.53^{***}	0.54^{***}	0.60^{***}	0.61^{***}	

***$p<0.001$; LBW = live body weight; BL= body length; WH = wither height; CG = chest girth; CD = chest depth; SW= shoulder width; HR = height at rump; RL= rump length; RW = rump width; HW = head width; HL = head length; FCL= fore cannon length; FCC= fore cannon circumference; EL= ear length were heavier ($p<0.01$) than females. Similarly, age of the animals had a considerable effect ($p<0.001$) on morphomtrical traits. As a result, all quantitative traits significantly increased with the age of the goats.

Association of morphometric traits

The Pearson correlation coefficients of live body weight with linear measurement traits of male and female goats are presented (Table 2). All traits showed positive and strong ($p<0.001$) associations with live body weight ranging from 0.61 to 0.94 for male and 0.66 to 0.95 for female population.

In both female and male goat populations CG, BL, and WH showed a strong and positive correlations with live body weight. In the female population, CG had strong positive correlation (r = 0.95) with live body weight followed by BL (r = 0.94), RH (r = 0.94) and WH (r = 0.94). Likewise, in male goat population, CG had strong positive correlation (r = 0.94) with live body weight followed by BL (r = 0.93), WH (r = 0.92), RH (r = 0.92), CD (r = 0.92) and SW (r = 0.92).

Prediction of live body weight

Models for prediction of live weight from different linear body measurement of sex of sampled goats are presented (Table 3). All independent variables were fitted into the model and through stepwise elimination procedures, the optimum model was identified. Stepwise multiple linear regression analysis was used to predict body weight from linear measurements, which had a positive correlation with body weight. The best fitted prediction models (explanatory variables) were selected with smaller C (P) and higher R^2 values and simplicity of measurement under field condition. The result of stepwise regression analysis revealed that CG was more consistent in predicting body weight than other linear body measurements in both sexes.

Structural and functional indices of studied goats

From measured quantitative traits, fifteen structural and functional indices were calculated for the goat populations of the study area (Table 4). The structural indices result revealed that the body index of goats in the study area was 0.84 that classify them as brevigline. Height slope value of sampled goats was negative. Relative body or length index of the current study was 0.92.

Table 3**.** Best-fitted regression models to predict live body weight from morphometrical traits of male and female goats

Sex group	Best-fitted regression equations	R^2	C(p)	P-value
Does	-42.8 + 1.02*CG	0.90	466	<0.001
	-43.0 + 0.645*CG + 0.896*CD	0.93	195	<0.001
	-41.2+0.447*CG + 0.684*CD + 1.30*RW	0.94	100	<0.001
Bucks	-39.6 + 0.978*CG	0.88	420	<0.001
	-38.9 + 0.592*CG + 1.669*SW	0.92	208	<0.001
	-41.2 + 0.447*CG + 1.281*SW + 1.348*RL	0.94	136	<0.001
Both sexes	-42.0 + 1.01*CG	0.90	871	<0.001
	-43.1 + 0.628*CG + 0.94*CD	0.93	389	<0.001
	-43.1 + 0.450*CG + 0.722*CD + 1.388*RW	0.94	185	<0.001

CG = chest girth; CD = chest depth; SW = shoulder width; RW = rump width; RL = rump length

Table 4. Average values of structural indices for goat types in the three districts

Structural Indices	Mean	SD	CV
Cephalic index	57.1	4.31	7.55
Body index	0.84	0.03	3.51
Height slope	-2.50	1.48	-59.0
Relative depth of thorax	45.9	2.15	4.69
Proportionality	109	3.01	2.76
Longitudinal pelvic index	20.6	0.96	4.65
Depth index	0.46	0.02	4.69
Relative body or length index	0.92	0.03	2.74
Dactyl thorax index	10.6	0.78	7.39
Pectoral index	1.89	0.08	4.47
Thoracic development	1.09	0.04	3.32
Body ratio	0.96	0.02	2.33
Relative canon thickness index	11.6	0.86	7.46
Foreleg index	33.1	3.1	9.42
Compact index	4.06	0.78	19.3

SD = standard deviation, CV = coefficient of variation

The dactyl thorax index of goats in the study area was 10.6. The average weight of goat in the study area was below 35 kg, thus they are a small or elipometric. Longitudinal pelvic index serves to estimate the meat capacity of the animal, relating the length of rump to the height at withers. The compact index value of the current study was 4.06 while the thoracic development of goat in the current study was 1.09. Body ratio of goats in the study area was 0.96 and the proportionality index was 109. Relative depth of thorax index of goats in the study area was 45.9.

Discussion

Effect of fixed factors

The difference in quantitative traits between districts might have resulted from different management practices of the farmers. Goats in Omo Nada district possess significantly lower values for body weight, BL, WH, CG, HR, RL, RW, horn length, and ear length. This might possibly be due to relatively poor management practices of the farmers in the Omo Nada district. Moreover, according to focal group discussion held with selected community members in this district, farmers frequently move their goats a long distance in search water during the dry season than those of Limu Seka and Nono Benja districts. On the other hand, under natural conditions, indigenous livestock breeds may suffer from vitamin and mineral deficiencies, as well as limitations in food quantity and quality, which may affect the linear body measurement traits.

Sex had also a significant effect on all measured quantitative traits. Jimmy et al. (2010) indicated that the sex related differences might be a function of the sex differential hormonal effect on the growth of animals. Moreover, Frandson and Elmer (1981) stated that differences due to sex in body weight and linear body measurements might be due to release of androgen hormone which has growth and weight stimulating effects on male animals. The current results concur with those of Yakob et al. (2015), Ahmed et al. (2016), Gelana and Belete (2016), Bekalu et al. (2016) and Hulunim et al. (2017) who reported that males were heavier than females in most quantitative traits for goat populations reared in different parts of Ethiopia.

In the current study, body weight and all linear body measurement traits had a significant difference in all age (dentition) groups in which when the goat age is increased, body weight and linear body measurements also increased. This implies that goats attained higher body weight at the latter age which is in good agreement with those of Ahmed et al. (2016) for Western highland goats in Horro Guduru Wollega zone and Gelana and Belete (2016) in Sinana district of Bale zone of Ethiopia, who reported that all body measurements were increased as age group increased and higher body weight come at the oldest age class of goat.

Predicting live body weight

The strong positive and significant correlation between live body weight and CG in both sexes suggested its importance for the prediction of body weight. The current results are in good agreement with the earlier reports of various scholars (Thiruvenkadan, 2005; Yakob et al., 2015; Ahmed et al., 2016; Bekalu et al., 2016). The higher association of live body weight with CG is possibly due to a relatively larger contribution of chest girth to body weight which consists of bones, muscles and viscera as suggested by Melesse et al. (2013b).

The high correlation coefficient values between morphometrical and live body weight indicates that either or the combination of these quantitative traits could be used to estimate live weight of goats in the fields in the absence of weighing scale. An increase in any one of the morphometrical traits would result in a corresponding increase in live body weight which is in agreement with the report of Jimmy et al. (2010). On the other hand, the positive correlation of these traits indicates that the traits are under the same genetic influence which could be further used for selection criteria in which selection of one trait will result in the improvement of the other due to correlated response of the traits.

Even though knowing the live weight of animals is important in the livestock production and marketing practices, measuring the live weight of animals is often difficult under village condition due to unavailability of weighing scales due to high cost. To predict the live weight of animals without weighing scales, mathematical equations can be developed based on weight-linear body measurement data (Thiruvenkadan, 2005; Melesse et al., 2013b).

The result of stepwise regression analysis revealed that CG was more consistent in predicting live body weight than other linear body measurements in both sexes. This observation is in good agreement with the reports of various scholars in different parts of Ethiopia (Yakob et al., 2015; Ahmed et al., 2016; Bekalu et al., 2016;

Hulunim et al., 2017). The multiple regression analysis indicated that the addition of other linear body measurement traits to the CG did not result in a significant increase in adjusted R^2, but it significantly improved the accuracy of prediction by decreasing the error source (data not shown) even though the quantity of increment was too small. Consequently, at farmers level where weighing scales are not available using more than one trait may be difficult to measure and may bored farmers. Moreover, adding more variables under farmers' management level will be unpractical due to accuracy problem that increase the source of error.

Using chest girth lonely to predict body weight of female and male sampled goat could gave an accurate prediction because the addition of other quantitative traits to the CG did not result in a significant increase of adjusted R^2, although it improves the accuracy of prediction. Therefore, the simplified predicted equation of live body weight for the female and male goats would be 42.8 + 1.02*CG and -39.6 + 0.978*CG, respectively.

Structural and functional indices

Height slope value of sampled goats was negative that indicates wither height is smaller than rump height which suggest that these goats types are shorter in front than in rearward. This further indicates that such animals have strong fore-quarters that enable them to climb heights more than their shorter fore-legged and access forages to browse (Salako, 2006). Relative body or length index of the current study was 0.92 which is slightly consistent with Chiemela et al. (2016) who reported an index of 0.93 for Central highland goat in South Wollo. Salako (2006) suggested that these indices are more closely associated with bone growth (fore-limb length, height slope, and relative body index or length index) are more appropriate for assessment of type for which the breed was developed. The relative body index and balance indices indicate the carcass yield capacity of live animals. The lower value of relative body index in the present study compared to the report of Chacón et al. (2011) and Chiemela et al. (2016) may suggest that the carcass yield of the current goats is expected to be low.

Dactyl thorax index provides an idea of the degree of fineness of the skeleton of an animal. The dactyl thorax index of goats in the study area was 10.6 that classified them as medium (intermediary) meat type animals, which is consistent with that of Chiemela et al. (2016) who reported an index value of 10.6 for Central Highland goat in South Wollo. Chacón et al. (2011) reported lower dactyl thorax index (9.58) for Cuban Creole goats than observed in the present study.

The average weight of goat in the study area was below 35 kg, thus they are a small or elipometric. Longitudinal pelvic index serves to estimate the meat capacity of the animal, relating the length of rump to the height at withers. Longitudinal pelvic indexes not exceeding 37 are suitable indicators for meat animals (Lopez et al., 1992; Salako, 2006). Longitudinal pelvic index of goat in the study area was 20.6, which would classify them as meat animals. According to Chiemela et al. (2016) the longitudinal pelvic index of central highland goat in South Wollo was 17.0, which is lower than the value obtained from the current study. Lower values of longitudinal pelvic index can be correlated to animals with a high incidence of dystocia (Chacón et al., 2011; Chiemela et al., 2016).

The compact index is a useful indicator of the overall value of the animals because it combines morphology and structure; and provides an accurate picture of type and function of livestock breed (Chiemela et al., 2016). Since the compact index value of the current study was 4.06, goats in the study area can be classified as meat type animals validating previous indices. Chiemela et al. (2016) and Chacón et al. (2011) also reported a compact index of 3.91 for Central highland goats in South Wollo; and 5.40 for adult Cuban Creole goats. Thoracic development of goat in the study area was 1.09 which is less than 1.2, indicating that the goats in the study area are characterized by poor thoracic development. This observation is consistent with that of Chiemela et al. (2016), who reported a value of 1.08; but was slightly lower than reported by Chacón et al. (2011).

Body ratio of goats in the study area was 0.96, which is consistent with the findings of Chacón et al. (2011) who reported similar value for Cuban Creole goats. However, the body ratio value in the current study was higher than reported by Chiemela et al. (2016) for the central highland goat in the South Wollo of Ethiopia. Proportionality index relates the body height to the body length and denotes the shape of the animal. Proportionality index of goat type in the current study was 109, which classify them as dairy type breeds.

Relative depth of thorax index indicates a relationship between chest depth and leg's length (Sastre, 2003). Relative depth of thorax index of goats in the study area was 45.9. Chiemela et al. (2016) and Chacón et al. (2011) reported relative depth thorax of 43.8 for central highland goat in south Wollo and 47.7 for adult Cuban Creole goats, respectively, which is comparable with the current findings. According to Sastre (2003), animals with higher relative depth of thorax values have a higher moving capacity, being more adapted to plains and long treks with bodies further from the ground to avoid heat radiation.

Conclusion

The results revealed that body weight and all the linear body measurement traits were significantly affected by districts, sex and age of the goats. Among measured quantitative traits, chest girth was found to be highly and positively associated with live body weight for both sex groups and can be used to attain a more reliable estimate of body weight. According to the values of the dactyl thorax index, longitudinal pelvic index and compact index, goats in the study area could be classified as medium (intermediary) meat type animals.

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Conflict of interest

Authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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