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Differentiation of the indigenous goat populations in Ethiopia based on morphometric features and zoometric indices: The primary step for conservation

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Abstract. *This study was conducted to describe the indigenous goat populations of South Gondar, Ethiopia based on morphometric traits and body indices. To this effect, morphometric measurements were taken from 512 goats (153 male and 359 female) of both sexes drawn from three districts (Farta, Fogera and Libokemkem). Twenty structural indices were computed from morphometric measurements. Results indicated that age at first kidding and kidding intervals was 13.6 and 8.39 months, respectively, with an average litter size of 1.54 kids. Sex affected (p<0.001) all quantitative traits except ear length (EL), rump width (RW) and fore canon circumference (FCC) being higher in bucks than in does. The effect of age was significant (p<0.001) for all morphometric traits except for EL resulting in a linear increase with advancing age in both sexes. Except for EL and scrotal circumferences (SC), all quantitative traits were (p<0.01) affected by district of the goats rearing. Accordingly, Fogera goats had higher live weight (LW), heart girth (HG), height at withers (HW), body length (BL), chest width (CW), rump height (RH), rump length (RL) and teat length (TL) than those of Libokemkem. Fogera goats had also the highest LW and HG compared with those of Farta. Conversely, the Farta goats had higher RW, BL, TL, RL, CW, chest depth (CD), and paunch girth (PG) than those of Libokemkem. Libokemkem goats were inferior in most of the studied morphometric traits. Both HG and HW variables were identified as best predictors of LW in both sexes. Structural indices indicated that the goat populations could be characterized as meat phenotype with short legs being well adapted to midland altitudes. In conclusion, goats reared in the region could have a genetic potential for meat production with very good prolificacy. The Fogera goats were particularly better in most morphometric traits indicating their suitability for commercial meat production. However, further on-station research is recommended to verify their potentials as meat animals for enhanced food security in the region.*

Keywords: body indices, indigenous goat, morphometric traits, reproductive traits, South Gondar

Introduction

Ethiopia is home of about 52.5 million goats in which nearly all of them are of local breeds (CSA, 2020/2021). They are reared in a crop-livestock and agro-pastoral farming systems, and are widely distributed across different agro-ecological zones of Ethiopia (Gizaw et al., 2010; Hassen et al., 2012; Dea et al., 2019). Goat meat production in Ethiopia had increased by 2% between 2005 and 2012 and expected to further increase in the upcoming years due to increased domestic and export demand for goat meat (Getachew and Fadiga, 2014). Moreover, in areas where there is a financial and physical limitation for resources to keep large ruminants, goat milk production is valued the most. Recent studies conducted by Wodajo et al. (2020) indicated that the respective 78% and 64% of women and men in Ethiopia related the importance of rearing goats with food security as compared with other livestock species.

The characterization of local animal genetic resources (based on morphological traits) plays a very fundamental role in classification of animals based on their size and shape (Melesse et al., 2013). It presents the primary step to be undertaken for the sustainable utilization of the available animal genetic resources through conservation. Data obtained from such studies could also provide valuable information on the suitability of animals for selection (Mwacharo et al., 2006). Moreover, structural and functional indices could be calculated from quantitative data that are obtained from any morphological characterization study. These indices are the combinations of several linear measurements that could offer estimation of an animal's structural conformation and functional trends as compared to individual measurements alone (Salako, 2006; Chacón et al., 2011).

Characterization studies conducted by various scholars have reported the existence of phenotypic variations among Ethiopian goat populations between and within these goat ecotypes (Hassen et al., 2012; Gatew et al., 2015; Dea et al., 2019). However, there are limited characterization studies conducted to describe the genetic potentials of indigenous goat populations found in Amhara Regional State in general and those of South Gondar zone in particular. For example, Hassen et al. (2012) conducted a morphological characterization study on indigenous goats in the representative zones of Amhara Region. Although South Gondar zone was one of them, the respective

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potential districts for goat production were not adequately represented in the study. In addition, reports dealing with structural and functional indices of goat populations in Ethiopia are generally scanty except the works reported by Chiemela et al. (2016) and Dea et al. (2019) for goats reared in specific locations with very few sample size. To the authors' knowledge, there is no information in the literature reporting on the structural indices of local goat populations in south Gondar. As a result, the potential of local goats as meat, dairy and dual-purpose phenotypes has never been reported using structural indices. Therefore, the aim of this study was to systematically characterize the indigenous goat populations of South Gondar region, Ethiopia based on morphometric traits and structural indices.

Material and methods

Sampling procedure

First, the relevant second hand information was collected from Agriculture and Rural Development office of South Gondar zone, Ethiopia. Based on the obtained information, multi-stage purposive sampling techniques were applied to select the study districts, kebeles (the smallest administrative units within a district), and individual households. In the first stage, three districts namely Farta, Fogera and Libokemkem were selected purposively according to their goat production potential. The number of goats reared in the Farta, Fogera and Libokemkem districts were 45,634, 41,326 and 61,770, respectively. In the second stage, based on the distribution of the goat population, three kebeles from each district were selected purposively. In the third stage, the households within kebeles were selected which possess at least five matured goats of both sexes and have long enough experiences in rearing goats.

The number of goats tested, by region of rearing, sex and age are presented in Table 1. For morphological characterization, a total of 512 goats (153 males and 359 females) were sampled. The owner's recall method along with dentition classes (pairs of permanent incisor, PPI) was used to estimate the ages of the goats. Consequently, goats with 1PPI, 2PPI, 3PPI and 4PPI were classified in the age groups of yearling, 2-year-old, 3-year-old and 4-year-old, respectively (Ebert and Solaiman, 2010). Each animal was further identified by its sex and sampling site.

Table 1. Number of goats tested, by region, sex and age

Age of the goats	Districts					
	Farta		Fogera		Libokemkem	
	Males, N=50	Females, N=102	Males, N=52	Females, N=104	Males, N=51	Females, N=153
1-2-year-old	18	26	20	26	20	40
2-3-year-old	15	21	14	25	14	38
3-4-year-old	11	22	10	27	11	37
4-year-old and above	6	33	8	26	6	38
Total	50	102	52	104	51	153

Data collection procedures

Morphometric traits: Data on 14 morphometric traits were collected according to the descriptor list of FAO (2012) for phenotypic characterizations of goats. Accordingly, the following traits were measured: live weight (LW), body length (BL), height at withers (HW), heart girth (HG), chest depth (CD), chest width (CW), paunch girth (PG) or abdominal circumference, rump height (RH), rump length (RL), rump width (RW), ear length (EL), fore cannon circumference (FCC), teat length (TL) and scrotal circumference (SC). All measurements were taken using plastic tape while LW using a suspended weighing scale with 50 kg capacity of 0.2 kg precision by placing each animal in a self-devised holding equipment. All measurements were taken early in the morning prior to feeding.

Structural and functional indices: To assess the type and function of indigenous goat populations in the study area, 20 structural and functional related indices were computed from the morphometric traits according to the methods of Chacón et al. (2011), Khargharia et al. (2015) and Barragán (2017).

Statistical analysis

Data on morphometric traits were subjected to GLM procedures of Statistical Analysis System (SAS, 2012, ver. 9.4) by fitting district, sex and age as fixed effects while structural indices were analyzed by fitting district and sex as main effects. When F-test declared significant, means were separated by Duncan multiple range test. Correlations of morphometric traits were computed for each sex separately using Pearson correlation coefficient. Moreover, stepwise regression procedure of SAS was used to regress LW on morphometric traits to determine the best-fitted regression equation for LW prediction in both sexes.

Results

Reproductive traits

According to the respondents, the overall mean age at first mating for males was 7.76 months (Table 2). The overall mean age at first kidding was 13.6 months. There were significant differences ($p<0.05$) among districts in kidding interval of does in which Libokemkem goats had the shortest than those of Fogera. The reproductive lifespan of Libokemkem does was ($p<0.05$) higher than that of Farta and Fogera. However, the longest lifespan was observed in Farta bucks and differed ($p<0.05$) from that of Libokemkem.

Table 2. Average maturity ages (in month) and reproductive lifespan (in year) of goats reared in three districts

Parameters	Farta	Fogera	Libokemkem	Overall mean	SEM
Age at first mating of bucks	7.88	7.80	7.59	7.76	0.11
Age at first kidding	13.8	13.7	13.5	13.6	0.12
Kidding intervals	8.39^{ab}	8.51^{b}	8.27^{a}	8.39	0.07
Litter size	1.47	1.49	1.65	1.54	0.08
Average reproductive lifespan of does	7.63^{a}	7.76^{a}	8.16^{b}	7.85	0.11
Average reproductive lifespan of bucks	5.65^{a}	6.00^{ab}	6.35^{b}	6.00	0.13

^{a,b} Row means with different superscript letters are significant at p<0.05; SEM = standard error of the mean.

Morphometric traits

As presented in Table 3, district had significant effect on all morphometric traits except EL and SC. Accordingly, Fogera goats had higher (p<0.05) LW, BL, HG, HW, CW, HR, RL and TL than those of Libokemkem. The values for BL, CD, CW, PG, RL, RW and TL for Farta goats were larger (p<0.05) than those of Libokemkem. Fogera goats had the highest LW and HG as compared to those of Farta and Libokemkem, while the Farta goats had the highest CD, PG and RW. The FCC in Farta and Libokemkem goats was higher (p<0.05) than that of Fogera. The effect of sex was significant (p<0.001) for all morphometric traits except RW, FCC and EL being higher in males than in females. Age had also significant (p<0.001) effect on all linear body measurement traits except for EL. Accordingly, most mophometrical traits increased (p<0.05) with age of both sex groups. The overall coefficient of variation (CV) ranged from 1.27% in HW to 11.8% in FCC. Relatively higher CV was also observed in RW, EL and TL.

Table 3. Effect of sex, age and district on live weight (kg) and morphometric traits (cm) in indigenous goat populations

Traits	Overall	CV,	District				Sex			Age				
	mean	%	Farta	Fogera	Libok	Pr>F	M	F	Pr>F	1PPI	2PPI	3PPI	4PPI	Pr>F
LW	28.6	3.83	28.6^{b}	29.0^{a}	28.4^{b}	<0.001	30.0	28.0	<0.001	25.1^{d}	27.4^{c}	30.5^{b}	32.5^{a}	<0.001
BL	60.4	2.14	60.7^{a}	60.6^{a}	59.9^{b}	<0.001	61.2	60.0	<0.001	57.3^{d}	59.2^{c}	61.8^{b}	64.1^{a}	<0.001
HW	68.0	1.27	68.0^{ab}	68.1^{a}	67.9^{b}	0.033	68.8	67.6	<0.001	65.2^{d}	67.1^{c}	69.4^{b}	71.1^{a}	<0.001
HG	71.5	1.52	71.3^{c}	71.9^{a}	71.5^{b}	<0.001	72.5	71.1	<0.001	68.9^{d}	70.8^{c}	73.0^{b}	74.3^{a}	<0.001
CD	30.1	3.04	30.5^{a}	30.2^{b}	29.8^{c}	<0.001	30.8	29.8	<0.001	27.5^{d}	29.3^{c}	31.5^{b}	33.0^{a}	<0.001
CW	15.7	4.80	15.8^{a}	15.8^{a}	15.5^{b}	0.001	16.3	15.4	<0.001	14.1^{d}	15.5^{c}	16.4^{b}	17.2^{a}	<0.001
PG	75.7	2.60	76.4^{a}	75.9^{b}	74.9^{c}	<0.001	77.4	74.9	<0.001	71.9^{d}	74.2^{c}	78.1^{b}	79.6^{a}	<0.001
HR	70.7	1.56	70.7^{ab}	70.9^{a}	70.5^{b}	0.004	71.3	70.5	<0.001	68.0^{d}	70.0^{c}	72.2^{b}	73.4^{a}	<0.001
RL	16.0	4.94	16.1^{a}	16.0^{a}	15.8^{b}	0.001	15.7	16.1	<0.001	15.0^{d}	15.7^{c}	16.4^{b}	17.2^{a}	<0.001
RW	13.0	9.58	13.5^{a}	12.8^{b}	13.0^{b}	<0.001	13.1	13.0	0.939	11.2^{c}	13.3^{b}	14.0^{a}	14.2^{a}	<0.001
FCC	7.88	11.8	8.00^{a}	7.69^{b}	7.94^{a}	0.007	7.88	7.88	0.900	7.20^{d}	7.69^{c}	8.11^{b}	8.72^{a}	<0.001
EL	14.6	7.26	14.7	14.6	14.5	0.220	14.7	14.5	0.080	14.5	14.6	14.6	14.6	0.670
SC	22.9	4.42	22.8	23.0	22.7	0.310	-	-	-	21.9^{c}	23.1^{b}	23.7^{a}	23.9^{a}	<0.001
TL	3.70	6.93	3.74^{a}	3.73^{a}	3.65^{b}	0.007	-	-	-	3.03^{d}	3.49^{c}	4.02^{b}	4.23^{a}	<0.001

$^{a-d}$Row means with different superscript letters within the same class are significant at p<0.05; Libok= Libokemkem, M= male, F= Female, LW= live weight, BL= body length, HW= height at withers, HG= heart girth, CD= chest depth, CW= chest width, PG= paunch girth, HR= height at rump, RL= rump length, RW= rump width, FCC= fore canon circumference, EL= ear length, SC= scrotal circumference, TL = teat length.

Phenotypic correlations among the morphometric traits

Phenotypic correlations between traits are shown in Table 4 for males and females separately. Regarding females, all morphological traits showed significant correlations; however, the EL (similar as in males) showed a different behavior being insignificant with other traits. In both male and female goats, LW was strongly and positively correlated (p<0.001) with all morphometric traits except EL. In female goats, the magnitude of the correlation of LW with HG, BL and HW was exceptionally high ranging from 0.93 to 0.96. Similarly, in male goats, the degree of association of LW was the body index highest with HG (0.95), HW (0.94) and BL (0.91). Moreover, positive and strong associations were observed in female goats between BL and HW, CD and HR whereas in male goats, it was among PG, HW, HG and CD traits all being highly significant (p<0.001). Height at withers was also positively correlated with HG, HR and CW while in males it was associated with HG, HR and CD (p<0.001). Although insignificant, EL of female goats was negatively correlated with FCC and RL whilst in males it correlated negatively with CW, HR, RL, RW and SC. A positive correlations of SC with RL (p<0.05) and RW as well as PG (p<0.01) was also observed. An interesting positive and strong correlation of TL was further observed with LW, HW, CD and HR amid similar values ranging from 0.80 to 0.82.

Table 4. Phenotypic correlations among morphometric traits in males (above the diagonal line, N=153) and in females (below the diagonal line, N=359)

	LW	BL	PG	EL	HW	HG	CD	CW	FCC	HR	RL	RW	SC
LW	1	**0.91*** **	0.78	0.06^{ns}	**0.94*** **	**0.95*** **	**0.87*** **	**0.81*** **	0.42***	**0.83*** **	0.55***	0.62***	0.54***
BL	**0.94*** **	1	**0.81*** **	0.07^{ns}	**0.86*** **	**0.81*** **	**0.83*** **	0.78***	0.41***	0.77***	0.51***	0.58***	0.53***
PG	**0.80*** **	0.79***	1	-0.05^{ns}	0.76***	0.73***	0.78***	0.72***	0.29**	0.73***	0.48***	0.54***	0.42**
EL	0.05^{ns}	0.07^{ns}	0.02^{ns}	1	0.03^{ns}	0.05^{ns}	0.01^{ns}	-0.01^{ns}	0.02^{ns}	-0.01^{ns}	-0.04^{ns}	-0.01^{ns}	-0.02^{ns}
HW	**0.93** **	**0.89*** **	**0.81*** **	0.03^{ns}	1	**0.90*** **	**0.85*** **	**0.83*** **	0.43***	**0.88*** **	0.55***	0.67***	0.54***
HG	**0.96*** **	0.84***	0.76***	0.02^{ns}	**0.89*** **	1	**0.82*** **	0.77***	0.37***	**0.81*** **	0.49***	0.59***	0.51***
CD	**0.87*** **	**0.86*** **	**0.84*** **	0.03^{ns}	**0.86*** **	**0.82*** **	1	**0.82*** **	0.42***	**0.80*** **	0.56***	0.63***	0.55***
CW	**0.80*** **	0.76***	0.72***	0.10^{ns}	**0.80*** **	0.77***	0.79***	1	0.48***	**0.80*** **	0.57***	0.62***	0.53***
FCC	0.52***	0.50***	0.47***	-0.01^{ns}	0.51***	0.50***	0.52***	0.46***	1	0.38***	0.28**	0.32**	0.19^{ns}
HR	0.**86*** **	**0.83*** **	0.79***	0.03^{ns}	**0.93*** **	0.82***	**0.84*** **	0.78***	0.48***	1	0.47***	0.65***	0.49***
RL	0.71***	0.69***	0.58***	-0.01^{ns}	0.71***	0.65***	0.68***	0.60***	0.43***	0.67***	1	0.56***	0.29*
RW	0.56***	0.52***	0.57***	0.04^{ns}	0.56***	0.57***	0.61***	0.57***	0.39***	0.55***	0.40***	1	0.42**
TL	**0.82*** **	0.79***	0.62***	0.01^{ns}	**0.82**	0.77***	**0.80*** **	0.76***	0.20^{ns}	**0.81*** **	0.64***	0.57***	-

Correlations higher than or equal to 0.80 are in bold (p<0.001); *** = p<0.001; ** = p<0.01; * = p<0.05; ns = not significant; LW= live weight, BL= body length, HW= height at withers, HG= heart girth, CD= chest depth, CW= chest width, PG= paunch girth, HR= height at rump, RL= rump length, RW= rump width, FCC= fore canon circumference, EL= ear length, SC= scrotal circumference, TL= teat length.

Prediction of live weight from morphometric traits

Multiple linear regression models that are developed for predicting the LW of goats from morphometric traits are presented in Table 5. Stepwise multiple regressions were used to predict LW from morphometric traits, which had a significant positive correlation with this variable. In the current study, the regression analysis indicated that either HG or HW could accurately estimate LW of female and male goats when weighing scales are not available or affordable to smallholder farmers with limited income. As presented in Figures 1 and 2, the pattern of LW prediction by fitting both HG and HW variables in the regression model has been plotted accurately as indicated by high r-square values. This indicates that both morphometric traits explain about 99% of the variation in the LW of indigenous goats reared in the study districts with almost all observations being distributed within the 95% prediction limits.

Table 5. Regression equations to estimate live weight of female and male goats

Females			Males		
Model	R^2	Adj. R^2	Model	R^2	Adj. R^2
Y = - 65.7 + 1.319*HG	99.7	99.7	Y = -74.5 + 1.44*HG	98.7	98.6
Y = - 56.4 + 1.25*HW	99.1	98.9	Y = - 63.4 + 1.356*HW	98.8	98.7

*Y= live weight; HG= heart girth; HW= height at withers

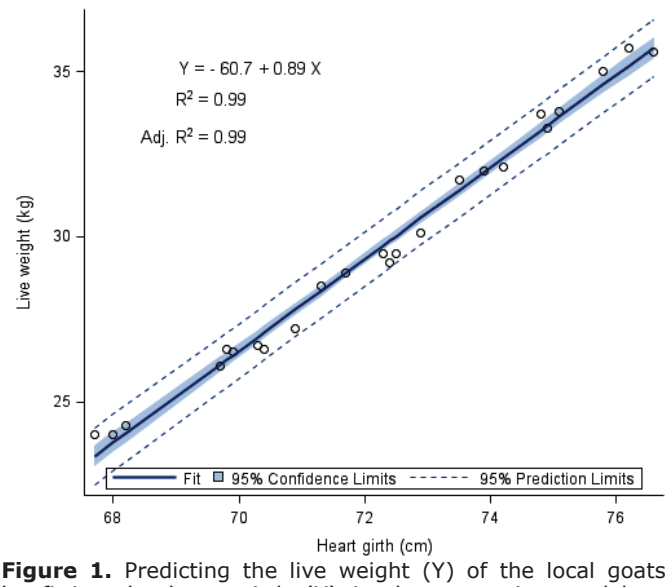

Figure 1. Predicting the live weight (Y) of the local goats by fitting the heart girth (X) in the regression model as explanatory variable (using pooled data)

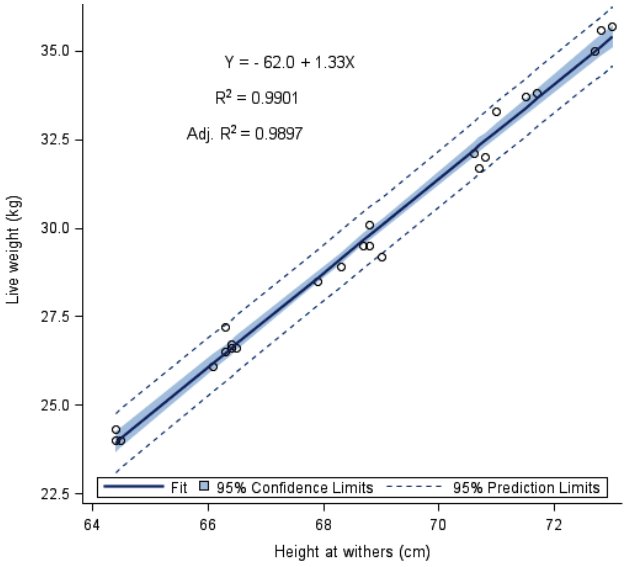

Figure 2. Predicting the live weight (Y) of the local goats by fitting the height at withers (X) in the regression model as explanatory variable (using pooled data)

Structural and functional indices

As shown in Table 6, district had significant effect only on longitudinal pelvic index (LPI), girth index (GI), dactyl costal index (DCI) and balance index (BaI). Accordingly, Farta goats had higher LPI and GI values than those of Libokemkem. Moreover, DCI and BI values were larger in Farta goats than that of Fogera. The effect of sex was significant for DCI, BaI, height slope index (HSI), LPI, body ratio index (BRI), conformation index (ConI), GI and compact index (CI). Female goats had larger ($p<0.05$) BaI, DCI, HSI and LPI values than males, whereas males were better in BR, ConI, GI and CI indices than females.

Body (BI), Body frame (BFI), proportionality (PrI), pelvic (PI), transversal pelvic (TPI), relative depth of thorax (RDI), dactyl thorax (DTI), thorax development (TDI), pictorial (PtI), area (AI), width slope (WSI) and relative cannon thickness (CTI) indices were similar across districts and sex groups. Although not significant, Fogera goats had relatively lower PI than other goat populations. Similarly, bucks had higher PI and AI values than females. The thorax development index (TDI) was similar among Fogera and Libokemkem goats while it was the lowest in Farta goat populations.

Table 6. Structural and functional indices of goat populations as affected by district and sex

Structural/functional indices	District			Sex		Overall
	Farta	Fogera	Libok	Male	Female	mean
Body index (BI)	85.3	84.4	84.2	84.9	84.4	84.6
Body frame index (BFI)	0.893	0.893	0.886	0.894	0.887	0.890
Compact index (CI)	4.27	4.34	4.28	4.47^{a}	4.13^{b}	4.30
Proportional index (PrI)	89.4	89.0	88.6	89.3	88.8	89.0
Pelvic index (PI)	84.3	80.1	83.6	84.4	80.9	82.7
Transverse pelvic index (TPI)	20.1	18.7	19.2	19.4	19.3	19.3
Longitudinal pelvic index (LPI)	22.9^{a}	22.5^{ab}	22.1^{b}	22.2^{b}	22.8^{a}	22.5
Relative depth of thorax index (RDI)	44.9	44.7	44.3	45.2	44.0	44.6
Thorax development index (TDI)	1.048	1.055	1.053	1.053	1.051	1.052
Dactyl thoracic index (DTI)	11.2	10.7	11.	11.0	11.1	11.0
Dactyl costal index (DCI)	49.8^{a}	48.2^{b}	50.7^{a}	48.1^{b}	51.0^{a}	49.6
Body ratio index (BRI)	0.963	0.961	0.965	0.968^{a}	0.958^{b}	0.963
Conformation/baron index (ConI)	75.3	76.5	76.0	77.2^{a}	77.7^{b}	75.9
Area index (AI)	4213	4216	4188	4358	4054	4206
Relative cannon thickness index (CTI)	11.8	11.3	11.9	11.6	11.6	11.6
Balance index (BaI)	0.450^{a}	0.419^{b}	0.429^{ab}	0.410^{b}	0.457^{a}	0.433
Pictorial index (PtI)	1.853	1.846	1.833	1.859	1.828	1.844
Width slop index (WSI)	0.193	0.178	0.183	0.186	0.183	0.184
Girth index (GI)	1.074^{a}	1.060^{ab}	1.054^{b}	1.071^{a}	1.054^{b}	1.063
Height slope index (HSI)	2.63	2.64	2.63	2.35^{b}	2.92^{a}	2.63

$^{a-d}$Means with different superscript letters across the column within a group are significant; Libok = Libokemkem.

Discussion

Reproductive traits

The overall mean age at first kidding in the current study was 13.6 months, which is slightly higher than that of Chanie et al. (2014) who reported 12.2 months of age for local goats. According to reports of Abegaze (2014), age at first kidding for does reared in north-western lowland of Ethiopia were 12.4 months which was lower than observed in the current study. Gatew et al. (2015) reported an extended age of first kidding ranging from 15.9 to 20.2 months for local goats. The possible reasons for such differences among local goats might be due to variations in ecotype, production systems, incidence of diseases and availability of feed resources.

Kidding interval is one of the important reproductive traits that influence the general performance of farm animals. The average kidding interval in the current study is in line with that of local goats reported by Muluneh et al. (2016). Sheriff et al. (2019) established a kidding interval of 7.2 to 7.8 months for goats in north-west Ethiopia, which is slightly lower than observed in the present study.

The reproductive life spans of male and female goats in the study area were 6.35 and 8.2 years, respectively, which indicate that goats stayed in reproduction for an extended period providing services to their owners. This finding is slightly lower than reported by Sheriff et al. (2019) for Arab and Oromo goats in north-west Ethiopia. The overall average litter size in the current study was 1.54, which may suggest the practice of selecting female goats for improved litter size. The finding is higher than that of Asefa et al. (2015) who reported a litter size of 1.33 in Eastern Ethiopia.

Morphometric traits

Fogera goats had the highest LW and HG values as compared to those of Farta and Libokemkem. However, Farta goats were superior to those Fogera and Libokemkem in CD, PG and RW while the Libokemkem goats were inferior to those of Farta and Fogera goats in most of the morphometric traits. Such variation in quantitative traits might be due to difference in the management practices among the communities and availability of feed and water resources. Moreover, such

differences might be explained by the existence of disparity in the genetic makeup of these ecotypes particularly between the Libokemkem and the other two goat populations. This calls for molecular based study to provide proof of existence of dissimilarity among the studied goat populations.

Male goats were found to be heavier than the females, which is in good agreement with that of Seid et al. (2016) and Dea et al. (2019) who reported similar findings in goats reared in Western highland (Wollega zone) and Southern lowland (Gamo zone) parts of the country, respectively. In contrary, Jeda and Asefa (2016) established that female goats raised in Eastern Ethiopia had higher LW than those of bucks. These inconsistencies might be attributed to age differences of both sexes in which the data were collected. Moreover, such conflicting results might be because of negative selection practised by the farmers as fast growing male kids are being sold at earlier age. The LW of male and female goats increased as dentition class increased from 1PPI to age group 4PPI. Such changes are explained by the skeletal muscle development as the age of the animal advances. Moreover, a steady increase in live weight with age indicates the absence of critical feed shortage in the study region.

Ear length of lowland Gamo goats as reported by Dea et al. (2019) was lower than observed in the present study (12.7 vs. 14.6 cm). However, the EL reported for midland Gamo goats by the same authors were similar to that of the present study (14.3 vs. 14.6 cm). Goat's ear length is crucial in adaptation to various climatic environments. Correlation of EL with other traits showed a different behavior being insignificant in both sexes. Moreover, EL was not affected by age in both sexes. These observations may suggest that the EL development is less dependent on the size of the animal.

The SC is an important trait that is closely associated with the testicular growth and sperm production capacity of domestic animals. Gatew et al. (2015) found relatively higher SC values for bucks in eastern Ethiopia than observed in the current study (27 vs. 23 cm). Since SC size is dependent on the maturity of the animal, the differences could be related to the age of bucks when data were collected. This has been supported by the present observation in which SC consistently increased with advancing age. Moreover, SC showed a significant positive correlation with the body weight (Table 4), which substantiated the dependency of SC on the body development of the animal. Consistent with the current results, Raji and Ajala (2015) observed a significant effect of body weight on SC for West African Dwarf buck. As SC is an indirect measurement of testicular size, knowing the increased size of testis may be used as an indicator in the onset of active spermatogenesis and, hence, the possibility of using bucks for breeding at an earlier age than normally recommended. Such knowledge might be particularly essential if young bucks are not kept together with the does for reasons related to control of inbreeding.

Live weight was positively and strongly correlated with some of the morphometric traits particularly with HG, HW and BL in both sexes (Table 4). Thus, LW can be predicted based on physical measurements taken from either of the traits by fitting to the regression model. Moreover, other morphometric traits were found to be positively and significantly correlated with each other, which suggests that selection for one of the traits will result in the improvement of the other traits particularly those that might be more difficult or expensive to measure in field conditions under smallholder production system. The stronger the correlation, the higher the response to selection in breeding goal trait which is evident in the present study. Thus, selection for correlated traits as observed in the present study might be a suitable genetic improvement strategy in local goats provided the heritability of such traits under selection is reasonably high.

Teat length positively affected milk production capacity of does (El-Gendy et al., 2014). Merkhan and Alkass (2011) reported 3.6 cm TL for Iraqi Black and Meriz goats, which is comparable with the current observations (3.7 cm). However, Alemayehu et al. (2015) reported lower TL (3.4 cm) for goats reared in West Amhara region of Ethiopia. The type of breed, feed availability, season, and health conditions of animals might explain such differences. Teat length significantly increased with the age of the does. Although not significant, similar patterns were observed by Merkhan and Alkass (2011) for the Iraqi goats. Since TL is highly and positively correlated with LW, HR, HW and CD (Table 4), then selection of female goats based on this trait will result in a better milk production provided the breeding goal is to enhance milk production.

Structural 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). Based on the results of BI, goats in south Gondar could be classified as brevigline. The thorax development index (TDI) was slightly above 1.0 indicating a smaller thoracic capacity, which suggests that south Gondar goats are inherently adapted to mid altitude rather than to higher elevations.

The Pelvic index (PI) serves as a racial diagnostic index and is used to determine the proportionality of the hindquarters and thus, related to the reproductive capacity of female goats (Cerqueira et al., 2011). According to the current result (PI=82.7), the goats' rump is described as a convex curve, with a predominance of the rump length over the width. Chacón et al. (2011) reported lower PI (76.0) for Cuban Creole goats while Dea et al. (2019) found much higher values for lowland Gamo goats than observed in the current findings. Such variations might be due to differences in breed and environment effect as well as age and sex of goats when the morphometric measurements were taken.

Proportionality index (PrI) relates the body height to the body length and designates the shape of a given animal population (Barragán, 2017). A PrI value less than 100 indicates that the animal's body tends to be rectangular which is a characteristic of meat phenotype, while greater than 100 denotes a square shape, which is an attribute of dairy phenotype (Barragán, 2017). In the current study, the lower PrI (89.0) would classify the south Gondar goat populations as meat type. The DTI helps to classify animals as hypermetric (large format), eumetric

(medium format), or elipometric (small format). According to the current DTI result (11.0), the goats in the study region could be classified as eumetric possessing characteristics of medium meat type. The compact index (CI), longitudinal pelvic index (LPI) and relative cannon thickness index (CTI) values further substantiated that goats in the study region are suitable for meat production. Nevertheless, the south Gondar goat populations showed low aptitude for meat production when assessed by relative depth of thorax index (RDI) and transverse pelvic index (TPI) that serve to estimate the meat aptitude of a given breed (Arredondo-Ruiz et al., 2012; Barragán, 2017). The CI of bucks in the current study is significantly higher than that of females suggesting the former being more suitable for meat production than the latter.

The relative depth of thorax index (RDI) indicates that south Gondar goats are characterized by relatively short leg that is close to the ground, which may suggest to their adaptation to flat land and mountain terrains. In the present study, the PtI values are similar across districts and sex groups indicating that they possess comparable adaptations with short legs as already confirmed by RDI values. The body frame index (BFI) in the current study was 0.89 which indicates that the goats in the study area possess longer body frame with respect to their wither height suggesting that goats in the study area may possess good space for the development of internal organs and carcass yield.

The body ratio index (BRI) in the present study is less than 1.0, which suggests that south Gondar goats are lower at wither than they are at the rump. This has been clearly demonstrated in female goats in which they had significantly lower BRI value than the bucks. The height slope index (HSI) has further validated this observation where the value is positive in both sexes being significantly lower in males than in females.

Conclusion

Goats in south Gondar region of Ethiopia demonstrated impressive prolific aptitude by producing above average litter size. Fogera goats had the largest body weight and heart girth values than those of the other two districts. Libokemkem goats were inferior in most of the studied quantitative traits. Male goats were superior in all traits than females except for rump width, canon circumference and ear length. Either heart girth or height at wither can be used as a reliable predictor of body weight in male and female goats in the absence of weighing scales. The structural and functional indices indicated that the goat populations in south Gondar are characterized as meat type with short legs. Further studies are recommended to validate their meat production and prolific potentials under a controlled environment.

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Conflict of interest

The authors declare that they have no conflict of interest.

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