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Research Article

Phenotypic characterization of the Gamo highland sheep population in Gamo Zone, South Ethiopia

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Abstract: *The study aimed to identify physical characteristics and prediction of live weight using linear body measurements of indigenous sheep types in two highland districts of the Gamo zone (Chencha and Qogota). Districts were purposively selected whereas farmers and animals were randomly selected. About 335 mature sheep (270 female and 65 male) were sampled for the body measurements. Both qualitative and quantitative data were analysed using SPSS version (20). Overall, the current findings revealed that mixed (62.50%) followed by black (21.90%) were the dominant coat colours with patchy coat colour patterns (56.30%). The majority of the sheep were horned (62.5%), curved horn (67.50%) and obliquely backward horn types (77.50%). Horizontal ear orientation (76.00%) and straight head profile (96.90) were predominantly observed. In general, about 71.60% of the sheep were hairy type and had straight crimp-curled hair (73.60%). The total hair coverage on the head, face, belly and leg was about 3.0%, 94%, 92.5% and 13.4%, respectively. About 55.20% of the study sheep revealed near hocks tail length. The mean body weight, body length, height at wither, chest girth, horn length, head length, hair length, ear length and tail length were 20.26±3.60 kg, 54.55±3.48, 55.13±3.83, 66.73±4.79, 9.42±7.46, 16.83±1.85, 7.41±3.12, 10.27±0.97 and 26.62±2.66 cm, respectively. In general, sex, district and age (dentition) significantly (P<0.05) affected linear body measurements. Body weight and most of the linear body measurements were positively correlated. Chest girth was the single best predictor of body weight (P<0.05). Molecular characterization of Gamo highland sheep is recommended for further advanced breeding strategies.*

Keywords: *Body weight, Chest girth, Highland sheep; Linear body measurement, Phenotypic traits*

1. Introduction

The total sheep population in Ethiopia is estimated to be about 42.9 million of this, and about 99.52% are indigenous (CSA, 2021). The majority of the sheep are found in the north western highlands of the country (Solomon *et al.,* 2008; Assen and Aklilu, 2012). Morphological and molecular characterizations of sheep breeds in the country are traditionally recognized by ethnic or geographic nomenclatures. In Ethiopia, only a few breeds have a fair description of their physical appearance (Fsahatsion *et al.,* 2018). Based on this, the sheep breeds have been classified into 14 traditional populations in 9 breeds within 6 major breed groups (Solomon, 2008).

Identification and characterization of the existing livestock genetic resources, their production environment and constraints are crucial for long-term genetic improvement, to diagnose the status and trends of the system and conservation (Getahun et al., 2008; Zewdu *et al.,* 2009; Aamir *et al.,* 2010; Sowande *et al*., 2010; Ibrahim and Isa, 2011; Asefa *et al*., 2017). The classical description of breeds is based upon phenotype because an organism's phenotype is principally a manifestation of its genotype, and it lends itself to direct measurement of the organism. As such, phenotypic characterisation is therefore complementary techniques for measuring genetic diversity (Fsahatsion *et al*., 2018).The productivity of sheep as in the case of most ruminants is markedly low due to several genetic and environmental factors (Markos, 2006).

Information on the phenotypic traits of the Gamo highland sheep population is limited despite its contribution and role as a source of cash income and improving food security in the highlands of the Gamo zone. For a more detailed characterization study of Gamo highland sheep; updating phenotypic appearances by routine inventories and on-going monitoring are vital since genetic resources and production systems are not static. Hence, this study attempted to physically characterize indigenous sheep types in the Gamo zone, south region, Ethiopia.

2. Materials and Methods

2.1. Description of the study area

The study was conducted in two districts (Chencha and Qogota) of Gamo zone Highlands of south Ethiopia. Gamo zone is bordered on the south by Dirashe special woreda, on the southwest by Debub Omo zone, on the northwest by the Konta zone, and on the north by Dawuro and Wolayta zones, on the northeast by Lake Abaya and on the southwest by the Amaro special woreda.

Chencha woreda is located in the Gamo zone of the Southern region, 37 kilometers north of Arba Minch. Part of the Gamo Zone, Chencha is bordered on the south by Arba Minch Zuria, on the west by Dita & Gofa on the north by Kucha and Boreda, and on the east by Mirab Abaya. Chencha has a longitude and latitude of 6°15′N and 37°34′E, respectively and an elevation of 2732 meters above sea level.

Qogota is one of the recently established woreda. It is bordered on the south by Chencha, on the west by Kucha, on the north by Boreda and on the east by Mirab-Abaya woredas. Qogota woreda has an altitude of 2569 meter above sea level with 6°17′26''N and 37°32′46''E.

Gamo highland areas are characterized by a mixed farming system. The major crop types produced include inset, barley, wheat, bean, pea and potatoes (Dereje, 2020).

2.2. Sources of animals

Indigenous sheep type found in the study districts of Gamo zone was used as experimental animals. Since it is on farm characterization, animals in the hands of farmers were used and data regarding body measurement and morphometric characteristics were collected early in the morning before the animal was released for grazing.

2.3. Sample size and sampling techniques

The study districts were selected purposively based on their highland agro-ecology and sheep population potential whereas smallholder farmers were selected randomly. For morphological characters (qualitative) and body measurements (quantitative) about 335 sheep (270 female and 65 male) from 70 households were selected based on sex and age of animals. Pregnant females (ewes) were excluded from the sampling because pregnancy has an influence on body parameters. Each experimental animal was identified by sex, site and estimated age group. All age groups of the sheep were classified into five age groups using the number Pairs of the Permanent Incisors (PPI): (0PPI, 1PPI, 2PPI, 3PPI and 4PPI) as indicated in Table 1 (ESGPIP, 2009).

Sheep sample size was determined based on the formula [1] described by Mezgebu *et al.* (2022).

$$n = \frac{N}{1+N(e)2} \quad [1]$$

Where;

- n = required sample size
- N = population size
- e = error margin (e = 0.07)

Table 1: Description of dentition with corresponding sheep age estimates

S/No.	Description	Estimated age	Source
1	The milk teeth have started to wear down, or are fully spread out	12 months	ESGPIP, 2009
2	With erupted and growing 1st pair of permanent teeth	14–17 month	
3	With erupted and growing 2nd pair of permanent teeth	18–23 month	
4	With erupted and growing 3rd pair of permanent teeth	24–36 month	
5	With erupted and growing 4th pair of permanent teeth	3–5 years	

2.4. Data collection

Data was recorded on the prepared format adopted from the standard description list developed by FAO (2012). All the data were taken early in the morning since body measurements are influenced by the posture, motion, and gut content of the animals.

Morphological characters like coat colour type and pattern, horn type, horn shape, horn orientation, ear orientation, head profile, wattle, beard, ruff and hair type were studied with naked eye observation.

Body weight in kg, chest girth, body length, height at wither, horn length, head length, hair length, ear length, tail length and crimp curl were measured using tailors measuring tape with records taken to the nearest centimetre after restraining and holding the animal in an unforced position (Figure 1). Weight was measured in the morning before their release for feeding to minimize post-prandial gut variation and measured using a suspended spring balance having 50 kg capacity with 0.2 g precision.

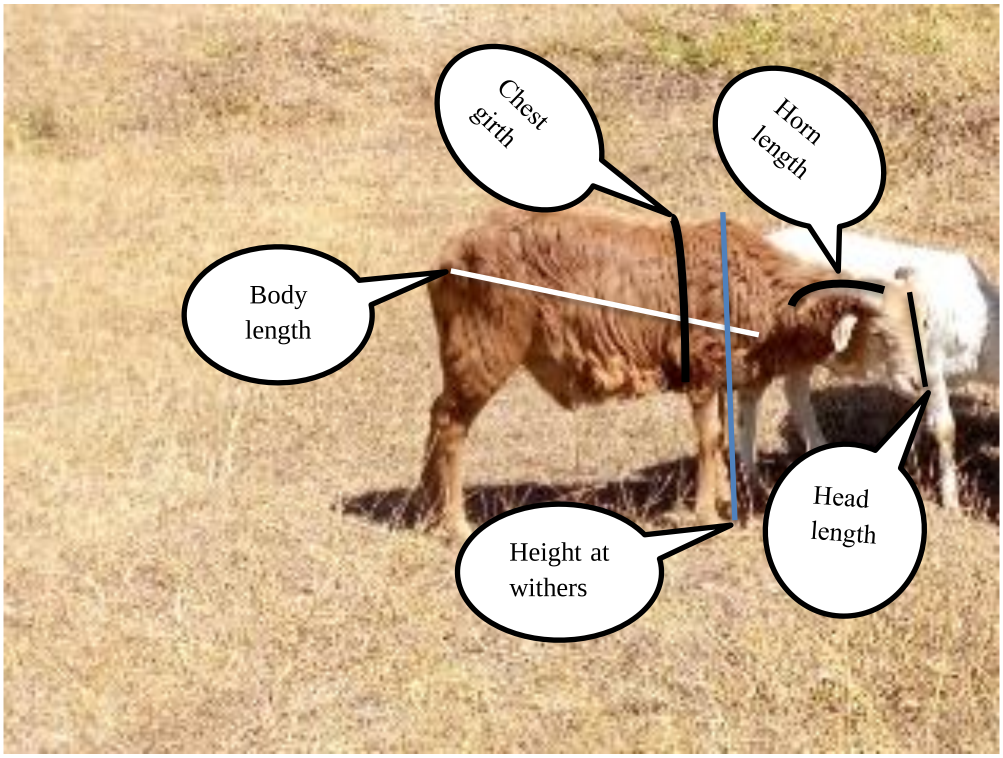

Figure 1: Body parts of the sheep

Source: Picture taken during the experiment

2.5. Data management and statistical analysis

All the collected data were coded and recorded in a Microsoft Excel spreadsheet. Qualitative data from individual observation was analyzed following the frequency procedures of (SPSS version 20, 2011). The chi-square test was employed to test the assumption of equal proportion between the categorical variables. Means, standard deviations, standard errors and coefficients of variation computed for all the quantitative traits measured using the General Linear Procedure (GLM) of SPSS. Means were separated by Duncan multiple range test. For adult animals, the location, sex and age group of the experimental sheep was fitted as fixed independent variables while body weight and linear body measurements were fitted as dependent variables. The model employed for analyses of body weight and other linear body measurements is presented below in formula [2].

$$Y = \mu + A_i + S_j + D_k + e_{ijk} \quad \textbf{[2]}$$

Where:

- Y = the observed (body weight or linear body measurements) in the i^{th} age group, j^{th} sex and k^{th} districts;
- μ = Overall mean;
- A_i = the effect of i^{th} age group (I = 0PPI, 1 PPI, 2PPI, 3 PPI and 4 PPI);
- Sj = the effect of j^{th} Sex (j = male and female);
- Dk = the effect of k^{th} district (Chencha and Qogota);
- eijk = random residual error

Pearson's correlation coefficients for each trait were estimated between body weight and other body measurements. A stepwise regression procedure was also used to determine the best-fitted regression equation for the prediction of body weight from body measurements. Best-fitted models were selected based on the coefficient of determination (R^2), mean square error and simplicity of measurement under field conditions. The following models were used for the analysis of multiple linear regressions [3].

$$Y = \alpha + \beta 1X1 + \beta 2X2 + \ldots\ldots + \beta n X n + ej \quad [3]$$

Where:

- Y = the response variable (body weight)
- A = the intercept X1, X2, X3, X4, X5, X6 and Xn = the explanatory variables (CG, BL, HW, HoL, HeL, HaL, EL and TL, respectively)
- β1, β2, ..., βn = regression coefficient of the variables X (X1, X2, ...,X n)
- ej = the residual random error

3. Results and Discussion

3.1. Characterization of the physical traits of sheep

Physical body characteristics of the Gamo highland sheep population were presented in Table 2 and Figure 1. The results showed that there was a clear presence of morphological variations of the indigenous sheep types. According to the report of Solomon *et al* (2008), there is high morphological, ecological, ethnic and production systems diversity of indigenous sheep distributions in Ethiopia. The results of Yakubu *et al.* (2010) pointed out that phenotypes are an expression of genetic characteristics, modified by environmental conditions and that variance in both genetics and environment may affect phenotypic variance.

The predominant coat colour types in the study areas were mixed (62.50%) followed by black (21.90%) with a patchy coat colour pattern (56.30%) of which 65% were found in the Qogota district. Majority of the sheep population were horned (62.50%), curved horn shape (67.50%) and obliquely backward horn orientation (77.50%). The predominant ear form was horizontal (78.10%). They were mainly characterized by the absence of wattle (92.5%) and the absence of ruff (64.20%). They are also characterized as having hairy (71.60%), straight crimp curl (73.10%), bare head hair (97.00%), bare hair cover (86.60%), face hair cover (94.00%) and belly hair cover (92.50%). The main tail types were thin-tailed (100%), and near to hock tail length (55.50%) followed by well above hocks tail length (40.30%). Almost, similar results were found for the Bale sheep population (Wossenie *et al.*, 2012; Belete *et al.,* 2017) and Wossenie (2012) for the Hararghe Highland sheep.

Table 2: Qualitative traits of the Gamo highland sheep in two districts

Traits	Number of observations	**Chencha (%)**	**Qogota (%)**	**Total (%)**	**χ2**	**Sig.**
Coat colour	White (30)	66.67	33.33	9.40	24.280	0.000
	Brown (20)	0.00	100.00	6.30		
	Black (70)	42.86	57.14	21.90		
	Mixed (200)	35.00	65.00	62.50		
Coat colour pattern	Plain (140)	28.57	71.43	43.80	8.470	0.004
	Patchy (180)	44.44	55.56	56.30		
Horn type	Polled (120)	20.83	79.17	37.50	22.760	0.000
	Horned (200)	47.50	52.50	62.50		
Horn shape	Straight (45)	0.00	100.00	22.50	66.330	0.000
	Curved (135)	55.56	44.44	67.50		
	Spiral (20)	100.00	0.00	10.00		
Horn orientation	Lateral (45)	88.89	11.11	22.50	39.890	0.000
	Obliquely backward (155)	35.48	64.52	77.50		
Ear orientation	Carried horizontal (250)	24.00	76.00	78.10	88.870	0.000
	Semi pendulous (70)	85.71	14.29	21.90		
Head profile	Straight (310)	38.71	61.29	96.90	6.190	0.013
	Slightly convex (10)	0.00	100.00	3.10		
Wattle	Present (25)	40.00	60.00	7.50	0.001	0.975
	Absent (310)	40.32	59.68	92.50		
Ruff	Present (120)	100.00	0.00	35.80	227.003	0.000
	Absent (215)	6.98	93.02	64.20		
Wool type	Hairy (240)	16.67	83.33	71.60	196.451	0.000
	Woolly (95)	100.00	0.00	28.40		
Crimp/curl	Straight (245)	30.61	69.39	73.10	35.564	0.000
	Low crimp frequency <4/ cm (90)	66.67	33.33	26.90		
Head hair cover	Covered (10)	100.00	0.00	3.00	15.271	0.000
	Bare (325)	38.46	61.54	97.00		
Face hair cover	Bare (20)	100.00	0.00	6.00	31.511	0.000
	Covered (315)	36.51	63.49	94.00		
Belly hair cover	Covered (310)	40.32	59.68	92.50	0.001	0.975
	Bare (25)	40.00	60.00	7.50		
Leg hair cover	Covered(45)	44.44	55.56	13.40	3.697	0.157
	Bare (285)	40.35	59.65	86.60		
Tail length	Well above hocks(135)	14.81	85.19	40.30	83.323	0.000
	Near hocks(185)	62.16	37.84	55.20		
	Well below hocks(15)	0.00	100.00	4.50		

3.2. Live body weight and linear body measurements

Live body weight and linear measurements body measurements were an important growth and economic trait. It was not always possible to measure it due to mainly the lack of weighing scales, particularly in rural areas. Body measurement can also be used routinely in weight estimation and selection programmes based on its utility in determining breed evolution trends (Belete *et al*., 2017).

3.2.1. *Sex effect*

The least-square means and standard errors for the effect of sex and their interaction on body weight and other body measurements are presented in Table 3. Body weight and some other linear body measurements have shown significant differences between sexes. For traits showing significant differences, males were larger than females. The current results contradict with the sheep type in the Selale area where females have larger linear body measurements than their male counterparts (Amelmal, 2011; Aberra *et al*., 2014).

3.2.2. *Age effect*

The size and shape of the animal increases until the animal reaches maturity and the effect of age on body weight and other body measurements was also observed in sheep breeds of Ethiopia (Tesfaye, 2008). Body weight and all body measurements were significantly affected by age group as observed in Table 2. Generally, the body measurements were increased as the age increased from the age group (1PPI) to the oldest 4PPI. Similar findings were reported by Fsahatsion *et al.* (2018) who noted that body weight and body measurements increased with age of ewes for the first three years and then decreased slightly for ewes above four years (Asefa *et al*., 2017).

3.2.3. *District effect*

District had a significant effect ($P<0.05$) on body weight and all other linear body measurements except hair length and ear length. Sheep in the Chencha district were higher on the above-mentioned traits compared to that of the Qogota district. The findings are in agreement with the report of Wossenie (2012) and Asefa *et al.* (2017).

Table 3: The least-square means and standard error (LSM ± SE) of body weight (kg) and linear body measurement (cm) of the Gamo sheep population

Traits (N)	BW	BL	HW	CG	HoL	HeL	HaL	EL	TL
Total (335)	20.26±3.60	54.55±3.48	55.13±3.83	66.73±4.79	9.42±7.46	16.83±1.85	7.41±3.12	10.27±0.97	26.62±2.66
R^2	0.83	0.70	0.71	0.86	0.94	0.57	0.78	0.56	0.39
Sex	*	*	*	*	*	*	*	*	NS
Male (65)	21.15±4.45[a]	56.00±2.33[a]	58.55±4.47[a]	72.18±3.43[a]	24.43±4.13[a]	17.82±1.19[a]	9.00±1.48[a]	9.77±1.07[a]	26.18±2.11
Female (270)	20.05±3.35[b]	54.25±3.60[b]	54.42±3.28[b]	65.60±4.23[b]	6.03±1.26[b]	16.62±1.90[b]	7.08±3.27[b]	10.38±0.92[b]	26.72±2.76
Location	*	*	*	*	*	*	NS	NS	*
Chencha (135)	20.76±4.01 [a]	56.00±3.04[a]	55.46±3.18[a]	67.12±4.23[a]	10.53±7.34[a]	17.08±0.96[a]	7.29±2.41	10.54±0.65	27.79±2.41[a]
Qogota (200)	19.93±3.27[b]	53.68±3.44[b]	54.93±4.17[b]	66.50±5.12[b]	8.32±7.47[b]	16.68±2.21[b]	7.49±3.49	10.11±1.09	25.92±2.56[b]
Age	*	*	*	*	*	*	*	*	*
0PPI (70)	15.50±2.12[d]	50.36±1.18[d]	53.18±2.93[c]	61.82±2.70[c]	11.67±9.74[b]	16.27±1.07[b]	7.27±1.11[b]	9.64±1.08[ab]	25.64±2.50[ab]
1PPI (85)	20.32±2.21[c]	53.94±2.67[c]	55.41±4.22[d]	67.35±5.18[b]	11.40±9.31[b]	16.00±2.99[b]	10.82±3.21[a]	9.91±0.90[b]	27.12±2.73[b]
2PPI (50)	23.10±3.81[a]	57.40±4.32[a]	59.70±3.73[a]	70.90±4.00[a]	24.00±0.00[a]	17.60±1.13[a]	6.65±1.90[a]	11.00±0.79[b]	26.80±3.63[a]
3PPI (85)	21.82±2.37[b]	55.71±2.21[b]	55.00±1.70[b]	67.53±3.57[b]	6.73±0.76[c]	17.18±0.93[b]	5.88±2.13[c]	10.47±0.86[a]	26.18±2.25[ab]
4PPI (45)	21.44±2.03[b]	55.44±2.26[b]	52.11±1.89[c]	65.44±3.37[b]	5.78±1.48[c]	17.56±0.51[b]	4.89±1.70[c]	10.56±0.51[a]	27.56±1.60[ab]

The means with different superscripts within the same column and class are statistically different. NS = Non significant (P>0.05); *Significant (p< 0.05); 0PPI = 0 pair of permanent incisors; 1PPI = 1 pair of permanent incisors; 2PPI = 2 pair of permanent incisors; 3 PPI = 3 pairs of permanent incisors; 4PPI = 4 pair of permanent incisors; BL = Body length; BW = Body Weight; CG = Chest Girth; HW = Height Weather; HaL = Hair length; HeL = Head Length; HoL = Horn Length; EL = Ear Length; TL = Tail length

3.3. Correlation between body weight and linear body measurements

According to Younas *et al.* (2013), determining animal live body weight, linear body measurements, and their inter-relationship and correlation is imperative for determining genetic potential, breed standards, and improved breeding programs. The association between body weight and different linear measurements for the Gamo highland sheep population are presented in Table 4. The highest coefficient of correlations was obtained between BW and CG (r = 0.79), BL (r = 0.73) and HeL (r = 0.72). These implied that a better prediction of body weight could be obtained in Gamo highland sheep by using chest girth, body length and head length as independent variables. Almost similar findings were presented for the positive and strong association between BW and CH for other sheep breeds (Solomon *et al.*, 2011; Abera *et al.*, 2014; Mesfin, 2015).

Table 4: Pearson correlation coefficient between body weight and different linear measurements for Gamo highland sheep population

Traits	BW	BL	HW	CG	HoL	HeL	HaL	EL	TL
BW									
BL	0.73*								
HW	0.54*	0.40*							
CG	0.79*	0.71*	0.63*						
HoL	0.32^{NS}	0.21^{NS}	0.71*	0.64*					
HeL	0.72*	0.52*	0.39*	0.57*	0.26^{NS}				
HaL	-0.35^{NS}	-0.36^{NS}	0.19^{NS}	-0.07^{NS}	0.37*	-0.42*			
EL	0.05^{NS}	-0.06^{NS}	-0.26^{NS}	-0.35*	-0.40*	-0.08^{NS}	-0.44*		
TL	0.42*	0.08^{NS}	0.29^{NS}	0.10^{NS}	-0.09^{NS}	0.35*	-0.47*	0.50*	

NS = Non-significant (P>0.05); *statistically significant (P<0.05); BW = Body Weight; BL = Body length; CG = Chest Girth; HW = Height at Weather; HaL = Hair length; HeL = Head Length; HoL = Horn Length; EL = Ear Length; TL = Tail length

3.4. Prediction of body weight from linear body measurements

The knowledge of livestock weight assessment remains the backbone on which all animal production management practices are hinged (Otoikhian *et al.*, 2008). Regression analysis was carried out to predict the live body weight of an animal over independent variables, which have a higher correlation with body weight to set an adequate model for the prediction of body weight as depicted in Table 5. In the current study, live weight estimation using chest girth alone would be preferable to combinations with other measurements because of the difficulty of the proper animal restraint during measurement and the low proportion of animals at each dentition class as well. The importance of chest girth in weight estimation demonstrated in the present study could be a result of the fact that muscle and some fat along with bone structure contribute to its formation (Okpeku *et al.*, 2011). Several authors in similar studies have concluded that heart girth can be used as a sole predictor of body weight due to the high associate regression coefficients obtained (Zewdu, 2008; Taye *et al.*, 2010; Asefa, 2017). However, the more measurement traits incorporated in the model, the more body weight predicted.

Table 5: Linear Regression coefficients for Gamo highland sheep population by stepwise method

Model	Unstandardized Coefficients		Standardized Coefficients	t	R^2	Sig.
	Beta	Standard error	Beta			
Constant	-16.21	2.08		-7.78		0.000
CG	0.56	0.03	0.79	17.75	0.63	0.000
Constant	-40.98	2.92		-14.01		0.000
CG	0.65	0.03	0.92	24.36	0.76	0.000
EL	1.80	0.17	0.39	10.31		0.000
Constant	-48.51	2.93		-16.57		0.000
CG	0.56	0.03	0.80	19.91	0.80	0.000
EL	1.75	0.16	0.38	10.95		0.000
HeL	0.80	0.13	0.24	6.24		0.000
Constant	-50.65	2.86		-17.70		0.000
CG	0.46	0.04	0.65	12.47	0.82	0.000
EL	1.55	0.16	0.34	9.64		0.000
HeL	0.76	0.13	0.22	6.10		0.000
BL	0.21	0.05	0.19	4.06		0.000
Constant	-49.34	2.70		-18.26		0.000
CG	0.41	0.04	0.58	11.32	0.84	0.000
EL	0.95	0.19	0.21	4.95		0.000
HeL	0.57	0.12	0.17	4.67		0.000
BL	0.27	0.05	0.24	5.32		0.000
TL	0.31	0.06	0.20	5.03		0.000

CG = chest girth, EL= ear length, HeL= head length, BL= body length, TL= tail length

4. Conclusion and Recommendations

The characterization of sheep in this study was helpful to livestock farmers and researchers in preserving the genetic resources of the indigenous Ethiopian sheep breeds. Even though the study areas were rich in sheep resources, little has been done to characterize, identify and document the existing indigenous sheep types. The current study revealed that Gamo highland sheep populations were identified as multi-coloured, thin-tailed, and moderately sized in general. Polymorphisms, both in qualitative and morphometric traits, were inferring considerable genetic variability. Therefore, population divergence in these morphological traits needs to be further verified by comparing relative levels by the DNA markers.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no competing interests.

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