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Multivariate Analysis of Phenotypic Traits of Indigenous Sheep of South-West, Ethiopia

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Abstract

The study was conducted to physically characterize indigenous sheep population in Dawuro zone and Konta special woreda of South-West region of Ethiopia. Physical observation and body weight and linear measurements were studied 630 mature sheep. Multivariate canonical and discriminant analysis were employed to differentiate populations. Sampled animals were identified by sex, age and location. Heart girth and body length were found to be the most important variables for estimation of body weight. The result shows the majority of the ewes and rams across all the locations had plain coat color pattern (52-62.9%) with dominant brown, brown and creamy, and brown and white coat color with fat tailed type. All squared Mahalanobis' distances obtained among districts populations for females and males were significant (P<0.0001), indicating the existence of measurable differences between females and males district populations or districts. For males and females, most individuals were classified into their source population.

Keywords: Body Weight; Correlation; Interaction; Mahalanobis Distances; Dawuro; Konta

Introduction

Ethiopia has the largest livestock inventory in Africa, including around about 65 million cattle, 40 million heads sheep, 51 million goats, 8 million camels and 49 million chickens in 2020 with wide distribution of different agro-ecological zones of the country [1]. Due to several constraints like technical (feeding, animal health and genotype), institutional, environmental and infrastructural constraints, and the productivity of indigenous sheep breeds is low [2]. While, indigenous sheep breeds have been known in its low productivity, but have great potential in contributing more to the livelihoods of the people in low-input, small-scale sheep farmers in crop -livestock and pastoral production systems [3].

Knowing the performance of sheep is the prerequisite for any breed improvement and research activities and identification of the liner body measurement of particular sheep breed /type is the base for different sheep breed improvement strategies and sheep productivity scheme while breeding (selection), feeding and health care and for market age determination knowing the body weight of a sheep is important. However, this fundamental knowledge is often unavailable for sheep in the small scale farming sector, due to unavailability of scales [4].

Body weight, tail type, coat cover and different body measurement are used to characterize or identify indigenous sheep breeds (types). Frequency of the most typical morphological characteristics can help to compare variations within breeds and distances between breeds. Dawuro and Konta zone are geographically located in Southern-West Region of Ethiopia. Even though the study areas are rich in livestock resources including small ruminants, nothing has been done to describe, identify and document the existing indigenous sheep performance of those particular zones. So, the overall objective of this study was to describe physical and performance characteristics of indigenous sheep types in the study areas.

Materials and methods

Description of the study areas

The study was conducted in two zones; Dawuro and konta. Both zones are located in South- western part of the country. Dawuro zone is bordered by Hadiya zone in the North, Kemebata-Tembaro zone in North east, Wolayita zone in the East, Gamo-Gofa zone in the west and Konta special woreda and Jimma (Oromiya) zone in the west [5]. Dawuro zone is delineated by Omo River in north and south and Gojeb River in North-west [6]. Dawuro is situated at an altitude ranging from 730 to 2850 m. a. s. l., longitude 37° 09'E and latitude 7° 08 'N. The capital of Dawuro zone is Tercha, which is located at about 507 km from Addis Ababa. The annual mean maximum and minimum temperature of the zone is 26.4 °C and 14.9 °C, respectively (Agricultural office of the zone). The annual mean rainfall of the zone ranged from 1201 to 1800 mm [7]. The main rainy season of the zone is between June to September (long rainy season), short rainy season from March to April, and dry season lasts from October to February and May (Agricultural office of the zone). Dawuro zone has five woredas and 37 kebeles or Peasant Associations (PA). Agro- ecologically Dawuro consist of highland (Dega; 20.9%), mid-highland (Woinadega; 41%) and lowland (Kolla; 37%). The land use pattern is composed of 30 %annual crops , 25%ofperennial crops, 10% of grazing land, 40 % covered with forest land and agro -forestry. Topographically the district consists of plain (10%), mountain (85%) and plateau (5%). Totally Dawuro zone covers about 446,082 hectare of land. From the natural vegetation perspective, Dawuro zone predominantly known for growing bamboo. Bamboo has a vital and critical role in each and every living process of Dawuro

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people. Most of the houses and fences are made of bamboo and the known cultural food in the area known as "Kocho", which is made of the Enset crop (Enset verticosum), is also processed with the material made of bamboo.

According to Central Statistical Agency (CSA) [8], Dawuro has an estimated total human population of about 492,000. The study zone has also a total of 332,490 cattle, 106,163 sheep, 51,755 goats, 6,724 horses, 2,655 donkeys, 5,237 mule, 171,716 poultry and 9,483 beehives (South Agriculture and Rural Development Office). Geographical location of the study areas are indicated in Figure 1.

The other area where the study was conducted was Konta zone of Southern-West region of Ethiopia. Konta zone is situated at an altitude of 900-2300 m.a.s.l. at a distance of 460 km from the capital (Addis Ababa). The average maximum and minimum annual temperature of the zone is 37˚C and 21˚C, respectively. The main rainy season lies in between June to September (long rainy season), short rainy season from March to April, and the dry season lasts from October to February and May (Agricultural office of Konta zone).

Agro- ecologically, Konta zone consists of highland (Dega;6%), mid-highland (Woinadega; 54%) and lowland (kola; 40%). About 30% of the land of Konta zone is covered withannual crops, 25% covered with perennial crops, 5% covered with grazing land, 15% covered with forest and bush land and 10% agro forestry. Topographically the district consists of plain 15%, mountain 80% and plateau 5%. (Agricultural Office of Konta Special woreda). Konta special woreda has 71,212 heads of cattle, 16,457 heads of sheep, 11,873 heads of goat, 1,137 heads of horse, 510 heads of mule, 77,226 poultry and 20,263 beehives (South Agriculture and Rural Development Office).

Sampling technique

Sampling frame was established in a multistage clustered sampling procedure in compliance with the main indigenous sheep types of the study area. Dawuro Zone has five woreda, of which 3 woreda were selected strategically based on agro-ecology and sheep population distribution. From each selected woreda of Dawuro and Konta zone, 3 peasant associations (PA; sampling sites) were selected based on the distribution of sheep population, agro-ecology and accessibility.

Rapid surveys procedure (ILCA) [9] in which sample flocks owners are observed only once were employed to record both qualitative and quantitative data. During a single visit to a sampling site qualitative and quantitative measurements were collected from 630 matured sheep of both sexes (70 per PA). The age at which local sheep attain sexual maturity was reported according to PPI (1 pair of permanent incisor) as 1PPI or 2PPI in most literatures. Maturity age of 1PPI was reported for Bonga and Horrro sheep breeds [4, 10].

The standard breed descriptor list for the sheep developed by FAO [11] was closely followed in selecting morphological variables. Quantitative traits including body length, height at wither, pelvic width, chest width, tail length, tail circumference, ear length and scrotum circumference was measured using measuring tape, while body weight was measured using suspended spring balance having 50 kg capacity.

Every experimental animal is identified by sex, age and location. Adult sheep was classified into four age groups as one pair of permanent incisors (age group I); two pairs of permanent incisors (age group II), three pairs of permanent incisors (age group III); four pairs of permanent incisors (age group IV), following the description of African sheep Wilson and Durkin [12]. Body condition score (BCS) was assessed subjectively and scored using the 5 point scale (1= very thin, 2 = thin, 3= average, 4 = fat and 5 = obese) for both of the sexes according to Hassamo *et al.* [13]. Morphological characters like coat color pattern, coat color type, hair type, head profile, ears, wattle, horn, ruff and tail were observed.

Data management and statistical data analysis

The collected data from each study site were checked for any error and corrected during the study period, coded and entered into computer for further analysis. Morphological (qualitative) and body linear measurement (quantitative) data were entered into Microsoft Excel, 2007 software for data management. Prior to data analysis, preliminary testes such as homogeneity test, normality test and screening of outliers were employed. Morphological characters were analyzed for male and female sheep using frequency procedure of Statistical Analysis System (SAS) [14]. Descriptive statistics were employed to summarize and describe categorical variables. For mature animals, sex, age group and location of the experimental sheep were fitted as fixed independent variables while body weight and linear body measurements except scrotum circumference were fitted as dependent

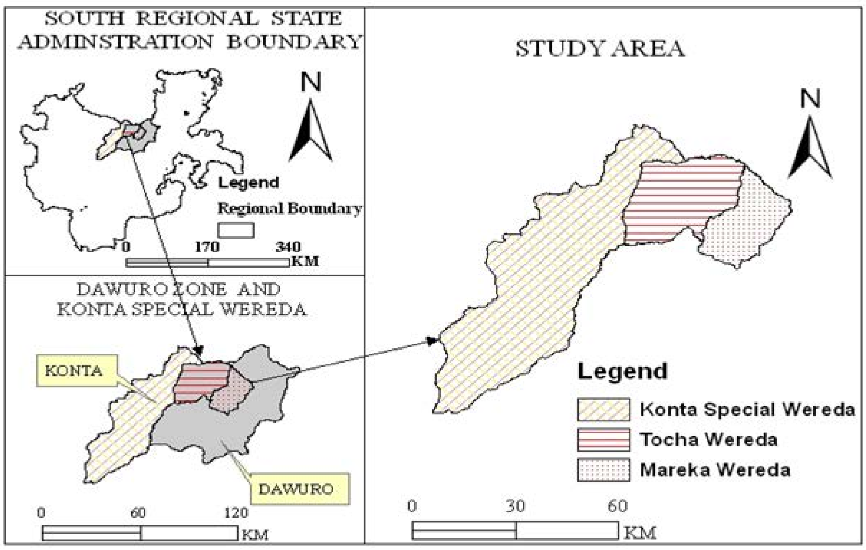

Figure 1: Map of the study areas.

variables. Only significant interaction among fixed effect discussed and stated in ANOVA table.

The quantitative variables taken from female and male animals were separately subjected to discriminate analysis procedures (SAS) [14] to determine the existence of population level phenotypic differences among the sample (district) sheep populations. Scrotum circumference was analyzed by fitting age group and location as fixed factor. Tukey-Kramer test was used to evaluate the difference among the compared groups. The model employed for analyses of adult (mature) body weight and other linear body measurements except scrotum circumference was:-

$Y_{ijk} = \mu + A_i + D_j + e_{ijk,}$

Where: Y_{ijk} = the observed k (body weight or linear body measurements) in the i^{th} age group and j^{th} Location, μ= overall mean, A_i = the effect of i^{th} age group (i = 1, 2, 3 and 4), D_j = the effect of j^{th} Location (j=1, 2, & 3), and e_{ijk}= random residual error.

For male sheep body weight and other body measurements including Heart Girth (HG), Body Length (BL), Height at wither (HW), Pelvic Width (PW), Ear Length (EL),Tail Length (TL), Body Condition (BC), Tail Circumference (TC) and Scrotum Circumference (SC) were considered, whereas Scrotum circumference (SC) were avoided for the analysis of female sheep. Correlations of body weight with different body measurement under consideration were computed for each of the categories of dentition classes and sex using Pearson correlation coefficient. Stepwise regression procedure of SAS where used to regress body weight for males within each age group using stepwise regression procedure of SAS in order to determine the best fitted regression equation for the prediction of body weight. Similar stepwise regression equation was also employed for females within each age group by excluding SC from the model. Best fitting models were selected based on its coefficient of determination (R^2), mean square error and simplicity of measurement under field condition. The following models were used for the estimation of body weight from body linear measurements.

For male:

$Y_j = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + e_j$

Y_j = the response variable (body weight)

α = the intercept

X_1…. X_6 are the explanatory variables (body length, height at wither, chest girth, tail length, tail circumference, scrotal circumference).

β_1..., β_6 are regression coefficients of the variables X_1.., X_6

e_j = random error

For female:

$Y_j = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + e_j$

Where:

Y_j = the dependent variable body weight

α = the intercept

X_1…X_5 are independent variables (body length, height at wither, chest girth, tail length, tail circumference).

β_1… β_6 are regression coefficients of the variable X_1..,X_6

e_j = random error

Results and discussion

Characterization of qualitative traits of Tocha, Mareka and Konta sheep

In a particular production system description of the physical characteristics of livestock breed is important to develop breeding strategy [15]. Morphological characters of Tocha ram and ewe are presented in Table 1. The majority of Tocha ewes had plain coat color pattern (62.9%) followed by patchy pattern (24.5%) while the proportion of ewes with spotty pattern are small (12.6%). Similar coat color pattern was reported for Bonga and Horro ewes [4]. On the other hand, the dominant coat color pattern of Tocha rams is plain (52 %) and patchy (48 %). Among the different coat color types of female sheep in Tocha, brown color accounted for 20%, brown and white accounted for 18.1% and white and black accounted for 14.4% (Table 1). Similarly, brown (34%), brown and white (14%), white and black (10%), brown and black (10%) and brown and creamy white colors (10%) were reported to be the major coat color types observed in male sheep of Tocha. Major colors like brown, brown and white and white and black were also frequently observed in samples population of Gumuz ewes [17]. The majority of (80%) female and male (94%) sheep had medium and smooth wool or coat hair. All the sampled female and male sheep had no horn, toggle and ruff. However, only 21.2% females and 9%

Table 1: Morphological characters of Tocha sheep.

Morphological Character	Attributes	Sex			
		Female		Male	
		N	%	N	%
Coat color pattern	Plain	100	62.9	26	52
	Patchy	39	24.5	24	48
	Spotted	21	12.6	0	0
Coat color type	White	10	6.2	3	6
	Black	9	5.6	2	4
	Brown	32	20	17	34
	Gray	0	0	2	4
	Reddish brown	0	0	1	2
	Creamy white	1	0.6	1	2
	White and black	23	14.4	5	10
	Brown and white	29	18.1	7	14
	Brown and black	11	6.9	5	10
	Brown and creamy white	24	15	5	10
	Gray and brown	3	1.9	1	2
	Gray and creamy white	1	0.6	0	0
	Brown, creamy white and white	2	1.2	0	0
	Gray and black	2	1.2	0	0
	Brawn, black and white	13	8.1	1	2
Hair type	Short and smooth hair	28	17.5	2	4
	Medium and smooth hair	128	80	47	94
	Long and coarse hair	4	2.5	1	2
Head profile	Straight	24	15	4	8
	Slightly convex	136	85	46	92
Tail type	Long fat tail	160	100	50	100
Tail form	Curved at the tip (twisted ended)	23	14.4	11	22
	Straight tip	126	78.8	35	70
	Blunt (rounded)	11	6.9	4	8
Ear form	Horizontal	12	7.5	5	10
	Semi-pendulous	148	92.5	45	90
Wattle	Present	34	21.2	9	18
	Absent	126	78.8	41	82

male had wattle. Tocha sheep have a characteristic of fat-tailed type. About 78.8 % of female and 70 % of male sheep population had straight down pointed or straight tip type tail and the remaining had slightly blunt (rounded) tail. Among sampled sheep, 85% of female sheep and 92% of male sheep had slightly convex head profile while only 15% of female and 8% male sheep had straight head profile. The face of sampled sheep was free from hair covering. Of the total sampled sheep population, 92.5% female and 90% male have semi-pendulous ear form or orientation and only 7.5% female and 10% male have horizontally oriented ears. Except head profile, where majority of Tocha sheep had slightly convex head profile compared to strait head profile in Bonga sheep, in almost all the qualitative traits measured(coat colour pattern, coat color type, hair type, tail type, tail form, ear form) Tocha sheep are similar with the characteristics of Bonga sheep [4]. However, in contrast with Menz sheep, which has short fat tail, long and coarse coat hair type and horn [16], Tocha sheep has long and fat tail, medium and smooth hair and hornless.

Morphological characters of Mareka rams (Figure 2) and ewes are presented in Table 2. About 57.6% of female and 59% male Mareka sheep had plain coat color pattern, while 32.1% of female and 41% male had patchy had coat color pattern. Only 10.3% female Mareka sheep had spotty pattern. Among the sampled female sheep 25.3% had brown coat color followed by 21.7% brown and creamy white and 15% white and black. Similarly, coat color types of brown and white, white and brown and creamy white were observed in Mareka male sheep with proportions of 23%, 21% and 16%, respectively. The majority (97%) of female and all (100%) male Mareka sheep had medium and smooth wool or coat hair. Similar with Tocha sheep, among all female and male sampled Mareka sheep, horn, toggle and ruff were absent. Only 16.3% females and 11% male Mareka sheep had wattle. Mareka female and male sheep is fat tailed (100%) and the tail of female was formed either straight tip (71.1%), curved at the tip (twisted ended) (23.5%) or Blunt (rounded) (5.4%). The tail of males sheep is mostly (82%) straight or curved at the tip (18%) tail form. Most of female Mareka sheep had slightly convex (93.4%) while few had straight (6.6%) head profile. Similarly, most Mareka male sheep had slightly convex (89%) head profile while the remaining had straight head profile (11%). Like Tocha sheep, 89.2 % female and 84% male Mareka sheep had semi- pendulous ears. The remaining 10.8% females and 16% males had horizontal ears.

There is strong resemblance of morphological characteristics in between Tocha and Mareka sheep. Mareka sheep has also similar morphological character with Bonga, Horro and Tahtay Maichew district, Northern Ethiopia sheep [1, 4]. However, in contrast to Mareka sheep, majority of Menz and Afar sheep had curved up tail form at the tip, long and coarse hair type and had horn as well as among the sampled sheep all are short fat tailed [16].

Figure 2: Dawuro (Mareka) ram (left) and ewe (right).

Table 2: Morphological characters of Mareka sheep.

Character	Attributes	Sex			
		Female		Male	
		N	%	N	%
Coat color pattern	Plain	95	57.6	26	59
	Patchy	53	32.1	18	41
	Spotted	18	10.3	0	0
Coat color type	White	17	10.2	9	21
	Black	2	1.2	3	6.8
	Brown	42	25.3	5	11
	Roan	0	0	2	4.5
	Gray	3	1.8	0	0
	Creamy white	1	0.6	0	0
	White and black	25	15.1	5	11
	Black and brown	1	0.6	0	0
	Brown and white	24	14.5	10	23
	Brown and black	9	5.4	3	6.8
	Brown and, creamy white	36	21.7	7	16
	Gray and creamy white	1	0.6	0	0
	Brown , black and white	5	3	0	0
Hair type	Short and smooth hair	4	2.4	0	0
	Medium and smooth hair	161	97	44	100
	Medium and coarse hair	1	0.6	0	0
Head profile	Straight	11	6.6	5	11
	Slightly convex	155	93.4	39	89
Tail type	Long fat tail	166	100	44	100
Tail form	Curved at the tip(twisted ended)	39	23.5	8	18
	Straight tip	118	71.1	36	82
	Blunt(rounded)	9	5.4	0	0
Ear form	Horizontal	18	10.8	7	16
	Semi-pendulous	148	89.2	37	84
wattle	Present	27	16.3	5	11
	Absent	139	83.7	39	89

The major qualitative traits of Konta sheep are presented in Table 3. Among the sampled 210 sheep in the district, 61.8% of females and 64.6 % of males had Plain coat color pattern while, 38.2% of females and 35.4% of males had patchy coat pattern. No spotted coat pattern was observed in the sampled sheep. Brown and creamy white (25.2%), Plain brown (22.1%) and Plain white (16.8%) coat color types were the dominant colors in sampled females. Similarly the males had mostly brown and creamy white (25.3%), Plain white (17.7%), white and black (17.7%) colored with the variety of other different colors in lesser frequency. In females, almost 58% and 42% had slightly convex and straight head profile, respectively. While 50.6% of the males had slightly convex and 49.4% had straight head profile. Similar to Dawuro (Tocha and Mareka) sheep the Konta sheep had a characteristic of fat-tailed (100%). In females, majority (87.8%) of the sampled population had straight down pointed tail while the rest (12.2 %) had curved tail at the tip (twisted ended). Male Konta sheep had mainly (79.7%) straight tip tail type and the remaining (20.3%) had curved at the tip (twisted ended) tail. In larger proportion, 82.4 % females and 88.6% males of Konta sheep had semi-pendulous ear form or orientation. Merely, 17.6% of females and 11.4% males carry horizontally oriented ears. Only 23.7% females and 26.6 % male sheep had wattle. Horn, toggle and ruff were not seen in the sampled sheep. The morphological variables considered in this study (coat color pattern, coat color, head profile, tail type, tail conformation and ear orientation) are similar between the two sexes and among the woreda. There is no major difference in morphological characters measured between the sampled sheep population in Dawuro (Tocha and Mareka) and Konta special woreda. It seems that there is also similarity among the sheep population of the three woreda in almost all morphological character as compared to Bonga and Horro sheep breed [4]. Correspondingly, Gumuz ewe and ram have similar trait of coat color pattern and head profile with Dawuro (Tocha and Mareka) and Konta special woreda sheep [17]. However, Gumuz sheep had thin tailed in contrast to the Dawuro and Konta sheep which had fat tailed. Likewise, Menz and Aafar sheep breeds had different attributes like tail type, presence or absence of horn, tail form, coat hair type and head profile compared to Dawuro (Tocha and Mareka) and Konta special woreda sheep [16].

Table 3: Morphological characters of Konta sheep.

Character	Attributes	Sex			
		Female		Male	
		N	%	N	%
Coat color pattern	Plain	81	61.8	51	64.6
	Patchy	50	38.2	28	35.4
Coat color type	White	22	16.8	14	17.7
	Black	6	4.6	1	1.3
	Brown	29	22.1	10	12.7
	Gray	0	0	3	3.8
	Roan	2	1.5	1	1.3
	White and black	12	9.2	14	17.7
	Black with dominant white	1	0.8	0	0
	Brown and white	15	11.5	12	15.2
	Brown and black	9	6.9	3	3.8
	Brown and creamy white	33	25.2	20	25.3
	Brown black and white	2	1.5	1	1.3
Hair type	Short and smooth hair	60	45.8	30	38
	Medium and smooth hair	65	49.6	47	59.5
	Medium and coarse hair	0	0	1	1.3
	Long and coarse hair	6	4.6	1	1.3
Head profile	Straight	55	42	39	49.4
	Slightly convex	76	58	40	50.6
Tail type	Long fat tail	131	100	79	100
Tail form	Curved at the tip (twisted ended)	16	12.2	16	20.3
	Straight tip	115	87.8	63	79.7
Ear form	Horizontal	23	17.6	9	11.4
	Semi-pendulous	108	82.4	70	88.6
wattle	Present	31	23.7	21	26.6
	Absent	100	76.3	58	73.4

Live body weight and liner measurements

It is not doubtful that the importance of body weight and different body measurements in breed improving strategies and selection toward grade traits which are important to boost the sheep productivity, as description of the physical characteristics of livestock breeds is important for developing a breeding plan in particular production system [15, 18]. The body weight and liner body measurements of sheep by sex, age groups and study site (woreda; location) are presented in Table 4(a)-4(c).

Effect of sex, age group, location and their interaction

- **Sex effect:** except body condition score ($p<0.05$) the sex of the sheep had no significant ($p>0.05$) effect on the body weight and other linear measurements. The weight of ewes (29.68 ± 0.14 kg) and rams (30.16 ± 0.22 kg) in current result is almost similar with the result of ewes (26.4 kg ± 0.16 kg) and rams (32.0 ± 0.28 kg) of indigenous sheep population in western part of Ethiopia, respectively [19]; however body weight of rams (30.16 ± 0.22 kg) is much more higher than what was reported for Menz (22.0 ±0.22 kg) and Afar (24.3 ± 0.50 kg) rams [16]. Similarly the weight of ewes (29.68 ±0.14 kg) in this study is higher than the value (27.65 ±0.21 kg) reported for Horro ewes [4].

- **Age effect:** Age group exerted strong significant effect ($p<0.01$) on body weight (BW), Tail length (TL), scrotal circumference (SC), height at wither (HW), heart girth (HG) and body length (BL). Similarly, tail circumference (TC), ear length (EL) and chest width (CW) were significantly ($p < 0.05$) affected by age group. Pelvic width (PW), tail width (TW) and body condition score (BC) were not affected ($p > 0.05$) by age group. As reported earlier, the size and shape of the animal increases until the animal reach its optimum growth point or until maturity [19, 20]. Body weight, scrotal circumference (SC), height at wither (HW), heart girth (HG) and body length (BL) were kept increased as the age increased from the dentition group 1(youngest) to dentition group 4 (oldest). The above variables (BW, SC, HW, HG and BL) reached their maximum value in the oldest age (4 pp) of

Table 4 (a): Least square mean (± SE) body weight (kg), body condition score and other body measurements (cm) of Dawuro and Konta sheep types by sex, age, location and their interactions.

Effect and level	BW		PW		TW		TL		TC		SC	
	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE
Overall	619	29.92±0.13	620	11.67±0.08	619	7.80±0.15	618	24.92±0.31	616	18.13±0.26	161	21.11±0.20
CV%	619	8.16	620	12.09	619	35.81	618	22.86	616	26.91	161	10.53
R^2	619	0.82	620	0.18	619	0.06	618	0.09	616	0.13	161	0.57
Sex		NS		NS		NS		NS		NS		Na
Female	454	29.68 ± 0.14^{a}	453	11.62±0.08^{a}	453	7.84±0.16^{a}	452	24.92±0.33^{a}	450	18.15±0.27^{a}		
Male	165	30.16 ± 0.22^{a}	167	11.75±0.12^{a}	166	7.75±0.23^{a}	166	24.92±0.48^{a}	166	18.12±0.40^{a}		
Age		**		NS		NS		**		*		**
1PP	180	21.96±0.20^{a}	182	11.53±0.11^{a}	181	8.11±0.22^{a}	181	27.45±0.45^{a}	179	18.75±0.38^{a}	51	17.19±0.31^{a}
2PP	186	28.24±0.20^{b}	186	11.56±0.11^{a}	186	7.78±0.21^{a}	185	25.67±0.45^{b}	186	18.57±0.38^{ab}	43	19.91±0.33^{b}
3PP	212	33.72±0.19^{c}	211	11.67±0.10^{a}	211	7.34±0.20^{a}	211	24.00±0.42^{c}	210	17.40±0.36^{b}	54	22.20±0.29^{c}
4PP	41	35.74±0.41^{d}	41	11.98±0.22^{a}	41	7.96±0.44^{a}	41	22.55±0.9^{cd}	41	17.82±0.77^{ab}	13	25.14±0.59^{d}
Location		*		**		**		*		**		NS
Tocha	205	30.18±0.20^{a}	205	11.92±0.11^{a}	204	7.17±0.22^{a}	205	24.00±0.45^{a}	204	16.74±0.38^{ab}	55	20.88±0.30^{a}
Mareka	207	29.48±0.23^{b}	207	10.82±0.11^{b}	207	7.60±0.22^{a}	207	25.35±0.4^{ab}	207	17.19±0.39^{b}	45	20.96±0.33^{a}
Konta	207	30.09±0.2^{ab}	208	12.32±0.11^{c}	208	8.61±0.22^{b}	206	25.40±0.46^{b}	205	20.48±0.38^{c}	61	21.49±0.31^{a}

^{a,b,c,d,e} means on the same column with different superscripts within the specified dentition group are significantly different (P<0.05); Ns = Non-significant(P>0.05); *significant at 0.05; **significant at 0.01; BW = Body weight; PW = Pelvic Width; TW = Tail Width; TL = Tail Length; TC = Tail Circumference; SC = Scrotal Circumference; 1 PPI= 1 Pair of Permanent Incisors; 2 PPI = 2 Pairs of Permanent Incisors; 4 PPI = 4 pair of permanent incisors.

Table 4 (b): Least square mean (± SE) body weight (kg), body condition score and other body measurements (cm) of Dawuro and Konta sheep types by sex, age, location and their interactions.

		EL		CW		HW		HG		BL		BC
Effect and level	**N**	**LSM±SE**	**N**	**LSM±SE**	**N**	**LSM±SE**	**N**	**LSM±SE**	**N**	**LSM±SE**	**N**	**LSM±SE**
Overall	619	10.26±0.05	619	15.04±0.10	617	65.71±0.24	619	74.25±0.06	618	63.54±0.26	621	2.94±0.02
CV%	619	9.18	619	12.52	617	6.79	619	1.41	618	7.54	621	10.94
R^2	619	0.05	619	0.11	617	0.06	619	0.08	618	0.12	621	0.02
Sex		NS		NS		NS		NS		NS		*
Female	453	10.34±0.05^{a}	453	15.16±0.11^{a}	450	65.68±0.25^{a}	452	74.30±0.06^{a}	452	63.69±0.27^{a}	454	2.97±0.02^{a}
Male	166	10.18±0.08^{a}	166	14.91±0.16^{a}	167	65.75±0.37^{a}	167	74.20±0.09^{a}	166	63.38±0.40^{a}	167	2.91±0.03^{b}
Age		*		*		**		**		**		NS
1PP	182	10.06±0.07^{a}	181	14.62±0.15^{a}	181	63.87±0.34^{a}	181	70.68±0.08^{a}	180	61.19±0.38^{a}	182	2.95±0.02^{a}
2PP	185	10.39±0.07^{b}	186	14.96±0.15^{ab}	186	65.93±0.34^{b}	185	73.77±0.08^{b}	186	63.74±0.38^{b}	186	2.91±0.02^{a}
3PP	211	10.20±0.07^{ab}	211	14.87±0.14^{ab}	209	66.11±0.32^{b}	212	75.26±0.08^{c}	211	64.04±0.35^{b}	212	2.92±0.02^{a}
4PP	41	10.38±0.15^{a}	41	15.69±0.30^{b}	41	66.95±0.70^{b}	41	77.30±0.16^{d}	41	65.18±0.76^{b}	41	2.99±0.05^{a}
Location		*		**		NS		NS		*		NS
Tocha	204	10.47±0.07^{a}	204	15.23±0.17^{a}	202	66.07±0.35^{a}	206	74.30±0.08^{a}	204	63.77±0.4^{ab}	206	2.92±0.03^{a}
Mareka	207	10.11±0.08^{b}	207	14.28±0.18^{b}	207	65.68±0.36^{a}	205	74.30±0.04^{a}	207	64.45±0.46^{a}	207	2.99±0.03^{a}
Konta	218	10.20±0.07^{b}	208	15.59±0.17^{a}	208	65.39±0.35^{a}	208	74.16±0.08^{a}	207	62.38±0.43^{b}	208	2.93±0.03^{a}

^{a,b,c,d} means on the same column with different superscripts within the specified dentition group are significantly different (P<0.05); Ns = Non-significant (P>0.05); *significant at 0.05; **significant at 0.01; EL = Ear Length; CW= Chest Width; HW = Height at Wither ; HG = Heart Girth; BL = Body Length; BCS= Body Condition Score; 1PPI= 1 Pair of Permanent Incisors; 2 PPI = 2Pairs of Permanent Incisors; 4PPI = 4 pairs of permanent incisors.

Table 4 (c): Least square mean (± SE) body weight (kg), body condition score and other body measurements (cm) of Dawuro and Konta sheep types by sex, age, location and their interactions.

Effect and Level	**BW**		**CW**		**BL**	
	N	**LSM ± SE**	**N**	**LSM ± SE**	**N**	**LSM ± SE**
Age by location		**		*		*
1 pp, Tocha	49	21.15±0.35^{a}	49	14.47±0.27^{ab}	49	59.62±0.69
1 pp, Mareka	48	22.22±0.36^{a}	48	13.89±0.28^{a}	48	62.22±0.70
1 pp, Konta	83	22.52±0.26^{a}	84	15.52±0.21^{b}	83	61.74±0.53
2 pp, Tocha	46	28.31±0.36^{b}	46	15.03±0.28^{ab}	46	64.71±0.54
2 pp, Mareka	83	28.24±0.29^{b}	83	14.54±0.21^{ac}	83	64.39±0.71
2 pp, Konta	57	28.16±0.32^{b}	57	15.30±0.25^{bc}	57	62.13±0.63
3 pp, Tocha	93	33.52±0.26^{c}	92	15.47±0.20^{bc}	92	64.73±0.51
3 pp, Mareka	65	33.76±0.31^{c}	65	13.93±0.24^{a}	65	64.56±0.60
3 pp, Konta	54	33.88±0.33^{c}	54	15.23±0.26^{bc}	54	62.83±0.66
4 pp, Tocha	17	37.73±0.58^{d}	17	15.96±0.46^{bc}	17	66.37±1.16
4 pp, Mareka	11	33.68±0.72^{c}	11	14.78±0.57^{ab}	11	66.32±1.44
4 pp, Konta	13	35.81±0.69^{cd}	13	16.32± 0.52^{bc}	13	62.84±1.33
Sex by age		**		_		_
Female, 1 PP	128	22.48±0.21^{a}		_		_
Female, 2 PP	141	28.27±0.21^{b}		_		_
Female, 3 PP	157	3.73±0.19^{c}		_		_
Female, 4 PP	28	34.24±0.45^{cd}		_		_
Male, 1 pp	52	21.45±0.34^{a}		_		_
Male, 2 pp	45	28.20±0.35^{b}		_		_
Male, 3 pp	55	33.71±0.32^{c}		_		_
Male, 4 pp	13	37.24±0.66^{e}		_		_

a,b,c,d,e means on the same column with different superscripts within the specified dentition group are significantly different (P<0.05); Ns = Non-significant (P>0.05); *significant at 0.05; **significant at 0.01; BW = Body weight; PW = Pelvic Width; TW = Tail Width; TL = Tail Length; TC = Tail Circumference; SC = Scrotal Circumference; 1PPI= 1 Pair of Permanent Incisors; 2 PPI = 2 Pairs of Permanent Incisors; 4PPI = 4 pair of permanent incisors.

the sheep and dentition group 3 and 4 had higher values than those between 1 and 2 dentition groups. The significant difference (p<0.01) among the four age groups on body measurements (BW, SC, HW, HG and BL) shows that those measurements were highly dependent on age. Variables such as TC, EL and CW were less (p<0.05) influenced by age and the variables such as PW, TW and BC not (p>0.05) influenced by age groups. The finding of this result of body weight and other body measurements is in agreement with the reports of different scholars Zewdu, Gobena et al. [4, 19] who reported that matured body weight of the animal almost fully attains at older age. As age increased the size of scrotal circumference also increased. The matured (age group 4) sheep had higher (p<0.05) scrotal circumference than the other age groups. The scrotal circumference of matured Dawuro and Konta sheep (25.14 ± 0.59 cm) is greater than matured Menz (24.5 ± 0.58 cm) sheep and less than matured Afar and sheep in western part of Ethiopia (27.5 ±0.67 and 26.6 ± 0.16 cm) [16, 19]. Different scholars like Tesfaye, Zewdu, Gobena et al. [4, 16, 19] also reported similar result with the current report about in animals at older age group had larger scrotal circumference than animals at younger age groups.

- **Location (woreda) effect**: Location was found to strongly influence (P < 0.01) pelvic width, tail circumference and chest width. Similarly body weight, tail length, ear length and body length were also influenced (p < 0.05) by location. However, scrotal circumference, height at wither, heart girth and body condition score were not influenced (p>0.05) by location. Tocha sheep (30.18 ± 0.20 kg) were slightly heavier than Mareka sheep (29.48 ± 0.23 kg) but sheep types in two locations (Tocha and Mareka) had the similar (P > 0.05) body weight compared to Konta (30.09 ±0.2 kg). Konta sheep had significantly higher values for pelvic width, tail width, tail circumference and chest width (P < 0.05) Tail length of Tocha sheep is shorter (p < 0.05) than Konta sheep but Mareka sheep had the same (p > 0.05) tail length with Tocha and Konta sheep. Disparately, Konta and Mareka sheep had smaller ear than Tocha sheep. Height and heart girth (Chest girth) of the sheep in tree locations had similar value (p > 0.05). Konta sheep had longer body length (P < 0.05) than Mareka but Tocha sheep, which had similar (p > 0.05) body length with Mareka and Konta sheep.

- **Sex by age group:** The interaction between sex and age group significantly (p < 0.01) affected only body weight of the sheep. The remaining parameters of body measurements were not affected by the sex-age interaction effect. The value of body weight for female sheep in age group 1, age group 2, age group 3 and age group 4 were 22.48 ± 0.21 kg, 28.27 ± 0.21 kg, 33.73 ± 0.19 kg and 34.24 ± 0.45 kg, respectively and the values for males in the same age groups were 21.45 ± 0.34 kg, 28.20 ± 0.35 kg, 33.71 ± 0.32 kg and 37.24 ± 0.66 kg, respectively. Both females and males in age group 1(1pp), age group 2(2 pp) and age group 3(3 pp) had the same (p>0.05) body weight value but males in age group 4(4 pp) were heavier (p<0.05) than females in age group 4(4pp). Body weight of males in age group 1(21.45 ± 0.34 kg) in the current study was lower than body weight of Menz males (22.48 ± 0.21 kg) in the same age group. However, body weight of females in age group I in the current study (22.9 ± 0.39 kg) was higher that the values reported for Menz ewes (19.1 ± 0.27 kg) in the same age group [16]. As reported previously (Zewudu) [4], body weight of ewes in age group 2 (28.27 ± 0.21 kg) is almost similar (28.62 ±0.29 kg) with ewes of Bonga and Horro in the same age group but ewes in age group 3 (33.73 ± 0.19 kg) and 4 (34.24 ± 0.45 kg) is heavier than ewes in the age group 3(30.81 ± 0.29 kg) and in the age group 4 (32.79 ± 0.16 kg) of Bonga and Horro ewes whereas males in age group 1(21.45 ± 0.34 kg) is much more lesser than (27.83 ± 1.06 kg) of Bonga and Horro rams in age group 1(1 pp).

- **Sex by location:** The interaction effect of sex and location was not significant (p>0.05) in all measurements.

- **Age by location:** As mentioned earlier, body weight increased until the animal reached maturity correspondingly across all the locations. Thus, body weight increased from the youngest (1pp) to the oldest (4 pp). The interaction of age group and location was highly significant (p<0.01) for body weight, for chest width and body length (p<0.05). Differently, the interaction was not significant for pelvic width, tail circumference ,chest width, tail length, ear length , scrotal circumference, height at wither, heart girth and body condition. Young (1 pp) sheep of Tocha, Mareka and Konta had similar (p>0.05) body weight. The age group 2 (2 pp) also had similar (p>0.05) body weight across the 3 locations and age group 3(3 pp) also had similar body weight in Tocha, Mareka and Konta while the body weight of Tocha (37.73 ± 0.58 kg) sheep in age group 4(4 pp) is heavier than Mareka (33.68 ± 0.72 kg) sheep but Konta (35.81 ±0.69 kg) sheep had similar body weight with Mareka (33.68 ± 0.72 kg) and Tocha (37.73 ± 0.58 kg) sheep in age group 4. Body weight of the first age group (1 pp) and age group 2 (2 pp) of the three locations is smaller than Bonga and Horro sheep in the same age groups. Except Mareka sheep, the body weight of Tocha and Konta sheep in age group 3 and 4 is higher than both Bonga and Horro sheep in age group 3 and 4 [4].

- **Correlation between body weight and body measurements**

Pearson correlation matrix that indicates the association between live weight and other body measurements in sampled sheep are shown in Table 5. Strong positive correlation (p<0.01) between body weight, height at wither, heart girth, body length, pelvic width, tail circumference and body condition score were observed in sampled female sheep age group of 1, 2 and 3. While tail length were significant (p<0.05) in age group 1 and 2, it was not significant in age group 3. The highest relationship between body weight and body length (r=0.57) and body weight and body condition score (r=0.84) were observed in females and males, respectively, in age group one. The highest association between heart girth and body weight were observed in female (r=0.46) and male

Table 5: Coefficients of correlation between body weight and other body measurements for Dawuro and Konta sheep within age groups and sex.

Traits		Age group									
		1PP		2PP		3PP		4PP		1-4PP	
		F	M	F	M	F	M	F	M	F	M
HW	r	0.54**	0.45**	0.23**	0.54**	0.38**	0.25^{NS}	0.18^{NS}	0.34^{NS}	0.33**	0.37**
	N	127	53	141	46	154	55	28	13	454	169
HG	r	0.26**	0.38**	0.46**	0.57**	0.39**	0.43**	0.06^{NS}	0.44^{NS}	0.81**	0.89**
	N	127	53	140	46	157	55	28	13	456	169
BL	r	0.57**	0.67**	0.34**	0.40**	0.53**	0.42**	-0.31	0.37^{NS}	0.36**	0.45**
	N	127	52	141	46	156	55	28	13	456	168
PW	r	0.26**	0.40**	0.27**	0.44**	0.35**	0.24^{NS}	0.10^{NS}	0.26^{NS}	0.14**	0.12^{NS}
	N	128	53	141	46	156	55	28	13	457	169
TL	r	0.19*	0.14^{NS}	0.19*	0.03^{NS}	0.13^{NS}	0.30*	-0.02	-0.07	-0.19**	-0.18*
	N	127	53	141	45	156	55	28	13	456	168
TC	r	0.56**	0.48**	0.31**	0.46**	0.39**	0.49**	0.18^{NS}	-0.2	0.02^{NS}	-0.02^{NS}
	N	126	52	141	46	155	55	28	13	454	168
SC	r	_	0.22^{NS}	_	0.41*	_	0.43**	_	-0.41	_	0.72**
	N	_	48	_	43	_	52	_	13	_	158
BC	r	0.47**	0.84**	0.33**	0.55**	0.39**	0.51**	0.06^{NS}	_	0.12*	0.27**
	N	128	53	141	46	157	55	28	_	458	169

(r=0.57) sheep of age group two. Body length of female sheep (r=0.53) and body condition score of male sheep (r=0.51) had the highest correlation with body weight, which was noticed in age group 3. Most independent parameters in age group 4 had negative relationship with body weight. This might be because of small number of observations in that particular age group.

Positive and highly significant (P<0.01) correlations were observed between body weight and most of the body measurements. In pooled data (age group 1-4) Pearson correlation matrix of the female sample population showed a strong positive correlation (p<0.01) between body weight, height at wither, heart girth, body length and pelvic width. The highest relationship between heart girth and body weight were observed in female population for the pooled data (0.81). Similarly, correlation matrix of the male sample population in pooled data also confirmed that a strong positive correlation (p<.01) between body weight, height at wither, heart girth, body length, scrotal circumference and body condition score. Among the positive correlation matrix of male sheep population in age group 1-4 there were high (0.89) correlation between body weight and heart girth.

Generally, similar to this study, the strong positive correlation (P< 0.01) between the dependent variable body weight and the independent variable chest girth to predict the body weight were observed in different sheep breeds for instance Gumez [17], Menz and Afar [16], and Bonga and Horro [4] sheep breeds of Ethiopia.

Scrotal circumference also revealed highest (r=0.72), significant (P<0.01) and positive relationship with live boy weight in sampled males. Except pelvic width the higher correlation coefficient of male sheep than female sheep indicates body weight could be predicted more accurately in males as compared to female. This is in agreement with the findings of Zewdu and Tesfaye [4, 16],

Multiple regression analysis

Table 6 shows that the number of variables entered in each step to predict the best fitted variable to estimate body weight and their contribution in terms of coefficient of determination (R^2) at different dentition and sex categories. Stepwise regressions procedure was carried out to predict the dependent variable body weight based on independent variables which had positive correlation with body weight.

Regression equation was developed for female and male using the pooled data for all age groups due to the low proportion of animals at each dentition classes. Around ten body measurements (EL, CW, HW, HG, BL, PW, TW, TL, TC and BC) were utilized in female for estimation of body weight. The male body weight also estimated using the above measurements and scrotal circumference.

Three variables with significant contribution to the prediction model which included heart girth, body length and height at wither were fitted first, second and third, where they accounted for67 % of the total variability of the female sheep. Across all the age groups of male sheep, heart girth alone accounted for about 79 % and body length for 81% of the variation in body weight, while step one procedure of stepwise regression of all sex and age category, for predication of body weight heart girth was consistently selected and entered into the model because of its higher coefficient of determination (R^2) value and its larger contribution to the model than other variables.

Strong relationship between body weight, heart girth, body length and height at wither of female sample population make it possible to predict the body weight based on these three linear measurements but for field condition simple measurement with maximum of one or two variables is enough to predict the dependent variable. This is because addition of more variable under field condition increases error,

Table 6: Prediction equations at different sex and age groups in Dawuro and Konta sheep.

Females age group	Equations	Intercept	β_1	β_2	β_3	β_4	β_5	R^2	R^2 Change
1PP	BL	6.17	0.26					0.36	0
	BL+TC	6.16	0.21	0.18				0.52	0.16
	BL+TC+HW	2.16	0.16	0.17	0.11			0.56	0.04
2PP	HG	-114. 87	1.94					0.21	0
	HG+CW	-92.89	1.58	0.28				0.29	0.08
3PP	BL	17.86	0.25					0.28	0
	BL+TC	17.78	0.21	0.12				0.36	0.08
	BL+TC+CW	16.75	0.1	0.18	0.26			0.4	0.04
	BL+TC+CW+HG	-14.27	0.16	0.08	0.26	0.4		0.44	0.04
Females age group 1-4 PP	HG	-105.86	1.83					0.65	0
(Number of female sheep=459)	HG+BL	-108.34	1.74	0.14				0.66	0.01
	HG+BL+HW	-110.58	1.71	0.1	0.11			0.67	0.01
Males age group									
1PP	BC	7.32	5.03					0.77	0
	BC+BL	-3.24	4.13	0.21				0.86	0.09
	BC+BL+HW	-7.95	3.95	0.15	0.15			0.89	0.03
2PP	CW	22.29	0.4					0.31	0
	CW+HG	-81.63	0.35	1.42				0.52	0.21
3PP	TC	27.77	0.36					0.32	0
	TC+CW	21.44	0.29	0.5				0.5	0.18
	TC+CW+BC	18.4	0.25	0.42	1.75			0.57	0.07
Males age group 1-4 PP	HG	-132.25	2.19					0.79	0
(Number of male sheep=171)	HG+BL	-133.97	2.05	0.19				0.81	0.02

HG= Heart Girth; BL=Body Length; HW= Height at wither; CW=Chest Width; PW = Pelvic Width; TC = Tail circumference; BCS= Body Condition Score; SC = Scrotal Circumference; PPI = 1 Pair of Permanent Incisors; 2 PPI = 2 Pairs of Permanent Incisors; 3 PPI = 3 Pairs of Permanent Incisors; 4 PPI = 4 Pair Permanent Incisors.

and besides, some variables are more affected by the animal posture compared to others, which makes it so difficult to measure such variables accurately. The positive correlation between body weight and heart girth and body length in males and female can be used to predict body weight based on it. The regression equations were developed for male and female by using chest girth and body length as independent variable and body weight as dependent (predicted) variable.

Parameter estimates in multiple linear regression model showed that rams had higher R^2 (81%) value than ewes (67%). This point out that those linear measurements could predict more accurately in males compared to females. Overall equation of the pooled age group using heart girth and body length as important variable used for the prediction of body weight for each male and female sheep. The prediction of body weight could be based on the following regression equation: Y=-108.34+1.74 x_1 + 0.14 x_2 for ewes and Y= -133.97+2.05 x_1 + 0.19 x_2 for rams.

Multivariate analysis for discrimination of sheep populations

Multivariate analysis was conducted using quantitative variables for mature females and males separately at all age classes. Among the multivariate analysis canonical and discriminant analyses were employed.

Canonical discriminate analysis

All squared Mahalanobis' distances obtained among districts populations for females and males were significant (P<0.0001), indicating the existence of measurable differences between females and males district populations or districts (Table 7). The largest distance was found between district 2 and 3 for both female (4.186) and male population (2.930). All multivariate tests i.e. Wilk's Lambda, Pillia's Trace, Hotelling-Lawley Trace and Ray's Greatest Root obtained from canonical discriminant analysis showed significant differences (P<0.0001) among districts. This result is consistent with that of the univariate analysis that tests the hypothesis that class means are equal. In this test, values of most quantitative variables considered were highly significantly different (P<0.0001) among districts.

Discriminant analysis

The discriminant analysis carried out gave complementary information to the results found in Table 8. The overall classification rates (hit rate) of female and male sample population were 39.7% and 32.2%, respectively. For females, most individuals were classified into their source population (54.86% for Tocha, 67.09% for Mareka, and 58.87 %t for Konta).

As indicated in Table 9 males also a more or less similar patterns were observed and most individuals were classified into their source population (64.81% district 1, 70.21% district 2, and 68.33% district 3).

Table 7: Squared Mahalanobis' distance among district populations for male and female populations.

District	Males			Females		
	1	2	3	1	2	3
1	0			0		
2	1.621	0		2.098	0	
3	1.096	2.93	0	2.15	4.186	0
District 1 = Tocha, 2 = Mareka, and 3 = Konta						

Table 8: Percent classified into each district (hit rate) for female populations using discriminant analysis.

From district	1	2	3	Over all
1	79 (54.86)	32 (22.22)	33 (22.92)	144 (100)
2	27 (17.09)	106 (67.09)	25 (15.82)	158 (100)
3	40 (28.37)	18 (12.77)	83 (58.87)	141 (100)
Total	**146 (32.96)**	**156 (35.21)**	**141 (31.83)**	**443 (100)**
Priors	0.3333	0.3333	0.3333	
Rate	0.4514	0.3291	0.4113	0.3973
District 1= Tocha, 2 = Mareka, and 3 = Konta				

Table 9: Percent classified into each district (hit rate) for male populations using discriminant analysis.

From district	1	2	3	Over all
1	35 (64.81)	7 (12.96)	12 (22.22)	54 (100)
2	9 (19.15)	33 (70.21)	5 (10.64)	47 (100)
3	10 (16.67)	9 (15.00)	41 (68.33)	60 (100)
Total	**54 (33.54)**	**49 (30.43)**	**58 (36.02)**	**161 (100)**
Priors	0.3333	0.3333	0.3333	
Rate	0.3519	0.2979	0.3167	0.3224
District 1 =Tocha, 2 =Mareka, and 3 =Konta				

Conclusion

The morphological variables considered in this study (coat color pattern, coat color, head profile, tail type, tail conformation and ear orientation) are similar between the two sexes and among the districts. Except body condition score (p<0.05), sex of the sheep had no significant (p>0.05) effect on the body weight and other measurements. Age group and location had strong significant effect (p<0.01) on body weight and other measurable traits. But, scrotal circumference, height at wither, heart girth and body condition score were not influenced (p>0.05) by location. The interaction of sex and age group was significant (p<0.01) on the body weight of the sheep. The interaction of age group and location was highly significant (p<0.01) for body weight and also significant (p<0.05) for chest width and body length. Differently, the interaction was not significant for pelvic width, tail circumference , chest width, tail length, ear length, scrotal circumference, height at wither, heart girth and body condition. In general, positive and highly significant (P<0.01) correlations were observed between body weight and most of the body measurements. Selection on chest girth and body length could result in improved live weight. Scrotal circumference had strong correlation with body weight; it may also be used as selection criteria of rams. Heart girth and body length were considered to be the most important variables for the prediction of body weight for each male and female sheep. All squared Mahalanobis' distances obtained among districts populations for females and males were significant (P<0.0001), indicating the existence of measurable differences between females and males district populations or districts. For males and females, most individuals were classified into their source population.

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Conflict of interest

The authors declare no conflict of interest.

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