

Phenotypic Characterization of Indigenous Goat Types in West Gojjam Zone, Amhara National Regional State, Ethiopia

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Abstract
The study was carried out in Bahirdar Zuria, Yilmana Densa and Gonji Kolela districts of Western Gojjam zone of Amhara National Regional State. The objectives of the study were to undertake phenotypic characterization of indigenous goat type found in the study area under farmers' management condition and to develop equation for prediction of body weight by using linear body measurements. A total of 600 goats were sampled randomly for characterization of phenotypic traits. Data were gathered through field observations and linear body measurements of sample populations. The Sampled goats were identified by sex, age and district. The most dominant coat color patterns in the sampled populations were plain and patchy with the most frequently observed coat color type being brown and fawn followed by white. Sex of animals had significant effect on all of the body measurements, except ear length, tail length and horn length. District effect was not significant ($p>0.05$) for all of the body measurements. Dentition classes of animals contributed significant differences to body weight and most of the linear body measurements. The result of the multiple regression analysis showed that chest girth explained more variation than any other linear body measurements in both does (88%) and bucks (91%). The prediction of body weight could be based on regression equation $y = -40.35 + 0.65x$ for female sample population and $y = -33.71 + 0.82x$ for male sample goat population where y and x are body weight and chest girth, respectively. Most of the body measurements of goats were affected by sex and dentition class differently, whereas district effect was not apparent across all of the body measurements. Further characterization of goats in the study area at molecular level should be done.
Keywords: Body weight, characterization, indigenous, linear body measurement, regression

1. Introduction

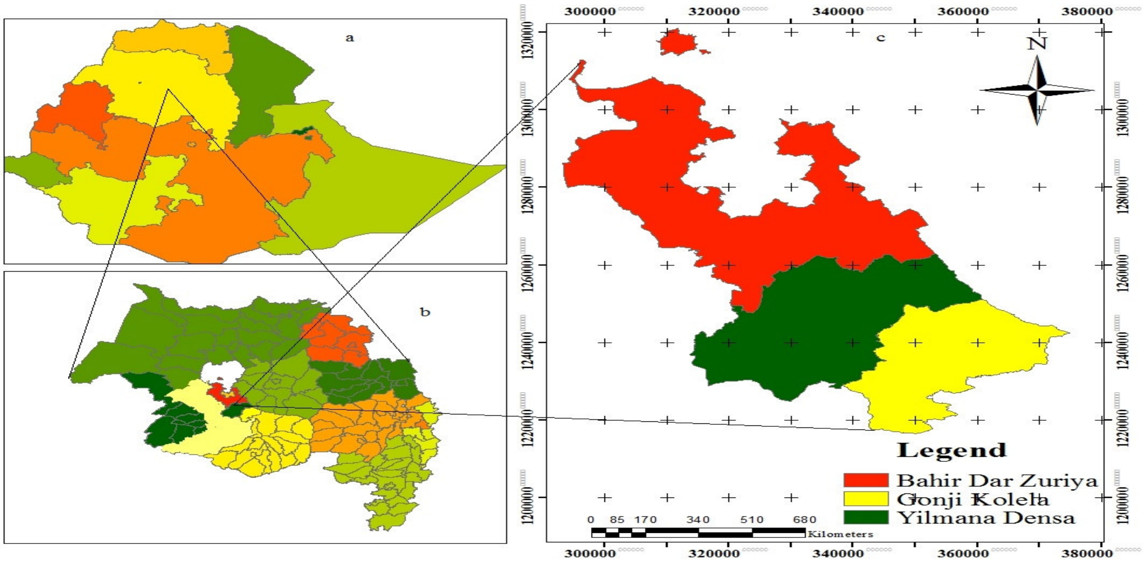
In developing countries, livestock production is mostly subsistence oriented and fulfills multiple functions that contribute more for food security (Roessler *et al.,* 2008; Duguma *et al.,* 2010). The demand for livestock products is increasing due to the growing urban population, while farm areas are shrinking considerably as a result of an increase in the rural population (Siegmund-Schultze *et al.,* 2009). Goat can survive and reproduce in harsh environmental conditions and on poor quality fibrous feeds. They have a high reproductive performance and are drought resistant (Peacock, 1996). They have also socio-economic importance whereby they provide meat, milk, skin and fiber, as well as manure and serve as the sole or subsidiary livelihood for a large number of small and marginal farmers and landless laborers (Thiruvenkadan and Karunanithi, 2006**).**

There are approximately 570 breeds and types of goats in the world, of which 89 are found in Africa (Galal, 2005). The goat population of Ethiopia ranks high both in Africa and the world. According to CSA (2012), the number of goats reported in the country is estimated to be about 22.6 million, of which about 70.6% are females and 29.4% are males. The goat population of Ethiopia has been phenotypically classified into 11 distinct major breed types or populations and five additional sub-types (Workneh, 1992; Alemayehu, 1993; Nigatu, 1994; FARM-Africa, 1996; Getinet, 2001; IBC, 2004). However, genetic/molecular characterization revealed only the presence of only eight distinctively different breed types or populations in the country: Arsi-Bale, Gumez, Keffa, Woyto-Guji, Abergelle, Afar, highland goats (previously separated as Central and North-West highland) and the goats from the previously known as Hararghe highland, Short-eared Somali and Long-eared Somali (Tesfaye, 2004). Nevertheless, it has been documented that about 75% of the genetic diversity of the Ethiopian goats is present in four breeds: Afar, Abergelle, Gumuz and keffa with marginal loss of diversity of 24.32%, 19.22%, 16.59% and 12.19%, respectively (Tesfaye 2004). Designing appropriate breeding programs is impossible for breeds that have not been adequately characterized either phenotypically and/or genetically (Mwacharo et al2006). The first step of the characterization of local genetic resources is to assess variation of morphological traits (Delgado et al2001). Although phenotypic characterization is important in breed identification and classification, it is scanty in West Gojjam zone of Amhara National Regional State. This study, therefore, was carried out to undertake phenotypic characterization of indigenous goat type in their environment and to develop equation for prediction of body weight of goats by using LBMs.

2. Materials and Methods

2.1. Description of Study Area

Figure 1. Map of the study area (a: Ethiopia; b: Amhara National Regional State; c: study districts)



Bahir Dar Zuria woreda is bordered on the south by Yilmana Densa, on the southwest by Mecha, on the northwest by the Lesser Abay River, which separates it from Semien Achefer, on the north by Lake Tana, on the shores of Lake Tana situates the city and special zone of Bahir Dar, and on the east by the Abay River which separates it from the South Gondar Zone. Gonji Kolela was the second woreda selected for the study. It is bordered on the south by Bibugn woreda, on the East by Hulet Ejju Enese woreda, on the West by Yilmana Densa woreda and on the north by South Gondar Zone. Yilmana Densa was the third woreda considered for the study. It is bordered on the south by Kuarit, on the southwest by Sekela, on the west by Mecha, on the north by Bahir Dar Zuria, on the east by the Abay River and on the southeast by the East Gojjam Zone. The study areas situated at an elevation of between 1700 and 2200 masl. The average annual temperature and rainfall of the districts were range between 18^0C-21^0C and 1000-1150mm, respectively.

2.2. Sampling Procedure

A multi-stage purposive sampling technique was employed for the selection of districts and peasant associations for the study. In the first stage, districts known for goat populations were identified and followed by identification of potential peasant association and villages. Potentials for goat production and road accessibility were used as criteria in selecting the sites. Thus, three districts were purposively selected based on goat population potential and road accessibility. From each districts three peasant associations (PA) were selected purposively based on the same criteria. A total of 600 goats were used for measurement (200 from each district).

2.3. Data Collection

2.3.1. Qualitative traits

Visual observation was made and morphological features were recorded based on breed morphological characteristics descriptor list of FAO (2012) for phenotypic characterization of goat. Each animal was identified by its sex, dentition and sampling site. Dentition record was included, as this was the only reliable means to estimate the approximate age of an animal.

2.3.2. Quantitative traits

Linear body measurements were taken using measuring tape while body weight of animals was measured using suspended spring balance. Goats were classified into five age groups: no pair of permanent incisor (0 PPI), 1PPI, 2 PPI, 3 PPI and 4 PPI to represent age of less than 1 year, 1-1 1/2 years, 1½-2years, 2½-3 years and more than three years, respectively (Wilson, 1991).

2.4. Data Management and Analysis

2.4.1. Qualitative and body measurement data

Qualitative and quantitative body measurement data were first entered into Excel 2007 computer software and analyzed using statistical analysis system (SAS version 9.2, 2008). Qualitative data were analyzed using the frequency procedure of SAS, 2008 while quantitative data were analyzed using the Generalized Linear Model (GLM) procedure of SAS. Sex, district and age group were fitted as fixed effects while linear body measurements were fitted as dependent variables. When analysis of variance declares significance, least square means were separated. Pearson's correlation coefficients were estimated among body weight and linear body measurements and between linear body measurements for females and males (SAS, 2008). Correlations (Pearson's correlation coefficients) between body weight and the linear measurements were computed for the population within each sex. A multiple correspondence analysis was carried out on qualitative traits to determine their associations on a bi-dimensional graph. The REG procedures of SAS (2008) were used to determine the best fitted regression equation for the prediction of body weight from linear body measurements. For male goat body weight and other body measurements including Height at whither (HW), Rump height (RH), Body length (BL), Chest width (CW), Chest girth (CG), Rump length (RL), Rump width (RW), Cannon bone length (CBL), Ear length (EL), Horn length (HL), Tail length (TL), and Scrotum circumference (SC) were considered. The same body measurements except scrotum circumference were considered for females.

The following models were used for the estimation of body weight from LBM (s).

For male:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{12} X_{12} + e_j$

Where:

Y = the response variable (body weight)

β_0 =the intercept

$X_1, \ldots, X_{12}$ are the explanatory variables (height at wither, rump height, body length, chest width, chest girth, rump length, rump width, cannon bone length, ear length, horn length, tail length and scrotal circumference)

$\beta_1, \ldots, \beta_{12}$ are regression coefficients of the variables $X_1, \ldots, X_{12}$

ej =random error

For female:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{11} X_{11} + e_j$

Where:

Y = the dependent variable body weight

β_0 = the intercept

$X_1, \ldots, X_{11}$ are independent variables (height at whither, rump height, body length, chest width, chest girth, rump length, rump width, cannon bone length, ear length, horn length and tail length).

$\beta_1, \ldots, \beta_{11}$ are regression coefficients of the variable $X_1 \ldots, X_{11}$

ej =random error

3. Results and Discussion

3.1. Phenotypic Characterization

3.1.1. Qualitative traits of the sample population

The most frequent color patterns observed in the study area were patchy (44.5%), plain (42.83%) and spotted (12.67%). Brown/fawn coat type was mostly observed in the study area (Table 1). In contrast to this, in Afar region, red dominant coat color was observed except in Babbile district where white dominant coat color accounted for 42.5% (Mahilet, 2012). Smooth hair coat type was predominant in the study area, which accounted for 55.17%, whereas, glossy hair coat type were only 0.17% of the sampled goat population. In the study area among the sampled goat population the majority (85.67%) of goats had horn, whereas, 14.33% were polled. But in the other study all of the sampled goats in Gewane and Amibara districts were horned (Seifemichael, 2013). In contrast to Seifemichael (2013) in Gurawa district incidence of polled goat was higher than horned one (Mahilet, 2012). Straight horn shape was the most frequently observed in the study area (Table 1). About (65.5%) of the goats in the study area were having a horn with backward orientation and none had a horn with lateral orientation.

Horizontal ear orientation was the most frequently observed in the districts accounting for 41% of the sampled population, whereas 35.5% of goats had semi-pendulous ear orientation. The majority (91.5%) of goat population in the study area had concave head profile. Only 0.67% of goats had convex head profile and none had markedly convex head profile. According to Seifemichael (2013) the goat population in Gewane district having concave facial profile (50.50%) was lower than the current result. In the study area 62.17% of sampled goats had straight back profile. Beard was mostly observed in male goat population than females while toggle was more pronounced in female. Most of the male goat population in the study site possessed beard which accounted for 81.25%, 92.5% and 91.25% in Bahirdar Zuria, Yilmana Densa and Gonji Kolela, respectively. Whereas, 43.33% of female goats in Bahirdar Zuria, 35.83% in Yilmana Densa and 39.17% in Gonji Kolela districts possessed beard. A total of only 7.83% of both male and female goat population in the study area possessed wattle. Ruff was most frequent in male goat with 56.25% in Bahirdar Zuria, 58.75% in Yilmana Densa and 67.5% in Gonji Kolela while for female animals the proportions were 1.67% in Bahirdar Zuria, 2.5% in

Yilmana Densa and 5% in Gonji Kolela.

Figure 2. Goats with different coat color patterns at Gonji (left) and patchy coat color pattern of a buck at Ageta (Yilmana Densa) (right)

Table 1. Qualitative traits of goats in the study area by sex and district

Morphological Character	Districts: Bahirdar Zuria		Yilmana Densa		Gonji Kolela		Overall mean for both sexes
	Male N (%)	Female N (%)	Male N (%)	Female N (%)	Male N (%)	Female N (%)	N (%)
Coat color Pattern							
Plain	43(53.75)	45(37.5)	43(53.75)	45(37.5)	43(53.75	38(31.67)	257(42.83)
Patchy	29(36.25)	57(47.5)	30(37.5)	60(50)	35(43.75)	56(46.67)	267(44.50)
Spotted	8(10)	18(15)	7(8.75)	15(12.5)	2(2.5)	26(21.67)	76(12.67)
			X^2value=1.276ns				
Coat color type							
White	27(33.75)	36(30)	12(15)	24(20)	16(20)	22(18.33)	137(22.83)
Black	1(1.25)	6(5)	4(5)	10(8.33)	6(7.5)	7(5.83)	34(5.67)
Dark red	6(7.5)	2(1.67)	1(1.25)	5(4.17)	3(3.75)	4(3.33)	21(3.50)
Light red	6(7.5)	6(5)	6(7.5)	14(11.67)	4(5)	15(12.5)	51(8.50)
Brown/fawn	12(15)	22(18.33)	32(40)	21(17.5)	24(30)	29(24.17)	140(23.33)
Grey	5(6.25)	4(3.33)	3(3.75)	6(5)	6(7.5)	7(5.83)	31(5.17)
White dominant On black	8(10)	12(10)	5(6.25)	15(12.5)	6(7.5)	12(10)	58(9.67)
Black dominant on white	4(5)	7(5.83)	2(2.5)	5(4.17)	4(5)	7(5.83)	29(4.83)
White dominant On red	7(8.75)	15(12.5)	7(8.75)	11(9.17)	7(8.75)	10(8.33)	57(9.50)
Red dominant on white	4(5)	10(8.33)	8(10)	9(7.5)	4(5)	7(5.83)	42(7.00)
			X^2value =24.41ns				
Hair coat type							
Glossy	1(1.25)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	1(0.17)
Smooth hair	39(48.75)	74(61.67)	29(36.25)	75(62.5)	35(43.75)	79(65.83)	331(55.17)
Straight long hair	28(35)	31(25.83)	34(42.5)	18(15)	36(45)	17(14.17)	164(27.33)
Curly rough	9(11.25)	8(6.67)	13(16.25)	18(15)	3(3.75)	13(10.83)	64(10.67)
Dull	3(3.75)	7(5.83)	4(5)	9(7.5)	6(7.5)	11(9.17)	40(6.67)
			X^2value = 11.52ns				
Horn							
Present	66(82.5)	105(87.5)	76(95)	101(84.17)	74(92.5)	92(76.67)	514(85.67)
Absent	14(17.5)	15(12.5)	4(5)	19(15.83)	6(7.5)	28(23.33)	86(14.33)
			X^2value= 2.47ns				
Horn shape							
Straight	41(51.25)	42(35)	30(37.5)	55(45.83)	38(47.5)	70(58.33)	276(46)
Curved	32(40)	69(57.5)	38(47.5)	48(40)	39(48.75)	39(32.5)	265(44.17)
Spiral	7(8.75)	9(7.5)	12(15)	17(14.17)	3(3.75)	11(9.17)	59(9.83)
			X^2value = 14.03^*				

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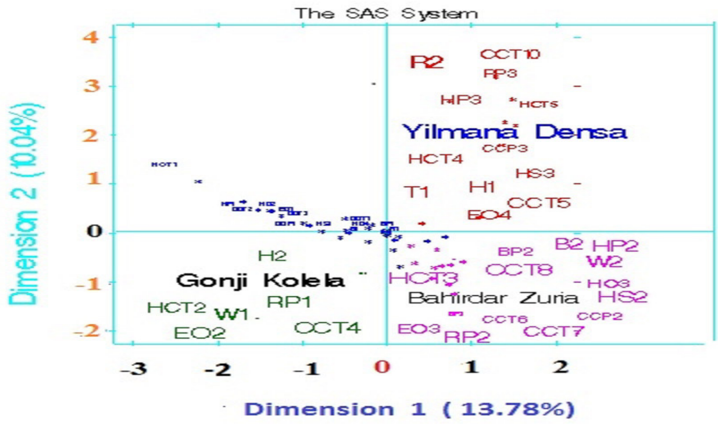
Horn orientation							
Lateral	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
Obliquely upward	11(13.75)	20(16.67)	9(11.25)	35(29.17)	11(13.75)	35(29.17)	121(20.17)
Back ward	43(53.75)	82(68.33)	50(62.5)	81(67.5)	52(65)	85(70.83)	393(65.50)
Polled or stumps	26(32.5)	18(15)	21(26.25)	4(3.33)	17(21.25)	0(0.00)	86(14.33)
			*X^2value =17.26**				
Ear orientation							
Erect	15(18.75)	21(17.5)	18(22.5)	23(19.17)	12(15)	18(15)	107(17.83)
Semi-pendulous	32(40)	41(34.17)	29(36.25)	42(35)	26(32.5)	43(35.83)	213(35.5)
Pendulous	6(7.5)	8(6.67)	4(5)	2(1.67)	9(11.25)	5(4.17)	34(5.67)
Horizontal	27(33.75)	50(41.67)	29(36.25)	53(44.17)	33(41.25)	54(45)	246(41)
			X^2value =6.19ns				
Head profile							
Straight	4(5)	11(9.17)	7(8.75)	9(7.5)	7(8.75)	9(7.5)	47(7.83)
Concave	75(93.75)	108(90)	73(91.25)	111(92.5)	71(88.75)	111(92.5)	549(91.5)
Convex	1(1.25)	1(0.83)	0(0.00)	0(0.00)	2(2.5)	0(0.00)	4(0.67)
Markedly convex	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
			X^2value=2.05ns				
Back profile							
Straight	51(63.75)	87(72.5)	46(57.5)	73(60.83)	44(55)	72(60)	373(62.17)
Slopes toward the rump	25(31.25)	33(27.5)	34(42.5)	47(39.17)	36(45)	48(40)	223(37.17)
Slopes toward the wither	4(5)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	4(0.67)
			*X^2value=15.73**				
Rump profile							
Flat	49(61.25)	71(59.17)	49(61.25)	74(61.67)	42(52.5)	71(59.17)	356(59.33)
Slopy	28(35)	45(37.5)	28(35)	39(32.5)	35(43.75)	46(38.33)	221(36.83)
Roofy	3(3.75)	4(3.33)	3(3.75)	7(5.83)	3(3.75)	3(2.5)	23(3.83)
			X^2value=2.91ns				
Beard							
Present	65(81.25)	52(43.33)	74(92.5)	43(35.83)	73(91.25)	47(39.17)	354(59)
Absent	15(18.75)	68(56.67)	6(7.5)	77(64.17)	7(8.75)	73(60.83)	246(41)
			X^2value=0.12ns				
Wattle							
Present	8(10)	5(4.17)	12(15)	6(5)	8(10)	8(6.67)	47(7.83)
Absent	72(90)	115(95.8)	68(85)	114(95)	72(90)	112(93).3	553(92.17)
			X^2value=0.88ns				
Ruff							
Present	45(56.25)	2(1.67)	47(58.75)	3(2.5)	54(67.5)	6(5)	157(26.17)
Absent	35(43.75)	118(98.3)	33(41.25)	117(97.5)	26(32.5)	114(95)	443(73.83)
			X^2value=2.398ns				
Toggle							
Present	3(3.75)	37(30.83)	13(16.25)	47(39.17)	17(21.25)	42(35)	159(26.5)
Absent	77(96.25)	83(69.17)	67(83.75)	73(60.83)	63(78.75)	78(65)	441(73.5)
			*X^2value=6.52**				

ns=non-significant;*P<0.05

A multiple correspondence analysis was carried out on the fourteen qualitative traits recorded and a bi-dimensional graph representing the associations among the different categories of qualitative traits is presented in Figure 3. The interpretation is based on points found in approximately the same direction from the origin and in approximately the same region of the space. From the figure it can be seen that 23.82% of the total variation is explained by the first two dimensions (13.78%) by the first and (10.04%) by the second dimensions. On the identified dimensions, the goat population in Bahirdar Zuria district were clustered together with grey, white and black (white dominant), white and black (black dominant) coat color type, patchy coat color pattern, straight long hair coat type, pendulous ear orientation, concave facial profile, backward horn orientation, curved horn shape, back profile with slopes toward the rump, sloppy rump profile, no beard and wattle. In Yilmana Densa district the goat populations were closely associated with red together with white (red dominant) and brown and fawn coat color type, spotted coat color pattern, curly rough and dull hair coat type, horizontal ear orientation, convex head profile, spiral horn shape, roofy rump profile, no ruff, having horn and toggle. Whereas, in Gonji Kolela district the goat population was closely associated with smooth hair coat type, having wattle, no horn, flat rump profile, semi-pendulous ear orientation and light red coat color type.

Figure 3. Bi-dimensional plot showing the associations among the categories of the different morphological variables



Legend for figure 3

Variable Name	Levels and Description
Coat color Pattern	CCP1=Plain CCP2=Patchy CCP3=Spotted
Coat color type	CCT1= White CCT2= Black CCT3=Dark red CCT4= Light red CCT5= Brown and fawn CCT6= Grey CCT7= White dominant on black CCT8=Black dominant on white CCT9=White dominant on red CCT10=Red dominant on white
Hair coat type	HCT1=Glossy HCT2=Smooth hair HCT3=Straight long hair HCT4=Curly rough HCT5=Dull
Horn	H1=Present H2=Absent
Horn shape	HS1=Straight HS2=Curved HS3=Spiral
Horn orientation	HO1=Lateral HO2=Obliquely upward HO3=Backward HO4=Polled or just stumps
Ear orientation	EO1=Erect EO2=Semi-pendulous EO3=Pendulous EO4=Carried horizontally
Head profile	HP1=Straight HP2=Concave HP3=Convex HP4=Markedly convex
Back profile	BP1= Straight BP2= Slopes toward the rump BP3=Slopes toward the wither
Rump profile	RP1=Flat RP2= Sloppy RP3= Roofy
Beard	B1=Present B2=Absent
Wattle	W1=Present W2=Absent
Ruff	R1=Present R2=Absent
Toggle	T1= Present T2= Absent

3.1.2. Body weight and linear body measurements

Sex effect: - The least square means and standard errors for the effect of sex and their interaction on body weight and other body measurement are presented in Table 2. In all three districts sex had significant effect on body weight, body length, chest girth, height at wither, rump height, rump width, cannon bone length, chest width and rump length, whereas e ar length, tail length and horn length were not affected by sex. Male goats were having consistently higher values than females.

Age effect: - The size and shape of the animal increases until the animal reach its maturity and the effect of age on body weight and other body measurements were also observed in different goat breeds of Ethiopia (Yoseph, 2007). Body weight and all body measurements were significantly affected by age except tail length and ear length. Body weight, chest girth, body length, height at wither, rump height, cannon bone length, rump length and rump width increased as age increased from 0PPI to 4PPI.

Location Effect: - Body measurements were not affected by location and this might be due to geographical proximity of the three districts. In contrast to this finding in Meta, Gurawa and Babbile districts, location was found to strongly affect body length, chest depth, height at whither, rump height, ear length, fore canon circumference, fore canon height, neck length, pelvic width, rump length, rump width, scrotal circumference and tail length (Mahilet, 2012).

Sex by age interaction: - The interaction of sex and age group was significant ($p<0.05$) for body weight and all other body measurements, except ear length, tail length and horn length. In each age group males were having higher values in height at wither, rump height, canon bone length, rump width, rump length and chest width than females. The value of body weight for goats of both sexes increased as dentition class increased from 0PPI to 4PPI.

Table 2. Least square mean (± SE) body weight (kg) and other linear body measurements by sex, age and location

Effect and Level	BL LSM±SE	CG LSM±SE	HW LSM±SE	RH LSM±SE	CBL LSM±SE	EL LSM±SE
Overall	60.19±0.23	74.87±0.36	64.51±0.24	66.86±0.25	12.78±0.05	13.89±0.05
R^2	0.60	0.34	0.54	0.57	0.37	0.01
Sex	*	*	*	*	*	**Ns**
Male	60.91^{a} ±0.24	76.77^{a} ±0.47	65.81^{a} ±0.27	68.98^{a} ±0.26	13.15^{a} ±0.06	13.89^{a} ±0.07
Female	59.71^{b} ±0.19	73.59^{b} ±0.38	63.65^{b}±0.22	65.45^{b} ±0.21	12.54^{b} ±0.05	13.89^{b}±0.06
Age	*	*	*	*	*	**Ns**
0PPI	53.41^{e}±0.34	68.09^{d}±0.68	59.96^{c}±0.38	62.34^{c}±0.38	11.79^{d}±0.07	13.94^{a}±0.13
1PPI	57.39^{d}±0.34	71.45^{c}±0.61	60.44^{c}±0.38	63.11^{c}±0.37	12.38^{c}±0.09	13.08^{a}±0.13
2PPI	61.65^{c}±0.36	76.91^{b}±0.68	63.77^{b}±0.33	66.00^{b}±0.32	12.88^{b}±0.12	13.99^{a}±0.12
3PPI	63.76^{b}±0.34	79.37^{a}±0.68	69.68^{a}±0.29	72.13^{a}±0.38	13.46^{a}±0.09	13.80^{a}±0.13
4PPI	65.35^{a}±0.31	80.08^{a}±0.71	69.79^{a}±0.38	72.50^{a}±0.38	13.72^{a}±0.09	13.93^{a}±0.13
Location	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**
Bahirdar Zuria	60.25^{a}±0.26	75.42^{a}±0.52	64.96^{a}±0.30	67.39^{a}±0.29	12.85^{a}±0.07	13.86^{a}±0.09
Yilmana Densa	60.37^{a}±0.26	74.98^{a}±0.52	64.66^{a}±0.29	67.06^{a}±0.29	12.82^{a}±0.07	13.90^{a}±0.09
Gonji Kolela	60.32^{a}±0.26	75.15^{a}±0.52	64.57^{a}±0.29	67.20^{a}±0.29	12.87^{a}±0.07	13.91^{a}±0.09
Sex by age	*	*	*	*	*	**Ns**
Female, 0PPI	53.65^{f}±0.43	64.96^{e}±0.85	59.94^{e}±0.48	61.82^{e}±0.43	11.63^{g}±0.12	13.90^{a}±0.16
Female,1PPI	56.53^{f}±0.43	71.88^{cd}±0.86	59.88^{e}±0.48	61.99^{e}±0.48	12.20^{ef}±0.12	13.83^{a}±0.16
Female,2PPI	60.32^{c}±0.39	74.22^{c}±0.84	63.00^{d}±0.44	64.11^{d}±0.41	12.64^{d}±0.14	13.94^{a}±0.14
Female,3PPI	64.06^{b}±0.43	79.16^{b}±0.86	68.04^{b}±0.48	70.11^{b}±0.48	13.06^{c}±0.12	13.88^{a}±0.16
Female,4PPI	64.0^{b}±0.45	77.74^{b}±0.86	67.40^{b}±0.47	69.23^{bc}±0.48	13.15^{ab}±0.12	13.91^{a}±0.16
Male, 0PPI	53.17^{f} ±0.53	71.23^{d}±1.05	59.99^{e}±0.59	62.86^{de}±0.58	11.96^{fg}±0.15	13.98^{a}±0.19
Male,1PPI	58.25^{d} ±0.49	71.02^{d}±1.05	61.00^{e}±0.59	64.23^{d}±0.54	12.55^{de}±0.12	13.77^{a}±1.24
Male,2PPI	62.98^{b} ±0.56	79.61^{ab}±0.94	64.54^{c}±0.52	67.89^{c}±0.58	13.11^{c}±0.15	14.04^{a}±0.19
Male,3PPI	63.46^{b} ±0.53	79.58^{ab}±0.97	71.32^{a}±0.60	74.16^{a}±0.58	13.86^{b}±0.14	13.72^{a}±0.19
Male,4PPI	66.70^{a}±0.53	82.42^{a}±1.05	72.20^{a}±0.59	75.77^{a}±0.58	14.28^{a}±0.15	13.96^{a}±0.19

Effect and level	HL LSM±SE	RW LSM±SE	SC LSM±SE	TL LSM±SE	CW LSM±SE	RL LSM±SE	BW LSM±SE
Overall	9.0±0.15	15.4±0.07	21.26±0.18	13.5±0.05	16.71±0.1	13.19±0.07	28.03±0.33
CV%	35.67	7.93	10.98	8.77	11.23	9.10	20.39
R^2	0.16	0.53	0.35	0.04	0.47	0.51	0.52
Sex	**Ns**	*	-	**Ns**	*	*	*
Male	8.94^{a}±0.17	16.00^{a}±0.08	21.26±0.18	13.55^{a}±0.07	17.55^{a} ±0.12	13.97^{a}±0.07	29.19^{a}±0.37
Female	9.09^{a}±0.22	15.00^{b}±0.06	NA	13.46^{a}±0.06	16.16^{b} ±0.09	12.67^{b}±0.06	27.25^{b}±0.30
Age	*	*	*	**Ns**	*	*	*
0PPI	7.97^{cd}±0.30	13.79^{d}±0.12	19.55^{c}±0.34	13.58^{a}±0.11	15.04^{c}±0.17	11.98^{d}±0.11	20.05^{d}±0.53
1PPI	7.45^{d}±0.30	14.69^{c}±0.11	19.32^{c}±0.34	13.34^{a}±0.11	14.93^{c}±0.17	12.50^{c}±0.11	24.46^{c}±0.53
2PPI	8.83^{c}±0.32	15.47^{b}±0.09	21.44^{b}±0.33	13.61^{a}±0.11	17.23^{b}±0.15	13.30^{b}±0.10	29.19^{b}±0.52
3PPI	9.84^{b}±0.31	16.63^{a}±0.11	22.55^{a}±0.34	13.63^{a}±0.12	18.47^{a}±0.17	14.30^{a}±0.11	32.68^{a}±0.53
4PPI	11.0^{a}±0.32	16.92^{a}±0.11	23.42^{a}±0.34	13.38^{a}±0.11	18.59^{a}±0.17	14.51^{a}±0.11	33.74^{a}±0.53
Location	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**	**Ns**
Bahirdar Zuria	8.66^{a}±0.24	15.46^{a}±0.08	21.52^{a}±0.26	13.63^{a}±0.08	17.02^{a}±0.13	13.38^{a}±0.08	28.80^{a}±0.41
Yilmana Densa	9.21^{a}±0.25	15.56^{a}±0.08	21.14^{a}±0.26	13.46^{a}±0.08	16.77^{a}±0.13	13.32^{a}±0.08	27.78^{a}±0.41
Gonji Kolela	9.17^{a}±0.24	15.48^{a}±0.08	21.11^{a}±0.26	13.43^{a}±0.08	16.76^{a}±0.13	13.26^{a}±0.08	28.09^{a}±0.41
Sex by age	**Ns**	*		**Ns**	*	*	*
Female, 0PPI	7.81^{ef}±0.40	13.56^{f}±0.15	**NA**	13.49^{ab}±.14	14.67^{e}±0.23	10.99^{e}±0.14	19.0^{f}±0.67
Female. 1PP1	8.21^{e}±0.40	14.59^{d}±0.14	**NA**	13.51^{ab}±.14	14.63^{e}±0.22	12.10^{d}±0.14	22.14^{e}±.67
Female. 2PPI	8.88^{de}±0.41	15.01^{c}±0.14	**NA**	13.55^{ab}±.14	16.38^{c}±0.22	12.67^{c}±0.13	27.15^{d}±.65
Female. 3PPI	9.99^{bc}±0.38	15.82^{b}±0.14	**NA**	13.48^{ab}±.13	17.66^{b}±0.22	13.82^{b}±0.14	31.87^{a}±.66
Female. 4PPI	10.55^{ab}±0.40	16.00^{b}±0.14	**NA**	13.27^{ac}±.14	17.43^{b}±0.22	13.74^{b}±0.14	33.15^{abc}±.67
Male, 0PPI	8.12^{e}±0.46	14.03^{e}±0.19	19.55^{b}±0.34	13.67^{bc}±.17	15.40^{d}±0.27	12.96^{c}±0.17	23.80^{e}±.82
Male. 1PPI	6.69^{f}±0.46	14.78^{cd}±.17	19.32^{b}±0.34	13.17^{a}±.14	15.23^{de}±0.28	12.89^{c}±0.17	24.79^{e}±.84
Male. 2PPI	8.79^{cde}±.49	15.94^{b}±0.13	21.44^{c}±0.33	13.67^{bc}±.17	18.08^{b}±0.26	13.93^{b}±0.16	31.23^{c}±.80
Male, 3 PPI	9.68^{bcd}±.48	17.45^{a}±0.17	22.55^{a}±0.34	13.79^{b}±.15	19.28^{a}±0.27	15.18^{a}±0.17	32.50^{bc}±.82
Male, 4PPI	11.43^{a}±0.50	17.83^{a}±0.17	23.42^{a}±0.34	13.45^{ab}±.17	19.76^{a}±0.27	14.86^{a}±0.17	34.33^{ab}±.82

a,b,c,d,e,f,g 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; N.A= not available, EL= Ear length; RH= rump height; CBL= cannon bone length; RL= Rump length; RW= Rump width; SC= Scrotal circumference; BL= body length; CG= chest girth; HW= height at wither; BW=body weight; 0PPI= No Pair of Permanent Incisors; 1PPI= 1 Pair of Permanent Incisors; 2 PPI = 2Pairs of Permanent Incisors; 3PPI= 3 Pairs of Permanent Incisors; 4PPI = 4 pair of permanent incisors.

Figure 4. Relationship of live body weight with age and sex of goats

Regression Equation:
BW(SEX:f) = 19.15833 + 3.28125*PPI
BW(SEX:m) = 23.38162 + 2.768376*PPI

f = female and m = male; 0 = goat with no pair of permanent incisor (PPI), 1 = goat with1pair of permanent incisor, 2 = goat with 2 pair of permanent incisors, 3 = goat with 3 pair of permanent incisors, and 4 = goat with 4 pair of permanent incisors; BW =Body weight (observed response variable)

3.2. Correlation between Body Weight and LBMs

In males positive and strong association were found between body weight and chest girth (r=0.95), wither height (r=0.89), body length (r=0.90), rump height (r=0.90), chest width (r=0.92), rump width (r=0.90), rump length (r=0.91), and scrotal circumference (r=0.89). These linear body measurements were highly affected by the change in body weight; hence, they are more important in prediction of live body weight of the animal. Cannon bone length (r=0.62) had moderate and positive correlation with body weight. Horn length (r=0.45) showed mild and positive correlation, whereas tail length did not showed significant correlation and ear length showed negative correlation with body weight in both sexes. In females also chest girth (r=0.94), body length (r=0.88), height at wither (r=0.93), rump height (r=0.93), chest width (r=0.89), rump width (r=0.90) and rump length (r=0.92) showed strong positive correlation with body weight. Cannon bone length (r=0.67) and horn length (r=0.56) had moderate and positive correlation with body weight. Among the body measurements, chest girth was the most strongly correlated trait with body weight (r= 0.95 for males; r= 0.94 for females). This highest association of chest girth with body weight than other body measurements was in agreement with other results (Topal and Macit, 2004; Thiruvenkadan, 2005; Afolayan *et al.,* 2006).

Table 3. Coefficient of correlations between body weight and linear body measurements (Above diagonal for female and below diagonal for male)

	BW	CG	BL	HW	RH	CBL	EL	HL	CW	RW	TL	RL
BW		0.94*	0.88*	0.93*	0.93*	0.67*	-.03*	0.56*	0.89*	0.90*	0.01*	0.94*
CG	0.95*		0.62*	0.69*	0.69*	0.47*	-.04*	0.43*	0.73*	0.74*	0.05*	0.71*
BL	0.90*	0.68*		0.71*	0.68*	0.44*	-.01*	0.45*	0.65*	0.68*	0.00*	0.73*
HW	0.89*	0.69*	0.68*		0.78*	0.45*	-.01*	0.43*	0.74*	0.70*	0.02*	0.73*
RH	0.90*	0.69*	0.70*	0.78*		0.45*	-.02*	0.43*	0.74*	0.69*	0.02*	0.72*
CBL	0.62*	0.42*	0.47*	0.46*	0.48*		-.04*	0.23*	0.45*	0.45*	0.09*	0.46*
EL	-.03*	-.02*	-.02*	-.02*	-.01*	-.05*		0.05*	-.02*	-.01*	0.03*	-.01*
HL	0.45*	0.30*	0.24*	0.28*	0.31*	0.19*	.01*		0.49*	0.48*	0.02*	0.46*
CW	0.92*	0.72*	0.69*	0.74*	0.74*	0.48	-.02*	0.31*		0.71*	0.03*	0.70*
RW	0.90*	0.68*	0.72*	0.73*	0.75*	0.48*	-.03*	0.33*	0.73*		0.04*	0.75*
TL	0.00*	-.01*	-.01*	0.04*	0.02*	-.09*	0.06*	-.07*	0.01*	0.00*		0.01*
RL	0.91*	0.70*	0.62*	0.69*	0.68*	0.42*	-.04*	0.26*	0.70*	0.70*	0.01*	
SC	0.89*	0.71*	0.63*	0.70*	0.69*	0.46*	-.04*	0.30*	0.73*	0.69*	-.02*	0.69*

BW =Body weight; CG= Chest girth; BL=Body length; HW=Height at withers; RH = Rump height; CBL= Cannon bone length; EL=Ear length; HL= Horn length; CW= Chest width; RW= Rump width; TL= Tail length; RL= Rump length; SC= Scrotal circumference. **$P<0.05$.*

3.3. Prediction of Body Weight from LBMs

Weight has been the pivot on which animal production thrives. The knowledge of livestock weight assessment remains the backbone on which all animal production management practices are hinged (Otoikhian, *et al*., 2008). There is often a great need for livestock herdsmen to know how much their animals weigh. Reasonable skill in estimating weight is, therefore, necessary for the stockman as it will frequently be necessary to know weights when a weighbridge is not readily available or its use is not practically feasible (Singh and Mishra, 2004). Multiple linear regression analysis was carried out to predict live body weight of an animal. Regression of body weight over independent variables, which have higher correlation with body weight, was done to set adequate model for the prediction of body weight separately for each sex. In this study in order to develop the prediction equation, only eight quantitative traits were selected in the prediction equation for does (CG, HW, CW, RL, RW, HL, BL and TL) and only seven linear body measurements were taken to be incorporated in to the model for bucks (CG, BL, RL, RH, HW, HL and CBL) (Table 5). The fitted prediction model was selected with smaller C (p), AIC, SBC, RMSE and higher R^2 values. Chest girth selected first, which explain more variation than any other linear body measurements in both does (88%) and bucks (91%). Although there is slight increment on adjusted R^2 value when new variable added in the model, in the case of field measurement or if there is no availability of enough equipments and materials for measurement using only chest girth measurement for the prediction of body weight might be sufficient. The overall equation for all age group using CG as explanatory variable might be used for the prediction of body weight for male and female sample goat population in all districts. Thus, prediction of body weight could be based on regression equation $y = -40.35 + 0.65x$ for female sample population and $y = -33.71 + 0.82x$ for male sample goat population where, y and x are body weight and chest girth, respectively.

Table 4. Multiple regression analysis of live weight on different body measurements of does in all age groups

Model	Parameters													
	Intercept	*β1*	*β2*	*β3*	*β4*	*β5*	*β6*	*β7*	*β 8*	Adj. R^2	C(p)	AIC	RMSE	SBC
CG	-40.35	0.65								0.88	232.8	739.3	2.18	707.1
CG+HW	-64.68	0.51	0.86							0.93	180.6	681.2	1.98	632.8
CG+HW+CW	-84.23	0.77	1.42	-2.23						0.95	83.36	648.7	1.89	596.4
CG+HW+CW+RL	-78.42	0.67	1.16	-2.03	1.18					0.95	62.87	546.4	1.84	558.9
CG+HW+CW+RL+RW	-71.25	0.79	1.09	-1.87	2.4	-2.02				0.96	56.74	515.8	1.81	542.3
CG+HW+CW+RL+RW+HL	-72.71	0.77	1.06	-1.76	2.43	-1.79	-0.14			0.96	39.98	501.7	1.78	539.7
CG+HW+CW+RL+RW+HL+BL	-73.12	0.80	0.98	-1.71	2.02	1.88	-0.16	0.17		0.97	17.88	499.8	1.76	535.6
CG+HW+CW+RL+RW+HL+BL+TL	-71.32	0.81	0.99	-1.72	1.98	1.87	-0.16	1.98	-0.15	0.97	9.57	487.6	1.63	518.9

CG = Chest girth; HW = Height at wither; CW = Chest width; RL = Rump length; RW = Rump width; BL = Body length; TL = Tail length; HL = Horn length

Table 5. Multiple regression analysis of live weight on different body measurements of bucks in all age groups

Model	Parameters												
	Intercept	*B1*	*β2*	*β3*	*β4*	*β5*	*β6*	*β7*	Adjusted R^2	C(p)	AIC	RMSE	SBC
CG	-33.71	0.82							0.91	96.75	132.6	1.84	242.7
CG+BL	-37.46	0.61	0.31						0.92	88.32	125.3	1.79	219.5
CG+BL+RL	-37.26	0.44	0.29	1.06					0.93	42.82	101.5	1.68	212.8
CG+BL+RL+RH	-37.82	0.43	0.24	0.94	0.08				0.93	39.92	98.5	1.54	199.5
CG+BL+RL+RH+HW	-38.58	0.44	0.23	1.04	0.34	-0.28			0.94	26.71	92.3	1.48	176.4
CG+BL+RL+RH+HW+HL	-39.91	0.45	0.21	1.07	0.42	-0.33	-0.06		0.94	18.55	86.8	1.44	173.7
CG+BL+RL+RH+HW+HL+CBL	-39.24	0.44	0.23	1.09	0.44	-0.34	-0.06	-0.19	0.94	8.44	77.9	1.38	168.8

CG = Chest girth; HW = Height at wither; CBL = Cannon bone length; RH = Rump height; BL = Body length; RL = Rump length; HL = Horn length 4. Summary, Conclusions and Recommendations

The study was conducted to develop equation for prediction of body weight by using linear body measurements and to undertake phenotypic characterization of indigenous goat type. The study on characterization of physical features was done by observation and measurement on animals (N =600). The most dominant coat color patterns in the sample populations were plain and patchy with the most frequently observed coat color type being brown and fawn followed by white. The majority of the sample populations had concave head profile followed by straight. Sex of animals had significant effect ($P<0.05$) on body weight and all of the body measurements except, ear length, tail length and horn length. District effect was not significant in all of the body measurements ($P > 0.05$). Dentition classes of animals contributed significant differences to body weight and most of the linear body measurements, except ear length and tail length. Chest girth was selected first, which explain more variation than any other linear body measurements in both does (88%) and bucks (91%). The prediction of body weight could be based on regression equation $y = -40.35 + 0.65x$ for female sample population and $y = -33.71 + 0.82x$ for male sample goat population where y and x are body weight and chest girth, respectively. Generally most of the body measurements of goats were affected by sex and dentition class differently, whereas district effect was not apparent across all of the body measurements. Further characterization of goats in the study area at molecular level should be done.

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