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Phenotypic Characterization of Dorper, Local Sheep and Their Crossbred Sheep Population in North Eastern Amhara, Ethiopia

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Abstract
The study was conducted at Sirinka Agriculture Research Center to phenotypically characterize local (N=81), F_1 Local x pure Dorper 50% crossbred (N=128) and pure Dorper (N=94) sheep populations. We included 303 animals in the study. The animals were grouped into three age groups based on PPI as (0 PPI, 1 PPI, and ≥2 PPI). A total of 17 linear measurements, body weight and scrotal circumference for males were taken from each animal. General linear model of SAS 2008 was used for statistical analysis of the collected data. Breed, sex and age were the fixed effects considered for the analysis. Body weight and most of the linear measurements were significantly (P<0.01) affected by breed, age and sex effects. Body weight had the mean value of 28.47±0.8kg, 35.94±0.53kg and 46.65kg for local, crossbred and pure Dorper sheep, respectively. 41.32± 0.68kg and 32.61±0.54kg were the mean value of body weight of male and female sheep, respectively. Positive and highly significant (P<0.01) correlations were observed between body weight and most of the body measurements for all the three sheep breeds. The result of multiple linear regression analysis showed that chest girth explained more variation than any other measurements in both ewes (52%) and rams (78%) of local sheep, ewes (59%) and rams (86%) of crossbred sheep. The result of multiple linear regression analysis showed that chest girth (86%) and punch girth (70%) explained more variation than any other measurements in Dorper rams and ewes, respectively. Thus, it can be concluded that pure Dorper and crossbred sheep exhibit meat type traits. It was suggested to observe the performances of pure Dorper and crossbreds in farmers' management condition.
Keywords: Crossbred, Dorper, Phenotype, Meat type, Structural index

1. INTRODUCTION

Sheep population and diversity distribution in Ethiopia is paralleled with its diverse ecology. This diversity grouped into 9 breeds and 14 traditional sheep populations (G. Solomon *et al.,* 2007), and inhabited in the low land, midland, and highland agro ecologies of the country (IBC, 2004).

Sheep are the second most important species of livestock next to cattle in Ethiopia (CSA, 2016). Sheep production in Ethiopia is a major agricultural activity with a huge economic impact (IBC, 2004; G. Solomon *et al*., 2008). It plays an important economic role and makes a significant contribution to both domestic and export markets through provision of food (meat and milk) and non-food (manure, skin and wool) products.

In Ethiopia, attempts have been made to improve productivity of indigenous sheep through crossing with exotic breeds such as Corriedeale, Hampshire, Romney, Awassi and Dorper (G. Solomon and G. Tesfaye, 2009). Hence, to improve productivity of the local sheep through crossing, Dorper breed was imported from South Africa and stationed at Sirinka Agricultural Research Center (L. Mesfin *et al*., 2014).

Crossbreeding is considered as one of the options and it is potentially attractive breed improvement method due to its quick benefits as the result of breed complementarily and heterosis effects (Leymaster, 2002; Hayes *et al*., 2009).

Detailed and up-to-date information on indigenous knowledge of managing the breed, identification of important traits and typical features with full participation of farmers are important for effective and sustainable utilization of typical sheep breeds. Even though, crossbred sheep were highly distributed to the farmers in the study area information on morphometric measurements of the breeds, about the relationship between body linear measurements of the breeds, method of estimation of live body weight of the breeds', identification of important traits and features of the breed was not adequately available.

This study was carried out to evaluate variation on the structural indices and other morphometeric measurements among three populations in Ethiopia.

2. MATERIALS AND METHODS

2.1 Study Areas

The study was conducted at Sirinka Agricultural Research Center Amhara Regional State, Ethiopia. Sirinka is situated at an elevation of 1850 meters above sea level. It has a bi-modal type of rainfall receiving a mean annual rainfall at about 950 mm, in which the main rainy season "summer" occurs from June to September and the short rainy season “autumn” runs from February to April is erratic. The mean maximum and minimum temperatures of the area are 26ºC and 13ºC, respectively (SARC).

2.1.1 Description of breeds

The local sheep kept at the Sirinka station locally named as “Tumelie”. The community in the study area believes that the local sheep was a cross between Wollo and Afar sheep population. Solomon *et al.* (2008) classified this sheep population as Afar sheep breed, however, Sisay (2009) grouped it with the rift valley sheep. F_1 Local × Dorper (50%) crossbred animals are cross of local and pure Dorper sheep populations which was developed from a Dorset Horn ram and a Blackhead Persian ewe in the harsh dry regions of South Africa (Richard, 2010).

2.1.2 Animals’ management

The management system in the herd was that lambs born all year round were raised together with their parent dams until weaning (85-95 days). After weaning, lambs were managed as a flock separately from their dams grazed on natural pasture until they are distributed to the local farmers. During mating ewes kept together with their respective sire groups.

Concentrate supplementations were provided for each sheep based on their age and physiological status. Lactating ewes and rams supplemented 300g/h/day of concentrate, consisting of 32% noug cake, 65.5% wheat bran, 1% limestone and 0.5% salt and none lactating ewes supplemented with 200 g/h/day of concentrate. Lambs had no access to concentrate feed other than their dam’s milk and grazing before weaning. After weaning they are supplemented with 100-150g/h/day of concentrate until they are able to graze actively.

All animals received appropriate treatment for common health problems as per the recommendations of the research centers. They are treated regularly for internal and external parasites.

2.2 Data Collection Procedures

Data were collected on 17 and body weight for male sheep and 16 and body weight for female sheep from the three (local, crossbred and Dorper) sheep populations belonging to three age groups: 0 pair of permanent incisor (0PPI), 1 pair of permanent incisors (1PPI) and 2 and above pairs of permanent incisors (≥2PPI). The latter 3PPI and 4PPI age group was included in ≥2PPI because of small number of observations in these age groups. The linear measurements were chest girth (CG), chest depth (CD), sternum height (SH), punch girth (PG), body length (BL), height at wither (HW), height at rump (HR), rump length (RL), shoulder width (WS), rump width (RL), neck length (NL), head length (HDL), head width (HDW), fore cannon length (CL), hind limb (HL), fore limb (FL) and scrotal circumference (SC) (Figure xxx).

All Local and crossbreds were measured for the linear measurements by using measuring tape and weighed using a spring balance. All the pure Dorper sheep were also measured by using measuring tape but were weighed by suspension balance. All the measurements were taken by one person/researcher in order to minimize measuring bias. The FAO (2012) quantitative sheep breed descriptor list and measuring techniques were followed to characterize the sheep types based on their structural indices. Before measuring various parameters, the animals were restrained and calmed properly. All measurements were taken early in the morning prior to feeding to protect gut feeling and were taken to an up-right plane during measurement. Pregnant and lactating animals were excluded from sampling.

2.3 Data management and Analysis

The study populations were classified according to breed, sex and age within a breed All the structural indices(CG, CD, SH.PG, BL, HW, HR, RL, WS, RW, NL, HDL, HDW, CL., HL, FL, SC) and body weight were analyzed using the Generalized Linear Model (G.L.M.) procedures of the Statistical Analysis System (SAS version 2008). The fixed factors considered in this model were breed, sex and age. When the analysis declared significant, the least square means were separated using Tukey-kramer test (SAS, 2008). Pearson’s correlation coefficients were estimated among structural indices and body weight for females and males by using (SAS, 2008). Correlation coefficients between body weight and the structural indices were computed for the population within each sex. Multiple linear regression procedures of SAS (2008) were used to determine the best fitted regression equation for the prediction of body weight from linear body measurements. Model to analyze body weight and other structural indices for local, crossbred and Dorper sheep except scrotum circumference was:

Model1.

$Y_{lijk} = \mu + B_l + S_i + A_{j} + (E)_{lijk}$

Where, Y_{lijk} = the observed k (body weight or linear body measurements except scrotum Circumference) in the l^{th} breed, j^{th} age group and i^{th} sex

Y_{lijk} = Observation on response variables

μ = Population mean

B_l = the effect of l^{th} breed (l = local, crossbred and Dorper)

S_i = the effect of i^{th} sex (i = male, female)

A_j = the effect of j^{th} age group (j = 0PPI, 1PPI, ≥2PPI), where, 0PPI= 0 pair of permanent incisor, 1PPI= 1 pair of permanent incisor and ≥2PPI= 2 and above pairs of permanent incisor
E_{ijk} = random residual error
The following model was used to analyze the scrotum circumference for all sheep breeds was:
Model2.
$Y_{ij} = m + B_l + A_i + E_{lij}$
Where: Y_{ij} = the observed j (scrotum circumference) in the i^{th} age group and l^{th} breed
m = overall mean
B_l= the effect of l^{th} breed (l = local, crossbred and Dorper)
A_i = the effect of i^{th} age group (i = 0, 1 and 2)
E_{lij} = random residual error
The following models were used for the analysis of multiple linear regressions.
Model3. For male:
$Y_j = \beta_0 + \beta_1X_1 + \beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7+e_j$
Where:
Yj = the response variable; body weight
β_0 = the intercept
X_1, X_2, X_3, X_4, X_5, X_6, X_7 are the independent variables body length, chest girth, punch girth, height at wither, held limb, shoulder width, and scrotal circumference, respectively.
$\beta_1, \beta_2 ...\beta_7$ is the regression coefficient of the variable $X_1, X_2 ... X_7$
e_j = the residual error
Model4. For female:
$Y_j = \beta_0 + \beta_1X_1 + \beta_2X_2 +\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+ej$
Where:
Y_j = the dependent variable body weight
β_0= the intercept
X_1, X_2, X_3, X_4, X_5, X_6, are the independent variables body length, chest girth, punch girth, height at wither, held limb and shoulder width, respectively.
$\beta_1, \beta_2...\beta_7$ is the regression coefficient of the variable $X_1, X_2... X_7$
e_j = the residual error

3. RESULTS AND DISCUSSION

3.1 Body Weight and Linear Body Measurements

The least square means and standard errors of body weight and other body measurements were presented in Table 1. The comparisons in the study were mainly across breed, sex and age group on morphometric traits dimensions to provide evidence of breed type and existing relationship between live body weight and linear body measurements. The main sources of variation or fixed effects for live body weight and linear body measurement employed were breed, sex and age. The overall mean value of body weight (36.96kg), body length (961.35cm), chest girth (75.55cm) punch girth (90.22cm), wither height (61.21cm) rump height (62.41cm), shoulder width (20.08cm), rump width (17.23cm) and scrotal circumference (25.64cm.

Breed effect: The least square means and standard errors for the effect of breed, sex and age on body weight and other body measurements of the three (local, Dorper and crossbred) sheep breeds are presented in Tables 1. The analysis result indicated that most of the body linear measurements were highly significantly (P<0.01) affected by breed effect. Similarly Scrotal circumference was significantly (P<0.05) affected by breed effect. Body weight (28.47kg, body length (54.41cm), chest girth (70.27cm), rump width (15.35cm) and scrotal circumference (25.42cm) of local sheep. Body weight of local sheep in this report was larger than the previous on farm report of M. Tassew *et al.,* (2015) which was (25.51kg) for Habru and Gubalafto sheep type. This may be due to management and nutritional differences that sheep at on station level may get better nutrition in terms of quality and quantity and also they may get better health treatments.

Live body weight, body length, chest girth, rump width and scrotal circumference of crosses scored the mean value of 35.94kg, 61.22cm, 73.67cm, 17.47cm and 25.20cm, respectively. Body weight of crossbred sheep was in agreement with the previous study Solomon *et al*., (2007) on Gumz sheep rams which was 34.6kg.

Most linear measurements of crossbred sheep were significantly (P<0.01) larger than local sheep. This difference may due to heterosis effect on body weight and linear measurements the crossbred animals get. In general the crossbreds had larger measurements than local breeds. Crossbreds had better skeletal and muscle development indicating that they were better for meat production than local sheep.

Sex effect: Sex had highly significant (P<0.001) effect on live body weight and all of body linear measurements except rump width which was non-significant (P>0.05). Strong significant (P<0.001) differences were observed in live body weight and most of linear body measurements between male and female sheep. Body weights

(41.32kg, body length (62.87cm), chest girth (77.85cm), punch girth (92.82cm), wither height (63.07cm), rump height (63.63cm), rump (20.81cm) and shoulder width (22.05cm) were the mean value of rams. All the above measurements in accordance order for the ewes scored 32.61kg, 59.83cm, 73.25cm, 87.62cm, 59.34cm, 61.18cm, 19.95cm and 18.11cm, respectively.

The effect of sex on body weight and other linear measurements obtained in this study was in agreement with previous on farm results (T. Mengistie *et al.,* 2010; A. Alemayehu, 2011; H. Mulata *et al.,* 2014). However, this report disagreed with previous report of (A. Bosenu *et al.,* 2014) reported that sex had no significant effect on body weight of rams and ewes for indigenous sheep types in Selale area. Body weight of ewes and rams in the current result was larger than the previous on-farm report of M. Tasew *et al.,* (2015) which was 24.00±0.021kg and 28.13±0.29kg for ewes and rams respectively. Similarly this result was larger than the previous report by G. Tesfaye *et al.,* (2009) on Afar which was 24.3kg for male and 21.2kg for female sheep. In this study male sheep were larger than female sheep in body weight and most of other linear measurements suggesting the traits are sex dependent. The differences in body weight and body conformation (size of height, length, and girth) between male and female sheep expressed as the sexual morphological variation (Banerjee *et al.,* 2014).

***Age effect*:** Age effect was significant for most parameters used in the study. The result indicates that age had highly significant (P<0.001) effect on body weight and all other body linear measurements except head width. Body weight (37.24kg, 44.11kg)body length (62.26cm), 64.24cm , chest girth (75.90cm, 81.37cm), punch girth (91.75cm, 98.64cm), height at weather (61.44cm, 64.48cm), height at rump (62.99cm, 64.92cm), rump length (18.30cm, 21.39cm), shoulder width (20.39cm, 21.54cm)and scrotal circumference (25.79cm, 28.09cm) had the mean value of 1PPI and ≥2PPI age group respectively.

Body weight of 0PPI age group was greater than the previous yearling weight of crossbreds at wet season report of L. Mesfin *et al*., (2014) which was 27.72kg and but in agreement with 12.66 month body weight of crossbreds which was 30.68kg in southern regional state (B. Ermias , 2014). Body weight of sheep at 0PPI age group in this study was smaller than matured body weight (32.2kg) of Washera sheep (T. Mengistie, 2010). 0PPI age group in this study was greater than 6 month weight (24.30kg) of 50% Dorper x Menz sheep reported by A. Ayele *et al*., (2015). The result of body weight of 1PPI age group was larger than previous yearling weight of 50% Dorper x Menz (32.43kg) and Dorper x Afar (31.33kg) sheep reported by A. Ayele *et al.,* (2015) in Debre Birhan Agricultural Research Center.

Body weight and most of body linear measurements structural indices in this study showed significant variability in an increasing trend as animal age advances. This implies that growth patterns of the animal might be explained well by body measurements. This result in line with (K. Alayu *et al*., 2014) who found similar result on indigenous goat types in north Gondar zone. Height at wither and chest girth significantly increased as the age advances implies that animals were increased in their body size or skeletal size and also increased in their body condition as reported by Fajemilehin Samuel *et al.* (2008) that height at withers at any given time reflects the animal's skeletal size and that heart girth reflects body condition.

In addition the size of scrotal circumference at ≥2PPI age group in this study was significantly (P<0.001) larger than 0PPI and 1PPI age groups. This could be a good indicator of the age at which the animal attains their maximum sexual maturity. In this report the size and shape of the animal increased as the age advanced. This implies that the shape and size of the animal increased until the animal reached its maturity (G. Tesfaye *et al*., 2009; M. Tassew *et al*., 2015; A. Mesfin *et al.,* 2016).

Table1. Least squares means ± standard errors of body weight (kg) and other body measurements (cm) for the effects of breed, sex, and age of local, crossbreds and pure Dorper sheep.

Effects	Wt		BL		CG		CD		SH		PG	
and level	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE
Over all	303	36.96±0.45	303	61.35±0.28	303	75.55±.33	303	25.12±0.25	303	32.55±0.17	303	90.22±0.62
CV%	303	18.36	303	7.03	303	6.69	303	15.75	303	8.11	303	10.58
R^2	303	0.72	303	0.66	303	0.70	303	0.18	303	0.22	303	0.68
Breed		**		**		**		NS		NS		**
Local	81	28.47±0.81^{c}	81	54.41±0.58^{c}	81	70.27±0.94^{c}	81	25.62±0.68	81	32.79±0.39	81	75.65±1.44^{c}
Dorper	94	46.65±0.88^{a}	94	68.27±0.52^{a}	94	82.93±0.64^{a}	94	25.68±0.35	94	32.66±0.24	94	105.36±0.85^{a}
Cross	128	35.94±0.53^{b}	128	61.22±.038^{b}	128	73.67±0.62^{b}	128	24.30±0.44	128	32.95±0.26	128	90.13±0.95^{b}
Sex		**		**		**		**		**		**
Male	115	41.32±0.68^{a}	115	62.87±0.42^{a}	115	77.85±0.50^{a}	115	26.62±0.38^{a}	115	33.38±0.26^{a}	115	92.82±0.95^{a}
Female	188	32.61±0.54^{b}	188	59.83±0.34^{b}	188	73.25±0.40^{b}	188	23.59±0.30^{b}	188	31.71±.21^{b}	188	87.62±0.76^{b}
Age		**		**		**		**		**		**
0PPI	76	29.55±0.82^{c}	76	57.53±0.51^{c}	76	69.39±0.60^{c}	76	24.52±0.46^{bc}	76	30.93±0.31^{bc}	76	80.26±1.15^{c}
1PP	72	37.24±0.84^{b}	72	62.26±0.52^{b}	72	75.90±0.61^{b}	72	24.72±0.47^{b}	72	32.82±0.32^{ab}	72	91.75±1.17^{b}
≥2PPI	155	44.11±0.58^{a}	155	64.24±0.36^{a}	155	81.37±0.42^{a}	155	26.08±0.32^{a}	155	33.88±0.22^{a}	155	98.64±0.81^{a}

Means with different superscripts within the same column and class are statistically different. Ns = Non significant; *significant at 0.05; **significant at 0.01. 0 PPI = 0 pair of Permanent incisors; 1PPI = 1 pair of permanent incisor and ≥2 PPI = 2 or more pairs of permanent incisors. Wt = body weight, BL= body length, CG = chest girth, CD = chest depth, SH = sternum height, PG = punch girth

Table1. (Continued)

Effects and level	NL		CL		HL		FL		HW		HR	
	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE
Over all	303	24.56±0.16	303	11.55±1.00	303	51.99±0.19	303	41.43±0.24	303	61.21±0.23	303	62.41±0.22
CV%	303	10.13	303	13.52	303	5.78	303	9.16	303	5.91	303	5.49
R^2	303	0.38	303	0.29	303	0.47	303	0.16	303	0.45	303	0.37
Breed		**		NS		*		**		NS		**
Local	81	24.96±0.26^{b}	81	11.33±0.10	81	52.81±0.34^{a}	81	44.06±0.49^{a}	81	61.77±0.43	81	64.72±0.39^{a}
Dorper	94	26.58±0.31^{a}	94	11.80±0.26	94	52.78±0.32^{ab}	94	41.27±0.45^{b}	94	61.93±0.41	94	61.65±0.39^{b}
Cross	128	23.04±0.25^{bc}	128	11.37±0.11	128	51.31±0.32^{bc}	128	40.05±0.32^{c}	128	60.18±0.56	128	61.89±0.33^{bc}
Sex		**		**		**		**		**		**
Male	115	25.00±0.24^{a}	115	12.22±0.15^{a}	115	53.67±0.29^{a}	155	42.27±0.37^{a}	155	63.07±0.35^{a}	155	63.63±0.33^{a}
Female	188	24.19±0.19^{b}	188	10.88±0.11^{b}	188	50.32±0.23^{b}	188	40.58±0.29^{b}	188	59.34±0.28^{b}	188	61.18±0.27^{b}
Age		**		**		**		**		**		**
0PPI	76	23.16±0.29^{bc}	76	10.85±0.18^{bc}	76	48.83±0.35^{c}	76	40.08±0.44^{c}	76	57.70±0.43^{c}	76	59.30±0.41^{c}
1PPI	72	24.55±0.30^{b}	71	11.45±0.19^{b}	71	52.75±0.36^{b}	72	41.44±0.45^{b}	72	61.44±0.43^{b}	72	62.99±0.41^{b}
≥2PPI	155	26.07±0.21^{a}	155	12.35±0.13^{a}	155	54.40±0.25^{a}	155	42.75±0.31^{a}	155	64.48±0.30^{a}	155	64.92±0.28^{a}

Means with different superscripts within the same column and class are statistically different. Ns = Non significant; *significant at 0.05; **significant at 0.01. 0 PPI = 0 pair of Permanent incisors; 1PPI = 1 pair of permanent incisor and ≥2 PPI = 2 or more pairs of permanent incisors. NL = Neck length, CL = fore cannon length, HL = hind limb, FL = Fore limb, HW = height at weather, HR = Height at wither

Table 1. (Continued)

Effects and level	RL		WS		RW		SC		HDL		HDW	
	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE	N	LSM±SE
Over all	303	20.38±0.15	303	20.08±0.20	303	17.23±0.14	303	25.64±.28	303	18.48±0.09	303	18.92±0.11
CV%	303	11.58	303	16.05	303	12.85	303	10.19	303	7.79	303	8.75
R^2	303	0.14	303	0.52	303	0.37	303	0.43	303	0.55	303	0.30
Breed		**		**		**		*		**		**
Local	81	19.76±0.35^{bc}	81	19.14±0.38^{bc}	81	15.35±0.31^{c}	20	25.50±.59^{ab}	81	17.44±0.20^{abc}	81	17.96±0.17^{bc}
Dorper	94	20.76±0.25^{a}	94	23.09±0.42^{a}	94	18.75±0.29^{a}	44	26.23±0.42^{a}	94	19.68±0.17^{a}	94	20.23±0.27^{a}
Cross	128	20.71±0.23^{ab}	128	19.29±0.25^{b}	128	17.47±0.20^{b}	51	25.20±0.38^{b}	128	18.48±0.13^{ab}	128	18.92±0.11^{b}
Sex		**		**		NS				**		**
Male	115	20.81±0.23^{a}	115	22.05±0.31^{a}		17.24±0.22	115		115	19.56±0.14^{a}	115	19.47±0.16^{a}
Female	188	19.95±0.18^{ab}	188	18.11±0.25^{b}		17.22±0.17	188		188	17.40±0.11^{b}	188	18.37±0.13^{ab}
Age		**		**		**		**		**		NS
0PPI	76	19.50±0.28^{b}	76	18.30±0.34^{c}	76	15.63±0.26^{bc}	35	23.05±0.45^{c}	76	17.42±0.17^{c}	76	18.52±0.19
1PPI	72	18.30±0.38^{bc}	72	20.39±0.38^{b}	72	17.51±0.27^{ab}	25	25.79±0.53^{b}	72	18.80±0.17^{ab}	72	18.95±0.20
≥2PPI	155	21.39±0.20^{a}	155	21.54±0.26^{a}	155	18.55±0.19^{a}	55	28.09±0.39^{a}	155	19.22±0.11^{a}	155	19.29±0.13

Means with different superscripts within the same column and class are statistically different. Ns = Non significant; *significant at 0.05; **significant at 0.01. 0 PPI = 0 pair of Permanent incisors; 1PPI = 1 pair of permanent incisor and ≥2 PPI = 2 or more pairs of permanent incisors. RL = Rump length, WS = Shoulder width, RW = Rump length, Scrotal circumference, HDL, Head length, HDW = Head width

3.2 Correlation of Body Weight and other Linear Body Measurements

The Pearson's correlation coefficient among quantitative variables for both sex groups of local crossbred and pure Dorper sheep were presented in Table 4.2, Table 4.3 and Table 4.4, respectively. Correlations between the quantitative traits in the local female sample sheep population showed low to strong positive values. Strong and significant (P<0.05) positive associations were observed between body weight with chest girth (r = 0.72), body length (r = 0.59) rump length (r = 0.58) and height at rump (r = 0.49) for local female sheep.

There was a negative correlation between punch girth and body length (r = -0.18). This negative correlation estimation showed that, breeders should be aware of the undesirable effects of selection based on only one group of traits (Jafari *et al.,* 2014).

Correlation coefficients between live weight and other measurements estimated for local male sheep were significant for all parameters. The highest relationship between body weight and chest girth (r = 0.88), fore limb (r = 0.87), height at rump (r = 0.83) and chest depth (r = 0.82) were observed in local male sheep. The highest correlation of chest girth with body weight than other body measurements was in harmony with the previous reports of A. Alemayehu, (2011); A. Bosenu *et al.,* (2014); M. Tassew *et al.,* (2015). The highest positive and significant correlation between body weight and chest girth suggest that this variables could provide a good estimate for predicting live weight for this sheep types.

Genetic correlations between body weight and all other traits except chest depth for crossbred sheep in both sexes were positive and ranged from low to high (r = 0.0.36 to 0.92), which indicated that traits were genetically linked. Body weight of crossbred male sheep showed strong (p<0.01) correlation with chest girth (r = 0.92), body length (r = 0.92), punch girth (r = 0.80) and height at wither (r = 0.78). Body weight of crossbred male sheep was positively significantly (P<0.05) correlated with all measurements considered in this study.

Most linear measurements were significantly (p<0.01) correlated with live body weight of female crossbred sheep. Whereas, chest girth (r = 0.77), punch girth (r = 0.75) and height at wither (r = 0.71) were positives and highly significant (p<0.01) with body weight of female crossbred sheep. Rump length (r = 0.33), shoulder width (r = 0.43) and rump width (r = 0.41) had moderate correlation with body weight for crossbred sheep. There was negative correlation between chest depth and sternum height (r = -0.05) and chest depth and neck length (r = -0.03) for female crossbred sheep. The high phenotypic correlations between body weight and other linear body measurements indicated that selection for body measurements would favor the selection for body weight (Khargharia *et al.,* 2015).

This study further reported that scrotal circumference was positively correlated with all other linear measurements for all sheep breeds. Scrotal circumference had correlation coefficient (r = 0.81, 0.71 and 0.61) with body weight for local, crossbred and Dorper sheep respectively. In general, the genetic and phenotypic correlations of scrotal circumference with measures of growth reported in the literature were positive (D. Gemeda *et al.,* 2002) which indicates that the chances were fairly small of selecting males with small testes for breeding purposes when measures of growth were considered in the selection program. The highest correlation between scrotal circumference and body weight (r = 0.81) for local rams indicated that genes contributed in body weight had more influence on reproductive ability in local rams (Abbasi and Ghafouri-Kesbi, 2011).

Heart girth yielded the highest partial contribution (0.88, 0.92 and 0.67) in local, crossbred and Dorper sheep in this study and was, therefore, the most important contributor to the selection index for all sheep breeds in this study.

All high correlations in this study indicated the interrelationships between/among the traits and such knowledge was very useful in breeding and management practices of livestock, as selection for a given trait directly favors other positively associated traits. However all negative correlations in this study indicated the interrelationships between/among the traits disfavors negatively associated traits (Yakubu, Salako and Abdullah, 2011; Birteeb *et al.,* 2012). The high correlation of different measurements with body weight would imply these measurements could be used as indirect selection criteria to improve live weight (Khan *et al.,* 2006; G. Solomon *et al.,* 2008, G. Tesfaye *et al*., 2009).

Table2. Phenotypic correlations among body measurements and weight of female and male local sheep (female on the above diagonal)

	CG	CD	SH	PG	HW	HR	RL	WS	RW	NL	CL	HL	FL	BL	Wt
CG		0.24	0.30*	0.40**	0.54**	0.56**	0.64**	0.33**	0.52**	0.25	0.07	0.53**	0.45**	0.37**	0.72**
CD	0.94**		0.31*	0.39**	0.45**	0.36**	0.30*	0.06	0.29*	0.22	0.20	0.26*	0.20	0.03	0.18
SH	0.89**	0.94**		0.12	0.45**	0.48**	0.33**	-0.12	0.43**	0.07	0.39**	0.55**	0.28*	0.15	0.25
PG	0.95**	0.90**	0.89**		0.22	0.18	0.18	0.15	0.05	0.14	0.17	0.26*	0.18	-0.18	0.24
HW	0.90**	0.90**	0.94**	0.88**		0.72**	0.57**	0.15	0.45**	0.27*	0.32*	0.62**	0.43**	0.29*	0.42**
HR	0.95**	0.95**	0.91**	0.91**	0.92**		0.52**	0.10	0.40**	0.42**	0.30*	0.70**	0.49**	0.33**	0.49**
RL	0.87**	0.93**	0.93**	0.84**	0.89**	0.88**		0.31*	0.68**	0.26*	0.13	0.43**	0.26*	0.32*	0.58**
WS	0.91**	0.87**	0.85**	0.93**	0.85**	0.89**	0.84**		0.35**	0.06	-0.02	0.12	-0.07	0.14	0.26*
RW	0.88**	0.88**	0.90**	0.88**	0.93**	0.89**	0.88**	0.84**		0.21	-0.01	0.39**	0.29*	0.24	0.35**
NL	0.86**	0.90**	0.94**	0.91**	0.88**	0.91**	0.88**	0.83**	0.86**		0.16	0.33**	0.31*	0.09	0.27*
CL	0.68**	0.57**	0.56*	0.66**	0.64**	0.59**	0.59**	0.49*	0.62**	0.55*		0.32*	0.25	0.16	0.16
HL	0.94**	0.91**	0.94**	0.92**	0.94**	0.96**	0.90**	0.87**	0.91**	0.96**	0.64**		0.56**	0.15	0.35**
FL	0.97**	0.94**	0.89**	0.91**	0.90**	0.96**	0.88**	0.91**	0.90**	0.88**	0.62**	0.96**		0.19	0.33**
BL	0.78**	0.81**	0.87**	0.78**	0.90**	0.84**	0.83**	0.75**	0.89**	0.83**	0.58**	0.86**	0.81**		0.59**
Wt	0.88**	0.82**	0.71**	0.78**	0.74**	0.83**	0.71**	0.72**	0.78**	0.65**	0.63**	0.78**	0.87**	0.61**	
SC	0.84**	0.90**	0.92**	0.79**	0.89**	0.86**	0.83**	0.72**	0.89**	0.79**	0.58**	0.85**	0.86**	0.83**	0.80**

*Correlation is significant at 0.05 levels (2 tailed), ** Correlation is significant at 0.01 levels (2 tailed). CG = chest girth, CD chest depth, Sternum height, PG = punch girth, HW = height at wither, HR = height at rump, Rump length, WS = Shoulder width, RW = Rump width, NL = Neck length, CL = Fore cannon length, HL = Hind limb, FL= Fore limb, BL = Body length, Wt = Weight

Table3. Phenotypic correlations among body measurements and weight of female and male of crossbred sheep (Females on the above diagonal)

	CG	CD	SH	PG	HW	HR	RL	WS	RW	NL	CL	HL	FL	BL	Wt
CG		0.12	0.70**	0.86**	0.76**	0.84**	0.49**	0.58**	0.46**	0.44**	0.39**	0.68**	0.46**	0.63**	0.77**
CD	0.32*		-0.05	0.07	0.06	0.08	0.20	0.15	0.15	-0.03	0.06	0.01	0.13	0.14	0.12
SH	0.40**	0.34*		0.79**	0.73**	0.74**	0.47**	0.36**	0.32**	0.52**	0.60**	0.62**	0.47**	0.56**	0.62**
PG	0.80**	0.24	0.38**		0.78**	0.82**	0.32**	0.47**	0.25*	0.40**	0.49**	0.70**	0.40**	0.56**	0.75**
HW	0.79**	0.55**	0.61**	0.62**		0.81**	0.30**	0.35**	0.33**	0.51**	0.43**	0.69**	0.51**	0.58**	0.71**
HR	0.67**	0.52**	0.63**	0.51**	0.85**		0.41**	0.41**	0.50**	0.52**	0.48**	0.72**	0.44**	0.59**	0.65**
RL	0.40**	0.39**	0.35*	0.29*	0.51**	0.44**		0.47**	0.52**	0.22*	0.39**	0.23*	0.28*	0.43**	0.33**
WS	0.71**	0.34*	0.24	0.60**	0.61**	0.63**	0.46**		0.26*	0.34**	0.27*	0.41**	0.29*	0.39**	0.43**
RW	0.62**	0.36**	0.14	0.44**	0.62**	0.40**	0.24	0.51**		0.23*	0.29*	0.35**	0.47**	0.43**	0.41**
NL	0.59**	0.40**	0.30*	0.48**	0.59**	0.50**	0.39**	0.49**	0.43**		0.39**	0.45**	0.55**	0.37**	0.47**
CL	0.58**	0.48**	0.47**	0.44**	0.71**	0.70**	0.32*	0.48**	0.39**	0.40**		0.41**	0.33**	0.23*	0.45**
HL	0.72**	0.41**	0.41**	0.69**	0.75**	0.71**	0.28*	0.67**	0.55**	0.50**	0.76**		0.51**	0.52**	0.69**
FL	0.42**	0.69**	0.57**	0.34*	0.62**	0.60**	0.38**	0.37**	0.40**	0.57**	0.55**	0.56**		0.46**	0.63**
BL	0.85**	0.27	0.43**	0.73**	0.73**	0.66**	0.51**	0.72**	0.54**	0.64**	0.52**	0.74**	0.43**		0.67**
Wt	0.92**	0.36**	0.41**	0.80**	0.78**	0.68**	0.50**	0.75**	0.60**	0.66**	0.57**	0.77**	0.50**	0.92**	
SC	0.68**	0.09	0.10	0.56**	0.46**	0.37**	0.41**	0.44**	0.55**	0.43**	0.25	0.44**	0.20	0.69**	0.71**

*Correlation is significant at 0.05 levels (2 tailed), ** Correlation is significant at 0.01 levels (2 tailed). CG = chest girth, CD chest depth, Sternum height, PG = punch girth, HW = height at wither, HR = height at rump, Rump length, WS = Shoulder width, RW = Rump width, NL = Neck length, CL = Fore cannon length, HL = Hind limb, FL= Fore limb, BL = Body length, Wt = Weight

Table4. Phenotypic correlations among body measurements and weight of female and male of Dorper sheep (Males on the above diagonal)

	CG	CD	SH	PG	HW	HR	RL	WS	RW	NL	CL	HL	FL	BL	Wt	SC
CG		0.86**	0.46**	0.91**	0.72**	0.65**	0.65**	0.70**	0.58**	0.77**	0.52**	0.74**	0.79**	0.60**	0.67**	0.92**
CD	0.61**		0.43**	0.78**	0.71**	0.57**	0.56**	0.52**	0.39**	0.60**	0.53**	0.79**	0.76**	0.62**	0.60**	0.81**
SH	0.26	0.26		0.42**	0.64**	0.54**	0.48**	0.21	0.30*	0.54**	0.09	0.25	0.49**	0.69**	0.63**	0.41**
PG	0.65**	0.44**	0.20		0.66**	0.62**	0.67**	0.70**	0.65**	0.75**	0.47**	0.67**	0.75**	0.45**	0.62**	0.85**
HW	0.52**	0.25	0.65**	0.30*		0.73**	0.52**	0.36*	0.51**	0.61**	0.25	0.43**	0.72**	0.68**	0.71**	0.71**
HR	0.44**	0.44**	0.50**	0.23	0.50**		0.75**	0.29	0.62**	0.66**	0.26	0.25	0.58**	0.51**	0.59**	0.52**
RL	0.19	0.18	-0.01	0.11	0.05	-0.02		0.47**	0.65**	0.73**	0.35*	0.27	0.42**	0.43**	0.64**	0.48**
WS	0.73**	0.62**	0.23	0.37**	0.44**	0.51**	0.10		0.41**	0.43**	0.31*	0.50**	0.45**	0.30*	0.52**	0.69**
RW	0.55**	0.34*	0.23	0.54**	0.45**	0.21	0.05	0.49**		0.74**	0.54**	0.21	0.48**	0.42**	0.50**	0.47**
NL	0.44**	0.36**	0.52**	0.40**	0.63**	0.45**	0.04	0.35*	0.54**		0.62**	0.41**	0.38*	0.37*	0.52**	0.50**
CL	0.42**	0.24	0.36*	0.43**	0.50**	0.30*	-0.20	0.21	0.35*	0.31*		0.65**	0.52**	0.52**	0.80**	0.41**
HL	0.58**	0.49**	0.54**	0.43**	0.59**	0.53**	0.09	0.54**	0.47**	0.54**	0.44**		0.69**	2.60**	0.79**	0.57**
FL	0.13	0.01	0.22	-0.24	0.50**	0.25	-0.15	0.14	0.03	0.16	0.08	0.29*		2.68**	0.66**	0.54**
BL	0.47**	0.40**	0.57**	0.30*	0.63**	0.45**	0.19	0.33*	0.21	0.49**	0.29*	0.67**	0.30*		0.64**	0.60**
Wt	0.73**	0.59**	0.41**	0.83**	0.54**	0.40**	0.01	0.60**	0.61**	0.50**	0.53**	0.69**	-0.03	0.60**		0.61**

*Correlation is significant at 0.05 levels (2 tailed), ** Correlation is significant at 0.01 levels (2 tailed) CG = chest girth, CD chest depth, Sternum height, PG = punch girth, HW = height at wither, HR = height at rump, Rump length, WS = Shoulder width, RW = Rump width, NL = Neck length, CL = Fore cannon length, HL = Hind limb, FL= Fore limb, BL = Body length, Wt = Weight

3.3 Prediction of Body Weight from other Body Linear Measurements

Table5 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 for local sheep. The two variables, chest girth and body length, with significant contribution to the prediction of live body weight of sheep were fitted in first and second model, and they accounted for 64% of the total variability of local female pooled age groups. Comparing for dentition groups of male crossbreds, the highest coefficient of determination was depicted at age group 1PPI ($R^2 = 0.98$) or 98% of the variation in weight was explained by two variables, CG and BL. CG, BL, HDW and NC which were included from first to fourth models, showed significant contribution to predict live body weight and were accounted 94% of the total variability of crossbred rams for pooled age group. In the pooled age of female crossbred animals, strong relationship between body weight and the linear body measurements (CG, BL, FL and PG) was observed and it accounted 74%.

Six variables (CG, FCC, FL, SC, ERL and NC) included in the model had significant contribution to the prediction of live body weight of pure Dorper male sheep where they accounted for 94% of the total variability.

Strong relationship between body weight and punch girth, shoulder width, sternum height and neck length for pure Dorper female sheep in pooled age group; make it possible to predict the body weight based on these four linear measurements. The differences in the coefficient of determination of equations between different dentition groups within the same breed and sex indicated that weight can be estimated using different equations for different sex and age groups with different accuracies.

Generally, chest girth alone accounted for about 78% and 52% of the variation for body weight in male and female local sheep respectively and 86% and 59% of the variation for F_1 crossbred sheep. This implies that Chest girth estimates in linear regression models could predict more accurately in males. In case of pure Dorper sheep breed regression analysis, chest girth which accounts 86% of the total variables was selected first the rams. Punch girth selected first for pure Dorper ewes which explain more variation (70%) than any other linear body measurement.

Instead of using separate equation for different age groups the overall equation of the pooled age group using explanatory variables might be used for the prediction of body weight for each male and female sheep. In this study chest girth was preferable for prediction of body weight for local, crossbred and pure Dorper male sheep. This idea was in agreement with (E. Zewdu *et al.,* 2009; G. Tesfaye *et al.,* 2009; M. Tasew., 2014). The prediction of body weight could be based on regression equation $y = -24.05+0.88x$ for local male, $y = -22.77 + 0.72x$ for local ewes, $y = -57.72 + 0.92x$ for cross male, $y = -22.61 + 0.77x$ for cross female, $y = -70.00 + 0.93x$ for Dorper rams and $y = -43.41 + 0.83x_1$ for Dorper ewes. Where, y, x *and* x_1 are body weight, chest girth and punch girth respectively.

Table5. Multiple regression analysis of live weight on different body measurements for local sheep by age group

		Parameters								
Male group	Age	Model	Intercept	β_1	β_2	β_3	β_4	R^2	Adj.R^2	SE
0PPI		CG	-18.73±7.00	0.92±0.18				0.84	0.82	1.62
1PPI		CL	-16.26±7.82	0.95±0.67				0.91	0.88	0.67
		CL+HW	-45.20±4.12	0.63±.24	0.44±0.09			0.99	0.93	0.16
≥2PPI		RW	-7.576±2.06	0.99±0.11				0.98	0.98	0.56
Over all		CG	-24.05±6.50	0.88±0.09				0.78	0.75	2.66
Female group	Age									
0PPI		PG	-36.57±10.32	0.96±0.14				0.92	0.89	1.77
		PG+WS	-31.20±2.03	1.01±0.03	0.28±0.06			0.99	0.99	0.33
1PPI		BL	-11.55±8.59	0.74±0.16				0.54	0.51	2.07
		BL+CG	-18.96±8.22	0.47±0.18	0.44±0.13			0.61	0.62	1.83
		BL+CG+FCC	-19.67±5.87	0.49±0.13	0.64±0.10	0.48±0.31		0.84	0.80	1.31
		BL+CG+FCC+RL	-15.24±5.03	0.43±0.11	0.38±0.11	0.56±0.27	0.43±0.23	0.90	0.87	1.07
≥2PPI		CG	-21.69±11.56	0.59±0.16				0.35	0.32	3.40
		CG+BL	-36.58±11.22	0.52±0.14	0.40±0.11			0.50	0.47	3.02
Over all		CG	-22.77±6.28	0.72±0.09				0.52	0.50	3.07
		CG+BL	-34.97±6.13	0.58±0.08	0.38±0.09			0.64	0.62	2.67

CG = Chest girth; BL = Body length; CL = Fore cannon length; FL = Fore limb; WH = Wither height; RW= Rump width; NL= Neck length; PG = Punch girth; WS = Shoulder width. 0 PPI = 0 pair of permanent incisors; 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors.

Table6. Multiple regression analysis of live weight on different body measurements for Crossbred rams by age group

				Parameters					
Age group	Model	Intercept	β_1	β_2	β_3	β_4	R^2	Adj.R^2	SE
0PPI	HDW	-58.96±18.60	0.78±0.99				0.60	0.57	3.37
	HDW+NC	-79.92±10.94	0.65±0.56	0.55±0.21			0.89	0.87	1.87
1PPI	CG	-43.09±7.73	0.97±0.10				0.93	0.93	1.70
	CG+BL	-52.63±4.86	0.81±0.07	0.27±0.08			0.98	0.48	0.95
≥2PPI	BL	-57.74±9.43	0.92±0.14				0.85	0.85	3.69
	BL+HDW	-70.02±9.04	0.68±0.18	0.32±0.66			0.90	0.89	3.16
Over all	CG	-57.72±5.85	0.92±0.07				0.86	0.85	5.18
	CG+BL	-70.65±4.70	0.51±0.10	0.49±0.14			0.92	0.92	3.79
	CG+BL+HDW	-84.84±5.79	0.42±0.10	0.42±0.13	0.19±0.44		0.94	0.94	3.39
	CG+BL+HDW+NC	-78.47±5.96	0. 33±0. 10	0. 39±0. 12	0.17±0. 43	0. 16±0. 11	0.95	0.94	3.20

CG = Chest girth; BL = Body length; HDW = Head width; FL = Fore limb; RW= Rump width; NC= Neck circumference; FCC = Fore cannon circumference; CD = Chest depth. 0 PPI = 0 pair of permanent incisors; 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors.

Table7. Multiple regression analysis of live weight on different body measurements for Crossbred ewes by age group

Parameters									
Age group	Model	Intercept	β_1	β_2	β_3	β_4	R^2	Adj.R^2	SE
0PPI	CG	-36.66±9.53	0.81±0.14				0.66	0.65	3.53
	CG+FL	-40.81±9.02	0.65±0.16	0.29±0.20			0.72	0.70	3.27
1PPI	PG	-2.78±7.74	0.75±0.08				0.57	0.54	2.48
	PG+CD	-17.40±6.18	0.74±0.06	0.49±0.14			0.81	0.79	1.68
	PG+CD+NC	-20.06±4.39	0.52±0.05	0.56±0.11	0.39±0.09		0.91	0.89	1.18
≥2PPI	HL	-22.87±13.99	0.61±0.27				0.37	0.35	4.14
	HL+BL	-55.34±14.36	0.48±0.23	0.47±0.19			0.58	0.55	3.44
Over all	CG	-22.61±5.40	0.77±0.07				0.59	0.58	3.00
	CG+FL	-38.94±5.84	0.60±0.07	0.35±0.15			0.68	0.68	3.51
	CG+FL+PG	-35.17±5.71	0.30±0.12	0.35±0.14	0.36±0.07		0.72	0.70	3.34
	FL+PG+BL	-42.67±6.46	0.32±0.14	0.49±0.04	0.25±0.13		0.73	0.72	3.24
	CG+FL+PG+BL	-44.65±6.51	0.20±0.13	0.30±0.14	0.34±0.07	0.21±0.13	0.74	0.73	3.21

CG = Chest girth; BL = Body length; PG = Punch girth; FL = Fore limb; HL = Hind limb; RW= Rump width; NC= Neck circumference; CD = Chest depth. 0 PPI = 0 pair of permanent incisors; 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors.

Table8. Multiple regression analysis of live weight on different body measurements for Dorper rams by age group

		Parameters							
Age group	Models	Intercept	β_1	β_2	β_3	β_4	R^2	Adj.R^2	SE
0PPI	RW	11.41±6.43	0.85±0.38				0.72	0.69	3.48
1PPI	NC	-10.89±6.34	0.96±0.16				0.93	0.92	1.70
	NC+HDL	-5.07±2.88	1.13±0.06	0.30±0.17			0.99	0.99	0.54
≥2PPI	CG	-95.69±13.25	0.93±0.14				0.86	0.85	3.98
	CG+HW	-123.60±14.35	0.86±0.13	0.22±0.19			0.90	0.89	3.30
	CG+HW+HR	-100.10±12.75	0.87±0.10	0.28±0.15	0.21±.14		0.94	0.93	2.58
	CG+HW+HR+WS	-104.34±10.35	0.75±0.10	0.30±0.12	0.19±.11	0.18±0.19	0.97	0.95	2.08
Over all	CG	-70.00±7.96	0.93±0.09				0.86	0.85	4.96
	CG+NC	-67.38±7.66	0.75±0.14	0.21±.0.20			0.87	0.87	4.72
	CG+NC+HW	-79.41±8.73	0.54±0.19	0.30±0.21	0.20±0.20		0.89	0.88	4.45
	CG+NC+HW+HR	-65.76±8.28	0.59±0.16	0.31±0.18	0.35±0.20	0.27±0.19	0.92	0.91	3.83

CG = Chest girth; BL = Body length; HR = Height at rump; FL = Fore limb; WH = Wither height; RW= Rump width; NC= Neck circumference; FCC = Fore cannon circumference; CD = Chest depth; RW = Rump width; CL = Fore cannon Length; HDL = Head length; WS = Shoulder width; ERL = Ear length and SC = Scrotal circumference.0 PPI = 0 pair of permanent incisors; 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors.

Table9. Multiple regression analysis of live weight on different body measurements for Dorper ewes by age group

		Parameters							
Age group	Models	Intercept	β_1	β_2	β_3	β_4	R^2	Adj. R^2	SE
0PPI	PG	-39.65±15.00	0.87±0.15				0.76	0.72	1.52
	PG+NC	-46.36±11.35	0.79±0.11	0.36±0.14			0.88	0.85	1.12
	PG+NC+HW	-49.86±7.33	0.69±0.08	0.33±0.09	0.30±0.07		0.96	0.93	0.72
1PPI	FCC	-85.29±12.58	0.776±1.07				0.60	0.55	1.55
	FCC+CD	-58.51±6.00	0.67±0.40	0.60±0.12			0.95	0.93	0.57
	FCC+CD+SH	-44.45±5.11	0.59±0.26	0.63±0.07	0.20±0.07		0.99	0.97	0.34
≥2PPI	PG	-44.23±12.14	0.82+0.11				0.68	0.66	4.46
	PG+WS	-39.71±8.70	0.65±0.09	0.44±0.12			0.84	0.83	3.18
	PG+WS+SH	-58.90±11.58	0.64±0.08	0.40±0.11	0.17±0.29		0.87	0.85	2.95
OVER ALL	PG	-43.41±8.41	0.83±0.08				0.70	0.69	4.64
	PG+WS	-44.57±6.932	0.70±0.07	0.34±0.13			0.80	79	3.82
	PG+ +WS+SH	-69.11±9.73	0.68±0.06	0.30±0.12	0.20±0.27		0.84	0.82	3.47
	PG+WS+SH+NC	-82.00±10.94	0.65±0.06	0.21±0.14	0.22±0.26	0.17±0.22	0.85	0.84	3.32

CG = Chest girth; BL = Body length; PG = Punch girth; WS = Shoulder width; WH = Wither height; RL= Rump length; NC= Neck circumference; FCC = Fore cannon circumference; CD = Chest depth; SH = Sternum height. 0 PPI = 0 pair of permanent incisors; 1PPI = 1 pair of permanent incisor and ≥ 2 PPI = 2 or more pairs of permanent incisors.

4. CONCLUSIONS AND RECOMMENDATIONS

From the current results obtained in this study the fixed effects breed, sex and age were sources of variation for most of the response variables (linear body measurements). All the fixed effects used in the study had a significant ($p<0.01$) effect on body weight and most of the body linear measurements. Pure Dorpers were larger in body weight and other linear body measurements than local and crossbred sheep; however, crossbred sheep performed significantly better than local sheep. Generally body linear measurements for the local, crossbred and pure Dorper sheep indicated that pure Dorpers and crossbreds were meat type animals. Dorper crossbred with the local sheep in eastern Amhara was good indicator to improve local sheep through crossbreeding. Thus, strengthen the crossbreeding program and distribution of crossbred sheep in the study area was suggested. Further research is needed to determine the performance of crossbreds under on farm conditions.

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