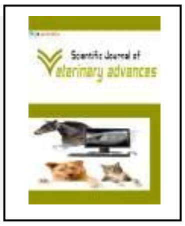
Sjournals
Scientific Journals
Scientific Journal of Veterinary Advances (2013) 2(9) 132-143
ISSN 2322-1879
doi: 10.14196/sjvs.v2i9.991

Contents lists available at Sjournals
Scientific Journal of Veterinary advances
Journal homepage: www.Sjournals.com



Original article

# Growth performance and linear body measurements of Washera, Farta and their crossbreed sheep under farmers management system in Western Highland of Amhara Region

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ARTICLE INFO

*Article history:*
Received 03 September 2013
Accepted 19 September 2013
Available online 29 September 2013

*Keywords:*
Washera
Farta
Growth performance
Regression equation
Crossbreds

ABSTRACT

The study was conducted in Farta and Lay Gaint districts of the Amhara Region. Data collected from 2007 to 2010 was used to evaluate growth performance and to characterize phenotypically using linear body measurements of Washera, Farta and their crossbred sheep. The fixed effects considered in this study were breed, district, lamb sex, parity of the dam, birth or lambing season and year, birth type and management system. Performance data were analyzed using general linear model procedure of Statistical Analysis System while the correlation and regression of linear body measurements on body weight and participatory rural appraisal were analysed using Statistical Package for Social Science. The least squares mean and standard errors of yearling weight for Washera, Farta and their crossbred sheep were 23.70±1.13kg, 20.08±0.73kg and 21.35±1.56kg, respectively; Whereas the averages daily gain from birth to 30 days for these sheep breeds were 84.79±4.65gm, 64.53±9.75gm and 82.21±5.61gm, respectively. Washera sheep breed has higher value for body weight; wither at height and pelvic width than Farta and crossbred sheep. Washera sheep was much better in growth performance and in linear body measurements followed by crossbred sheep.

## 1. Introduction

Growth performance is the most important production traits for successful animal production for whatever purpose (Zeleke, 2007). Body weight and growth traits are very important characteristic in animal husbandry due to selection criteria and economic benefit in sheep production (Cam et al., 2010; Vali Aghaali et al., 2010). Similarly, Solomon (2002b) report that lamb weight and daily live weight gain are not only important components of market lamb production but also are vital attributes for overall production. The growth performance of sheep is influenced by age of the dam, pre-mating weight of the dam, type of birth, sex, breed and season of birth (Mengistie et al., 2009a; Solomon et al., 2011).

Knowing the body weight of a sheep is important for a number of reasons, related to breeding (selection), feeding, health care and for market age determination since it is an important growth and economic trait (Tesfaye et al., 2009a; Cam et al., 2010). However, this fundamental knowledge is often unavailable for sheep in the small scale farming sector particularly in rural areas, due to mainly the lack of weighing scales (Atta and EI Khidir, 2004). Furthermore it has been found to be labour consuming and tiresome to lift-up and measure body weight using spring balance. Thus designing and implementing simple and cheap measurement system is crucial for village-based breeding program (Tesfaye et al., 2009a). For this linear body measurements are simple and easily measured variables for estimating live weight with relatively lower costs with a high relative accuracy and consistency (Sowande & Sobola, 2007).

Strong relationship of linear body measurements with body weight and the importance of body measurements for the prediction of body weight have been documented by many authors (Atta and El khidir, 2004; Thiruvenkadan, 2005; Adeyinka, 2006; Afolayan et al., 2006; Fasae et al., 2006; Khan et al., 2006; Mengistie et al., 2010). The choice of the best fitted regression model was assessed using coefficient of determination (Zewdu et al., 2009b). The differences in the coefficient of determination of the equations fitted between different dentition groups indicated that weight can be estimated using different equations for different age groups with different accuracies (Mengistie et al., 2010).

To evaluate growth performance as well as to characterize Washera, Farta and their crossbreed sheep based on quantitative characters and develop prediction equations for body weight estimation using linear body measurements.

## 2. Materials and methods

### 2.1. Description of the study area

The study was conducted at Farta and Lay Gayint districts of South Gonder Zone of Amhara Region of Ethiopia. Farta district is situated at 11°40′ N latitude and 38° E longitude and located at about 100 km north-east of Bahir Dar, capital city of the Amhara Region, Ethiopia. It lies within an altitude range of 1920-4135 m above sea level. The district receives an average annual rain fall of 900-1099 mm and a mean-range temperature of 9-25oC. The rainy season ranges from May to September (Abebaw and Melaku, 2009). The district's major socio- economic problem is food insecurity (Alemtsehay and Girma, 2006).

Lay Gayint district is located 175km from Bahir Dar and lies between altitude range of 1300-3500 m above seas level. It receives an annual average rain fall of 600-1100 mm and mean minimum and mean maximum temperatures of 9 and 19oC respectively (ENMA, unpublished). It is characterized by drought, sever soil erosion, poor soil fertility, frost and shortage of arable land, crop disease and pest hail damage, landslide and feed shortage (South Gonder Zone BOA, 2008).

### 2.2. Flock management

The participatory rural appraisal (PRA) results of this study indicated that farmers in the study area keep sheep in combination with other species of animals, usually with cattle and equines, depending on the availability of feed resources and the use or function of the animals. During crop harvesting times, sheep have access to browse crop aftermath while in dry season some farmers give supplementation for their sheep based on their physiological status. Breeding is year-round. All the farmers construct house for their sheep to protect them from sun, rain, wind, theft and wild animals (Shigdaf et al., 2009).

Since the start of data collection, internal and external parasite control has been carried out. For internal parasites the animals have been de-wormed three times a year (i.e. at the end of rainy season, at mid dry season and at the onset of rainy season). Animals have been sprayed for external parasites when tick infestation is high (as per the need). Vaccination against pasteurellosis, anthrax and black leg has been given once a year.

### 2.3. Data collection and management

The survival data were collected by enumerators and the on station data from Adet Washera sheep breed improvement sub-center in which both of them have been started from 2007 by Andassa Livestock Research Center. The collected data were coded and entered into Microsoft EXCEL, 2007 software program of the computer for further analysis. Preliminary data analysis like normality test and screening of outliers were employed before conducting the main data analysis.

### 2.4. Data analysis

The fixed effects fitted were the following: breed (Washera, Washera cross with Farta and Farta), district (Lay Gayint and Farta), lamb sex (Male and Female), parity of the dam (1, 2, 3, 4, 5 and ≥6), season of birth (dry and wet), year of birth (2007, 2008, 2009 and 2010) and lamb birth type (single and multiple).

Model 1. For analysis of variance of growth and growth rate for Washera, Farta and crossbred sheep was:

$Yijklmn = \mu + Bi + Dj + Gk + Sl + Tm + Yn + eijklmn$

Where: Yijklmn = the observation on weight and weight gain at different ages.

$\mu$ = over all mean

Bi= Fixed effect of breed (i = Washera, Farta, Washera*Farta)

Dj = Fixed effect of district (j = Lay Gayint and Farta)

Gk= Fixed effect of lamb sex (k = male, female)

Sl = Fixed effect of lamb birth season (l = dry, wet)

Tm = Fixed effect of lamb birth type (m = single, multiple)

Yn = Fixed effect of lamb birth year (n = 2007, 2008, 2009, 2010)

eijklmn = effect of random error

Lamb birth weight and ewe postpartum body weight were considered as a covariate for weight at birth & different ages and for average daily body weight gains but they were non-significant.

Model 2: For analysis of variance of body weight linear measurements

$Yijkl = \mu + Ai + Bj + Sk + Tl + eijkl$

Where: Yijkl = the observed body measurements of the animal.

$\mu$ = overall mean

Ai = the effect of age group (i = 0, 1, 2, 3 and >4)

Bj= Fixed effect of breed (i = Washera, Farta and Washera*Farta)

Sk = the effect of sex (k= male and female)

Tl= the effect of season of measurement (l= wet and dry)

eijkl= random residual error

Pearson's correlation coefficients for each breed were estimated between body weight and other body measurements within sex and age group. Body weight was regressed on body measurements that had strong correlation with body weight. Accordingly for each breed within each sex and age group stepwise regression analysis was carried out using statistical package for social sciences (SPSS version 16.0, 2009) to determine the best fitted regression equation. Simple and multiple prediction equations were developed for sex and age group.

Model 3: The model for multiple linear regressions analysis for each breed

$Wi = a + b1x1 + b2x2 + b3x3 + b4x4 + b5x5 + ei$

Where: Wi = the response variable; body weight

a= the intercept

x1, x2, x3, ...,x5 are the explanatory variables heart girth, body length, height at wither, pelvic width and ear length respectively.

b1, b2, b3...b5 are regression coefficient of the variables x1, x2, x3... x6

ei = the residual random error.

## 3. Results and discussion

### 3.1. Growth performance of Washera, Farta and their crossbred sheep

#### 3.1.1. Birth weight

The birth weight for Washera, Farta and their crossbred sheep were 2.61±0.01kg, 2.50±0.02 kg and 2.59±0.01kg, respectively. Those figures obtained in this study were comparable to Gumuz sheep (Solomon et al., 2011) and Washera sheep in its home area (Mengistie et al., 2009a) under on farm management.

Breed was significant source of variation for birth weight ($p<0.05$) in which Washera sheep lambs have heavier weight than Farta and crossbred sheep. Lambs of Lay Gayint district were significantly heavier than lambs of Farta district at birth ($p<0.01$). This could be due to the pregnant ewe supplementation practice by farmers in Lay Gayint district (Shigdaf et al., 2009).

Birth year was a significant ($p<0.01$) source of variation for lamb birth weight. There was a decreasing trend in birth weight from year 2008 to 2010; lambs born in 2008 were heavier than the other following years. The significant effect of year on birth weight indicates variation in the quality and quantity of feed available for pregnant ewes due to fluctuation of distribution of rainfall (Gemeda et al., 2002a) and a trend in decreasing grazing land in the area.

Type of birth was also significant ($P<0.01$) for birth weight: single-born lambs were heavier than their multiple contemporaries (2.65±0.01kg vs. 2.55±0.02kg). This difference could be because of the finite capacity of the maternal uterine space to gestate offspring (Gardner et al., 2007), as litter size increases individual birth weights decline (Mengistie et al., 2009a). The lambs born in the dry season were heavier than lambs born in the wet season (2.61±0.01kg vs. 2.59±0.01kg; $p<0.05$). This might be the preferential treatment of farmers for pregnant ewes in dry season.

#### 3.1.2. Weight at specific ages

The least squares mean and standard error of three month weight for Washera, Farta and their crossbred sheep were 11.78±0.45kg, 10.94±0.74 kg and 11.17±0.49kg, respectively. Breed was significant for three month weight ($p<0.05$). The least squares mean and standard errors of six month weight for Washera, Farta and their crossbred sheep were 14.63±0.40kg, 13.37±0.69kg and 14.55±0.49kg, respectively. Those figures obtained in this study are higher than Horro and Menz sheep (Kassahun, 2000) under on station but lower than Washera sheep at its home area under on farm management (Mengistie et al., 2009a).

Breed was significant for six month weight ($p<0.05$) in which Washera sheep lambs have heavier weight than Farta sheep but similar to crossbreds sheep. In the study areas the farmers have a practice of selling sheep at this age especially for Washera and crossbred sheep as explained in the group discussion so it is better to have good management practice to improve this marketable weight more.

The least squares mean and standard errors of yearling weight for Washera, Farta and their crossbred sheep were 23.70±1.13kg, 20.08±0.73kg and 21.35±1.56kg, respectively. The yearling weights of this finding are higher than what was reported for Horro and Menz sheep (Tibbo et al., 2004; Markos, 2006) under on station and equivalent with Washera sheep at its home area under on farm management (Mengistie et al., 2009a). This result calls for further improvement of yearling weights of those breeds in order to achieve yearling marketable weight (around 30kg) for international as well as local market interest.

Breed was significant ($p<0.01$) for yearling ages in which Washera sheep lambs have heavier weight than Farta sheep but similar to crossbred sheep (Table 1). The result shows that Washera and crossbred sheep have better growth performance than Farta sheep in the study area. This result was supported by farmers witness in the group discussion that Washera and crossbred sheep have better growth performance than Farta sheep as mentioned above. Effect of breed also reported by (Solomon, 2002b; Hassen et al. 2004).

The weight of lambs at different ages was significantly ($p<0.01$) affected by district. Lambs in Lay Gayint district weighed heavier than Farta district at one month, three month and six month weight but the reverse was happened at nine month and yearling weight. The variation in growth performance between districts might be an indication that lambs in Lay Gayint district has better management at early ages since the framers give high focus on lamb production. The difference in growth performance between districts might also be a positive feature to improve the management practice. The effect of district on growth performance was also observed by Berhanu and Aynalem (2009a) and Mengistie et al. (2009a).

Sex was an important source of variation ($p<0.05$) for only six month weight of lambs that males were superior over their female (15.80±0.46kg vs. 15.23±0.45kg). This result is comparable to Hassen et al. (2002) who reported the effect of sex after 5 months. Males appear to grow faster than respective females in utero (Loos et al., 2001; Rastogi, 2001) and this may be attributed to the action of sex hormones in their endocrinological and physiological functions which play a major role in accelerating growth (Markos, 2006; Abbas et al., 2010).

Birth year was significant (p<0.01) source of variation for weight at all considered ages for lambs under on farm. There was an increasing trend in weight at all ages from 2007 to 2010. Likewise the significant effect of year was reported in the literature (Tibbo et al., 2004; Mengistie et al., 2009a). Birth season was also significant (p<0.01) source of variation for one, six and nine month weight of lambs. Lambs born in dry season were heavier than lambs born in wet season at one month (6.35±0.17kg vs. 5.49±0.17kg) and at six month (14.79±0.42 vs.14.25±0.52kg) but the reverse were happened at yearling age (20.27±0.68 vs.19.71 ±0.47kg). This season variation might be due to the feed availability and the management difference for supplementing of lactating ewes and lambs.

Type of birth had significant (p<0.05) effect on lambs weight where single born lambs were heavier than multiple born lambs at one month (6.27±0.1kg vs. 5.78±0.24kg) and three month weights (11.22±0.42kg vs. 10.37±0.64kg). This difference could be the singles are the sole users of the milk from their dam (Markos, 2006). Generally in this study, its effect after three month was totally weakened which might be associated with the environmental adaptation and decreasing of maternal effect. Similarly, Benyi et al. (2009) reported that the superiority in weight and growth rate of the single-born lambs increased only up to weaning and then declined such that after weaning multiple-born had similar growth rate as singles.

### 3.2. Growth rate of Washera, Farta and their crossbred sheep

#### 3.2.1. Pre-weaning growth rate

The growth rate of Washera, Farta and their crossbred sheep from birth to 30 days were 84.79±4.65 gm, 64.53±9.75gm and 82.21±5.61gm, respectively. Those obtained figures were lower than for Washera sheep in its home area from birth to 30 days (143.37±13.46) under on farm management (Mengistie et al., 2009a). The least squares mean average daily gain of Washera, Farta and their crossbred sheep birth to three months of age were 97.52±5.01gm, 83.16±8.29gm and 100.67±5.5gm, respectively.

Breed was a significant (p<0.05) source of variation in lamb pre-weaning growth rate. Washera and crossbreed lambs have fast growth rate than Farta sheep at birth to 30 days (84.79±4.65g vs. 64.53±9.75g) and birth to 90 days (67.52±5.01g vs.58.16±8.29g). This finding indicates that lambs born from Washera sheep were fast grower since maternal in heritance is high at this age. Similarly, Mengistie et al. (2009a) observe that up to weaning lambs are mostly dependent on their dam for their growth requirement.

District was significant source of variation (p<0.01) for pre-weaning growth rate in which case lambs born in Lay Gayint district have fast growth rate than lambs born in Farta district. This might be due to the better lamb management practice of farmers in Lay Gayint. Similarly the effect of district on pre-weaning growth rate of sheep reported in literature (Mukasa-Mugerawa et al., 2000; Berhanu and Aynalem, 2009a).

The difference in pre-growth rate due to year effect was highly significant (p<0.01) for both ages considered. There was a yearly increasing trend year 2007 to 2010. A similar effect of year of birth was reported by Markos (2006). This difference of pre-weight gain between years could be partly associated with the difference in the nutritional fluctuation for ewes since up to weaning lambs are mostly dependent on their dam for their growth requirement (Mengistie et al. 2009a).

Season as a source of variation (p<0.01) for lamb growth rate from birth to one months; lambs born in dry season have higher average daily weight gain than wet season (94.86±5.78gm vs. 79.50±5.84gm) under on farm. Similarly, Markos (2006) report that lambs born in the dry season have fast growth rate than in the wet seasons. The higher growth rate of lambs born in the dry season than in wet seasons might be because of seasonal variation in feed availability both in quantity and quality on natural pasture.

Birth type has highly significant effect (p<0.01) on lamb growth rate from birth to one months and birth to three month of age under on farm; single born lambs have higher average daily weight gain than multiple born lambs at birth to one month (85.36±4.28gm vs. 79.00±8.04gm) and from birth to three month (107.39±4.75gm vs. 80.84±7.18gm), respectively.

#### 3.2.2. Post-weaning growth rate

The least squares mean and standard errors average daily gain from 90 to 180 days of Washera, Farta and their crossbred sheep were 88.03±4.48gm, 85.20±7.71gm and 87.20±5.49gm, respectively. Those obtained results were higher than for Washera sheep in its home area from 90 to 180 days (39.78±9.73g) (Mengistie et al., 2009a); this might be due to the better management of farmers for lambs since their life is depend on sheep production even though the study area is less productive. Breed has significant (p<0.05) effect on post-weaning growth rate in which Washera sheep has better post-weaning growth than Farta and crossbreed sheep.

**Table 1**
Least squares means and standard errors for birth weight (kg) and weight at different ages (kg)

| Source of Variation | Birth wt | | 30d wt | | 90d wt | | 180d wt | | 270d wt | | 360d wt | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | LSM±SE | N | LSM±SE | N | LSM±SE | N | LSM±SE | N | LSM±SE | N | LSM±SE |
| Overall | 1577 | 2.60±0.013 | 647 | 6.02±0.15 | 577 | 12.42±0.48 | 482 | 15.24±0.44 | 279 | 20.99±0.52 | 129 | 23.80±1.26 |
| CV (%) | 1577 | 12.61 | 647 | 28.72 | 577 | 28.88 | 482 | 25.86 | 279 | 21.72 | 129 | 21.77 |
| District | | ** | | ** | | ** | | ** | | ** | | ** |
| Farta | 565 | 2.53±0.01 | 185 | 5.02± 0.21 | 198 | 10.01±0.53 | 195 | 13.50±0.53 | 129 | 20.97±0.74 | 54 | 24.30±1.48 |
| Lay Gayint | 1012 | 2.67±0.01 | 462 | 5.55± 0.14 | 379 | 11.09± 0.49 | 287 | 14.54±0.41 | 150 | 19.01±0.48 | 75 | 20.30±1.26 |
| Breed | | * | | * | | * | | * | | ** | | ** |
| Washera | 1044 | 2.61±0.0 b | 343 | 7.25±0.13b | 318 | 12.78±0.45b | 277 | 15.63±0.40b | 123 | 21.57±0.68b | 70 | 24.70±1.13c |
| Farta | 183 | 2.50±0.02a | 134 | 5.04±0.29a | 123 | 9.94±0.74a | 125 | 12.37±0.69a | 84 | 18.32± 0.49a | 28 | 20.08±0.73a |
| Crosses | 350 | 2.59±0.01a | 170 | 6.17±0.16b | 136 | 11.17±0.49b | 80 | 14.55±0.49b | 72 | 20.08±0.73 b | 31 | 22.50±1.56b |
| Sex | | NS | | NS | | NS | | * | | NS | | NS |
| Female | 813 | 2.60±0.01 | 325 | 5.92±0.16 | 296 | 11.38±0.49 | 243 | 15.23±0.45 | 141 | 20.05±0.54 | 62 | 23.52±1.31 |
| Male | 764 | 2.60±0.01 | 322 | 5.82±0.17 | 281 | 11.22±0.50 | 239 | 15.80±0.46 | 138 | 21.93±0.55 | 67 | 23.09±1.29 |
| Birth year | | ** | | ** | | ** | | ** | | ** | | ** |
| 2007 | 418 | 2.62±0.01c | 161 | 5.36±0.25a | 122 | 8.33±0.41a | 199 | 10.94±0.38a | 102 | 15.88±0.55a | 57 | 21.79±1.26a |
| 2008 | 725 | 2.69±0.01d | 200 | 5.39±0.17a | 219 | 9.94± 0.35b | 214 | 12.88±0.37b | 100 | 17.25±0.57b | 42 | 22.33±1.45b |
| 2009 | 278 | 2.58±0.01b | 195 | 6.37±0.19b | 172 | 14.53±0.40c | 69 | 19.47±1.01c | 75 | 20.25±0.57b | 30 | 22.93±1.45b |
| 2010 | 156 | 2.53±0.02a | 91 | 6.46±0.20b | 64 | 12.39±1.50c | | | | | | |
| Birth season | | * | | ** | | NS | | ** | | ** | | NS |
| Dry | 1136 | 2.61±0.01 | 406 | 6.35±0.17 | 344 | 11.23±0.48 | 302 | 14.79±0.42 | 145 | 19.71±0.47 | 87 | 22.52±1.11 |
| Wet | 441 | 2.59±0.01 | 241 | 5.49±0.17 | 233 | 11.36± 0.51 | 180 | 14.25±0.52 | 134 | 20.27±0.68 | 42 | 22.08±1.60 |
| Birth type | | ** | | * | | ** | | NS | | NS | | NS |
| Single | 1245 | 2.65±0.01 | 497 | 6.27±0.12 | 442 | 11.22±0.42 | 342 | 14.95±0.37 | 159 | 19.30±0.41 | 105 | 23.82± 0.82 |
| Multiple | 332 | 2.55±0.02 | 150 | 5.78±0.24 | 135 | 10.37±0.64 | 140 | 13.09±0.59 | 120 | 19.68±0.77 | 34 | 21.78±2.05 |

N = number of observations; Means with different superscripts letters (a, b, c) within the same column and class are statistically different; Birth wt- birth weight; 30d wt- 30 days weight; 90d wt- 90 days weight; 180d wt- 180 days weight; 270d wt- 270 days weight; 360d wt- 360 days weight;
NS: Not significant (p>0.05); *p<0.05; **p<0.01.

District was a highly significant source of variation (p<0.01) for post-weaning growth rate that lambs born in Lay Gayint district have fast growth rate than lambs born in Farta district (90.22±4.6gm vs. 64.40±5.89gm). This might be due to the better lamb management practice of farmers in Lay Gayint district since they give high focus for sheep production. Similarly the effect of district on growth performance of sheep reported in literature (Mukasa-Mugerawa et al., 2000; Berhanu and Aynalem, 2009a).

In this study sex has a significant effect (p< 0.05) for 90 to 180 days average daily weight gain that male lambs were heavier than female lambs (89.97±5.19gm vs. 83.66±5.01gm). The effect of year was important in influencing post-weaning average daily gain (p<0.01) that lambs born in 2008 are heavier than lambs born in 2007 (101.91±4.1gm vs. 58.12±4.28gm).

Season was as a source of variation (p<0.01) for post-weaning growth rate; lambs born in wet season have higher average daily weight gain than dry season (78.69±4.67gm vs. 94.93±5.81gm). This might be attributed to the feed availability in wet season. Comparable to this result, Kassahun (2000) and Markos (2006) report the significant effect of season on post-weaning growth rate under on station management.

### 3.2.3. Overall growth rate

The least squares mean and standard errors for overall growth rate from birth to 360 days of Washera, Farta and their crossbred sheep were 64.09±3.13 gm, 53.69±4.82gm and 55.34±4.33gm, respectively. The results were relatively lower than Washera sheep in its home area from birth to one year of age 60.13±1.89g (Mengistie et al., 2009a) but comparable with Menz and Horro male lambs (Kassahun, 2000).

**Table 2**

Least squares means and standard errors for growth rates of Washera, Farta and their crossbred sheep

| Source of Variation | Birth to 30 days | | Birth to 90 days | | 90 to 180 days | | Birth to 360 days | |
|---|---|---|---|---|---|---|---|---|
| | N | LSM±SE | N | LSM±SE | N | LSM±SE | N | LSM±SE |
| Overall | 647 | 107.18±5.24 | 577 | 93.12±5.39 | 482 | 86.81±4.89 | 129 | 47.37±3.50 |
| CV (%) | 647 | 49.5 | 577 | 39.59 | 482 | 34.39 | 129 | 26.01 |
| District | | ** | | ** | | ** | | ** |
| Farta | 185 | 92.82±7.19 | 198 | 84.14±5.90 | 195 | 64.40±5.89 | 49 | 50.21±4.11 |
| Lay Gayint | 462 | 109.54±4.80 | 379 | 102.09±5.53 | 287 | 90.22±4.6 | 80 | 53.53±3.50 |
| Breed | | * | | * | | * | | * |
| Washera | 343 | 84.79±4.65b | 318 | 97.52±5.01b | 277 | 88.03±4.48b | 88 | 64.09±3.13b |
| Farta | 134 | 64.53±9.75a | 123 | 83.16±8.29a | 125 | 85.20±7.71a | 28 | 53.69±4.82a |
| Crosses | 170 | 82.21±5.6 b | 136 | 100.67±5.5b | 80 | 87.20±5.49b | 23 | 55.34±4.33a |
| Sex | | NS | | NS | | * | | NS |
| Female | 325 | 77.31±5.54 | 296 | 94.00±5.50 | 243 | 83.66±5.01 | 62 | 47.58±3.65 |
| Male | 322 | 77.04±5.67 | 281 | 93.23±5.6 | 239 | 89.97±5.19 | 67 | 48.16±3.58 |
| Birth year | | ** | | ** | | ** | | ** |
| 2007 | 61 | 51.76±8.53a | 122 | 82.01±4.63a | 209 | 58.12±4.28a | 78 | 43.57±3.50a |
| 2008 | 300 | 66.29±5.77a | 279 | 101.14±3.9b | 204 | 101.91±4.1c | 22 | 50.94±4.04b |
| 2009 | 195 | 98.85±6.37b | 172 | 104.04±4.4c | 70 | 88.12±4.28b | 29 | 49.94±4.04b |
| 2010 | 91 | 91.82±6.80c | 14 | 87.28±16.7a | | | | |
| Birthseason | | ** | | NS | | ** | | NS |
| Dry | 406 | 94.86±5.78 | 344 | 86.38±5.42 | 402 | 78.69±4.67 | 97 | 48.59±3.10 |
| Wet | 241 | 79.50±5.84 | 233 | 101.86±5.76 | 80 | 94.93±5.81 | 32 | 46.16±4.45 |
| Birth type | | * | | ** | | NS | | NS |
| Single | 497 | 85.36±4.28 | 442 | 107.39±4.75 | 342 | 91.62±4.20 | 84 | 50.20±2.29 |
| Multiple | 150 | 79.00±8.04 | 135 | 80.84±7.18 | 140 | 82.00±6.61 | 45 | 44.54±5.72 |

N = number of observations; Means with different superscripts letters (a, b, c) within the same column and class are statistically different; NS: Not significant (p>0.05); *p<0.05; **p<0.01.

Breed has significant (p<0.05) effect on overall growth rate that Washera and crossbred have higher growth rate than Farta sheep. District was a highly significant source of variation (p<0.01) for overall growth rate in which lambs born in Lay Gayint district have fast overall growth rate than lambs born in Farta district (Table 2). This might be due to the better lamb management practice of farmers in Lay Gayint district since they give high focus for sheep production. The effect of year was important in influencing average daily gain constantly (p<0.01) for overall growth rate in which its effect shows in consistency.

**3.2.4. Body weight and linear body measurements**

Least squares mean and standard errors of body weight and other linear body measurements of Washera, Farta and their crossbreed sheep under on farm management system are presented in Table 3. The live body weight for sheep at one PPI (27.68 kg) is an indicator for improvement to achieve recommended body weight of 30 kg at yearling age (Markos, 2006) for commercial market purpose.

Breed has a significant effect in most body measurements except heart girth (P<0.01). Washera sheep breed has higher value for body weight, wither at height and pelvic width than Farta and crossbred sheep. This shows that the breed has large body weight and large body size in comparison with Farta and crossbred sheep which was supported by the farmers explanation. In addition, it was superior in body length and ear length than Farta sheep but similar to crossbred sheep. This might be due to the genetic makeup effect on those measurements. Breed effects on body measurements were also reported by Zewdu et al. (2009b).

Sex of animals had consistence effect on all considered body measurements except pelvic width and ear length (P<0.01). All parameters were higher (P<0.05) in males. The higher body weight and body measurement values in males than females observed in this study might be due to the hormonal difference in growth. This was supported by Mengistie et al. (2010) that the superiority in the weight of males over females could be a result of the hormonal differences in their endocrinological and physiological functions. In addition Sowande and Sobola (2007) reported that ewes have slower rate of growth and reach maturity at smaller size due to the effect of oestrogen in restricting the growth of the long bones of the body.

**Table 3**
Linear body measurements of Washera, Farta and their crossbred sheep under on farm management system

| | | Body weight | Wither height | Body length | Heart girth | Pelvic width | Ear length |
|---|---|---|---|---|---|---|---|
| **Effects and level** | **N** | **LSM±SE** | **LSM±SE** | **LSM±SE** | **LSM±SE** | **LSM±SE** | **LSM±SE** |
| Overall | 1086 | 27.75±0.26 | 66.98±0.27 | 58.0±0.31 | 74.98±0.37 | 14.54±0.10 | 10.21±0.07 |
| CV% | 1086 | 16.87 | 6.99 | 9.08 | 8.43 | 12.61 | 12.28 |
| Breed | | ** | ** | ** | NS | ** | ** |
| Crossbred | 149 | 27.61± 0.44a | 66.90±0.47a | 58.46±0.53b | 75.25±0.63 | 14.6±0.18a | 10.2±0.13b |
| Farta | 378 | 26.86±0.43a | 65.78±0.46 a | 56.74±0.52a | 74.24±0.62 | 14.09±0.18a | 9.94±0.12a |
| Washera | 559 | 28.77±0.26b | 68.25± 0.28b | 58.78±0.32b | 75.44±0.38 | 14.92±0.1 b | 10.4±0.07b |
| Season | | ** | * | ** | ** | ** | ** |
| Dry | 458 | 28.53±0.28 | 67.30± 0.30 | 58.71±0.34 | 75.72±0.40 | 15.07±0.11 | 10.10±0.08 |
| Wet | 628 | 26.97±0.30 | 66.66±0.32 | 57.28±0.37 | 74.24±0.44 | 14.00±0.12 | 10.32±0.09 |
| Sex | | ** | ** | ** | ** | NS | NS |
| Female | 829 | 24.78±0.27 | 64.54±0.28 | 56.51±0.32 | 72.77±0.39 | 14.35±0.11 | 10.43±0.08 |
| Male | 257 | 30.72±0.44 | 69.43±0.47 | 59.48±0.53 | 77.18±0.63 | 14.73±0.18 | 10.40±0.13 |
| Age group | | ** | ** | ** | ** | ** | ** |
| 0 PPI | 325 | 16.62±0.27 a | 58.71±0.29 a | 49.84±0.33a | 61.89±0.3a | 11.7± 0.11 a | 9.69±0.08 a |
| 1 PPI | 87 | 27.68±0.52 b | 68.15±0.55 b | 59.04±0.63b | 75.78±0.7b | 14.70±0.21b | 10.43±0.15 b |
| 2 PPI | 49 | 30.60±0.71 c | 68.99±0.75 b | 59.9±0.86 b | 77.02±1.02b | 14.98±0.29 b | 10.12±0.21b |
| 3 PPI | 58 | 31.61±0.66 c | 69.78±0.70 b | 59.7±0.79b | 80.47±0.95c | 15.93±0.27 c | 10.42±0.19 b |
| ≥4 PPI | 567 | 32.22±0.38 c | 69.29±0.40 b | 61.4±0.46b | 79.73±0.55c | 15.37±0.16 b | 10.39±0.11 b |

N = number of observations; Means with different superscripts letters (a, b, c) within the same column and class are statistically different. NS = Non significant; *significant at 0.05; **significant at 0.01; PPI = pair of permanent incisor.

Age group have significant effect (P< 0.01) on body weight and all considered linear body measurements. The trend in all body measurements and body weight increased with increase in age group class from 0PPI to 2PPI but there was no much difference in age group class of the 2PPI and more. This may be attributed to the faster growth rate of younger animals compared to the older ones. Similar observation was made by Fikrte (2008) and Tesfaye et al. (2009b) that body weight and all the body measurements were significantly affected by age group.

### 2.5. Correlation between body weight and other linear body measurements

The Pearson's correlation coefficient of the body weight with linear body measurements of Washera, Farta and their crossbred sheep for different sex and age groups is presented in Table 4. Body weight was significantly correlated (P<0.01) with linear body measurements with correlation coefficient for overall sheep ranged from 0.25 for ear length to 0.86 for heart girth. Ear length showed negative correlation and non-significant for all breed. The observed positive correlations between weight and other body measurements were suggest that either of these variables or their combination could provide a good estimate for predicting body weight as well as indirect selection criteria to improve live weight of sheep (Cam et al., 2010; Tesfaye et al., 2009b). The higher association of body weight with heart girth was possibly due to relatively larger contribution in body weight by heart girth (consisting of bones, muscles, and viscera) (Thiruvenkadan, 2005).

**Table 4**
Phenotypic correlation between body weight and linear body measurements for Washera, Farta and their crossbred sheep

| Breed | Sex/Age | N | HW | BL | HG | PW | EL |
|---|---|---|---|---|---|---|---|
| Washera | Male, 0PPI | 89 | 0.76** | 0.56** | 0.68** | 0.62** | 0.30** |
| | Male, ≥1PPI | 59 | 0.67** | 0.65 | 0.76** | 0.66** | 0.15 ns |
| | Female, 0PPI | 65 | 0.44** | 0.48** | 0.56** | 0.37** | 0.28** |
| | Female, ≥1PPI | 342 | 0.31** | 0.58** | 0.54** | 0.15 ns | 0.11 ns |
| | Pooled | 559 | 0.82** | 0.78** | 0.85** | 0.73** | 0.31** |
| Farta | Male, 0PPI | 11 | 0.88** | 0.83** | 0.92** | 0.70** | 0.49 ns |
| | Male, ≥1PPI | 30 | 0.87** | 0.82** | 0.78** | 0.39 ns | 0.19 ns |
| | Female, 0PPI | 33 | 0.85** | 0.86** | 0.88** | 0.54** | 0.13 ns |
| | Female, ≥1PPI | 314 | 0.37** | 0.32** | 0.64** | 0.31** | -0.03 ns |
| | Pooled | 378 | 0.69** | 0.61** | 0.80** | 0.51** | 0.13* |
| Crosses | Male, 0PPI | 64 | 0.77** | 0.57** | 0.82** | 0.60** | 0.36** |
| | Male, ≥1PPI | 10 | 0.76 ** | 0.72 ns | 0.67** | 0.69** | -0.15 ns |
| | Female, 0PPI | 63 | 0.78** | 0.68** | 0.82** | 0.70** | 0.14 ns |
| | Female, ≥1PPI | 12 | 0.30 ns | 0.51** | 0.93** | 0.70 ns | -0.22 ns |
| | Pooled | 149 | 0.83** | 0.75** | 0.88** | 0.74** | 0.21* |
| Overall | | 1086 | 0.80** | 0.75** | 0.86** | 0.68** | 0.25* |

N = number of observations; **Correlation is significant at 0.01 level; *Correlation is significant at 0.05 level; ns correlation is not significant at 0.05 levels.

### 3.2.6. Prediction of body weight from other body measurements

Different regression models were developed for different breed with in sexes, age groups and for the pooled data (Table 5). Heart girth accounted for 85%, 80% and 88% of the highest variation in body weight for pooled data in Washera, Farta and their crossbred sheep, respectively. The finding of this result showed that heart girth (HG) alone can be used to predict body weight. Similarly, Mengistie et al. (2010) reported that under field conditions heart girth alone can be used to reduce complexity and bias that would come due to posture of animals when measuring. Therefore, body weight can be estimated for pooled Washera sheep Y= -18.25+0.61HG, for Farta sheep Y= -47.80+1.1HG and for crossbred sheep Y= -22.29 + 0.63HG under on farm management. Likewise, Kassahun (2000) found out that heart girth alone explains 83% and 81% of weight for Menz and Horro ram lambs and Mengistie et al. (2010) also reported that heart girth alone could provide a good estimate of predicting live weight of Washera sheep at different age groups in its home area.

Further addition of height at wither improved the r-squared value from 84% to 90% for all sheep in the study area. Despite better prediction of body weight from combinations of body measures, having these multiple variables to predict body weight posses a practical problem under field settings due to the higher labour and time needed for measurement and difficulty of proper animal restraint during measurement (Zewdu et al., 2009b; Tesfaye et al., 2009b). So for simplicity under farmer management condition, it is advisable to use the simple regression equation for body weight estimation using heart girth in this study.

**4. Conclusion**

When Washera, Farta and their crossbred sheep were evaluated biologically, Washera sheep was better in growth & growth rate performance and in linear body measurements followed by crossbred sheep. Linear body measurements except ear length were significantly and positively correlated to body weight in each breed. So, body weight could be estimated using regression equation for pooled Washera sheep Y= -18.25+0.61HG, for Farta sheep Y= -47.80+1.1HG and for crossbred sheep Y= -22.29 + 0.63HG under on farm management system.

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**Table 5**
Simple and multiple regression analysis of live weight for Washera, Farta and their crossbred sheep

| Breed | Sex/Dentition | Model | Intercept | b1 | b2 | b3 | Adj R-Sq | R2 change | Std error |
|---|---|---|---|---|---|---|---|---|---|
| Washera | Male, 0PPI | a+b1HW | -22.46±3.75 | 0.66±0.0 | | | 0.57 | 0.01 | 3.41 |
| | | a+b1HW+b2PW | -24.16±3.56 | 0.53±0.07 | 0.80±0.23 | | 0.62 | 0.05 | 3.21 |
| | Male, ≥1PPI | a+b1HG | -10.73±5.33 | 0.57±0.06 | | | 0.56 | 0.01 | 4.31 |
| | | a+b1HG+b2BL | -16.33±5.54 | 0.44±0.08 | 0.26±0.10 | | 0.60 | 0.04 | 4.11 |
| | Female, 0PPI | a+b1HG | -3.47±2.76 | 0.29±0.04 | | | 0.43 | 0.01 | 2.91 |
| | Female, ≥1PPI | a+b1HG | -5.05±2.55 | 0.44±0.03 | | | 0.34 | 0.01 | 2.83 |
| Pooled | | a+b1HG | -18.25±6.01 | 0.61±0.08 | | | 0.90 | 0.02 | 2.27 |
| Farta | Male, 0PPI | a+b1HG | -22.18±5.48 | 0.62±0.08 | | | 0.82 | 0.02 | 2.74 |
| | Male, ≥1PPI | a+b1HG | -57.70±12.39 | 1.29±0.17 | | | 0.73 | 0.03 | 4.81 |
| | Female, 0PPI | a+b1HG | -25.64±4.40 | 0.69±0.06 | | | 0.76 | 0.02 | 2.96 |
| | | a+b1HG+b2BL | -30.38±4.49 | 0.43±0.12 | 0.41±0.16 | | 0.79 | 0.03 | 2.74 |
| | Female,≥1PPI | a+b1HG | -20.49±8.75 | 0.20±0.05 | | | 0.63 | 0.14 | 2.47 |
| | pooled | a+b1HG | -47.80±8.56 | 1.00±0.11 | | | 0.84 | 0.01 | 3.53 |
| Crosses | Male, 0PPI | a+b1HG | -16.04±2.99 | 0.52±0.04 | | | 0.66 | 0.01 | 2.59 |
| | Male, ≥1PPI | a+b1HW | -25.86±17.78 | 0.81±0.24 | | | 0.53 | 0.02 | 3.28 |
| | | a+b1HW+b2PW | -43.76±13.74 | 0.65±0.17 | 1.87±0.61 | | 0.77 | 0.23 | 2.29 |
| | Female, 0PPI | a+b1HG | -12.48±2.38 | 0.40±0.03 | | | 0.70 | 0.70 | 2.60 |
| | Female,≥1PPI | a+b1HG | -30.32±6.93 | 0.64±0.07 | | | 0.86 | 0.01 | 2.26 |
| | pooled | a+b1HG | -22.29±1.84 | 0.63±0.02 | | | 0.77 | 0.77 | 3.22 |
| | | a+b1HG+b2HW | -31.65±2.27 | 0.42±0.04 | 0.37±0.06 | | 0.81 | 0.04 | 2.89 |
| | | a+b1HG+b2HW+b3BL | -31.20±2.18 | 0.25±0.06 | 0.33±0.06 | 0.17±0.04 | 0.83 | 0.01 | 2.78 |
| Overall | | a+b1HG | -30.72±4.04 | 0.76±0.05 | | | 0.84 | 0.02 | 2.88 |
| | | a+b1HG+b2HW | -25.11±4.74 | 0.37±0.10 | 0.50±0.14 | | 0.90 | 0.01 | 2.32 |

HG= Heart Girth; BL = Body length; HW = Wither height; PW=Pelvic Width; 0 PPI = 0 pair of permanent incisors and ≥ 1 PPI = 1 or more pairs of permanent incisors; b1, b2 and b3 are regression coefficient of the variables; Adj. R-Sq=Adjusted r-square