Production system and linear body measurements of Washera sheep in the Western highlands of the Amhara National Regional State, Ethiopia

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Abstract

A study was conducted to describe the production systems and the linear body measurements of Washera sheep in the northwestern highlands of Ethiopia. Data was collected using focus group discussion and field measurements. Washera sheep are kept by smallholder farmers in a mixed crop-livestock system. The major source of feed for sheep is communal pasture. Sheep are housed at night together with other livestock separated by woodlot. Mating is year round. Docking the fat tail of ewe lambs is a common practice. The average flock size per household obtained in the present study was 9.58 sheep. The sheep flock on average was composed of 52.2% young stock with milk teeth, 9.9% sheep with 1 pair of permanent incisors (PPI), 8.3% with 2 PPI, 5.2% with 3 PPI and 24.3% with 4 PPI and above. The overall body weight, wither height, body length, heart girth, pelvic width and ear length were 26.69±0.45 kg, 68.96±0.36 cm, 57.66±0.33 cm, 74.37±0.49 cm, 14.34±0.12 cm and 9.73±0.08 cm, respectively. The fixed effects of district, sex, dentition and the interaction between sex and dentition were sources of variations for most of the measured variables. The high correlation coefficients observed between body weight and heart girth for all dentition groups suggested heart girth alone or in combination with other body measurements could be used to predict live weight of Washera sheep. Differences in coefficient of determination of equations fitted for different dentition groups indicated that weight could be estimated using different equations for different age groups with different accuracies.

Key words: Heart girth, linear body measurement, traditional farming systems, Washera sheep.

Introduction

Ethiopia with its extremes of variable agro-climatic conditions and ecological systems is endowed with 21 million heads of sheep (CSA, 2003) categorized into 18 divers populations (Tibbo, 2006). Among these diverse sheep populations, Washera sheep is found in the Western highlands of the Amhara National Regional State (Sisay, 2002). The breed has a population of around 1.22 million (CSA, 2006) and are one of the most productive breeds (Chipman, 2003). Washera sheep also called Dangla is characterized by large body size, wide fat-tail usually curved upward tip, horizontally carried or semi-pendulous long ears, both sexes hornless and slightly concave facial profile. These sheep have long and thin legs, long neck, and prominently protruding brisket. Plain, patchy and spotted patterns of coat colour to which reddish brown with white patches or spots usually on the forehead and lower parts of the legs, plain reddish brown and plain white are dominant colour types (Sisay, 2002).

A primary procedure for any future improvement in genetic resource utilization and conservation is to describe the breed/type and its production system. Information on the description of body measurements of Ethiopian indigenous sheep in general and Washera sheep in particular is scanty. The objective of the study was, therefore, to collect data on the production system and morphological characters of Washera sheep kept under the traditional management system of the northwestern highlands of Ethiopia.

Materials and methods

The study area

The study was conducted on on-farm flocks in two districts in the northwestern highlands of Ethiopia. The first district, Yilmanadensa, is located between 11^{o}10'-11^{o}15'N and 37^{o}30'-37^{o}40'E. The second district, Quarit, is located between 11^{o}00'N and 37^{o}20'-37^{o}30'E. The study districts and flocks were selected purposively to superimpose on the ongoing project entitled '*Community- and Conservation-based Improvement Scheme (program) for Washera Sheep'*. Both of the study areas are situated at an altitude range of 1500 to >3000 m above sea level. The study areas have one rainy season, which extends from mid May to October and all the remaining months (November to mid May) are dry. Estimated average minimum and maximum air temperatures in the two districts are 13 and 24 ^{O}C, respectively (ENMA, unpublished).

Data collection and analysis

Data was collected in August 2007. Participatory rural appraisal (PRA) with a focus group discussion was used to investigate and understand the general sheep production system of the area. A check list focused on the major agricultural system, major crops produced, major livestock produced, and sheep production (management and marketing, feeds and feeding, reproduction management) was used.

For the morphological study, all sheep (N = 650) in the study flock above nine month of age were measured. The live weight of an animal was measured using a Salter scale (50 kg capacity with 200 gram precision). Other body measurements (heart girth, wither height, body length, pelvic width and ear length) were measured using flexible metal tape (3 meter length) to the nearest 0.5 cm after restraining and holding the animals in an unforced position. Heart girth was measured as the circumference of the chest posterior to the forelegs at right angles to the body axis. Wither height was recorded as the highest point measured as the vertical distance from the top of the shoulder to the ground (bottom of forelegs). Body length was measured as the horizontal length from the point of shoulder to the pin bone. Pelvic width was recorded as the horizontal distance between the extreme lateral points of the hook bone (*tuber coxae*) of the pelvis. Ear length was recorded as the length of the external ear from its root to the tip (Figure 1).

Analysis of variance of fixed effects of location, sex and dentition on body measurements were done by the General Linear Model procedures of Statistical Analysis System (SAS version 9.1). The statistical models used were:

$$Y_{ijk} = \mu \pm D_i \pm S_j \pm (DS)_{ij} \pm e_{ijk} \qquad \text{Model 1}$$

$$W = a \pm bG \text{ (linear)} \qquad \text{Model 2}$$

$$W = a \pm b_1G_1 \pm b_2G_2 \pm \ldots \pm b_nG_n \text{ (Multiple linear)} \qquad \text{Model 3}$$

Where, Y_{ijk} = The observation on body weight, wither height, heart girth, body length, pelvic width, ear length; W = The observation on live weight of the animal; μ = Overall mean; D_i = Fixed effect of district (i= Yilmanadensa, Quarit); S_j = Fixed effect of lamb sex (j = Female, Male); $(DS)_{ij}$ = the interaction effect of district with sex; a = Intercept; b=

Regression coefficient of weight on body measurements; G = Body measurements; n = n^{th} number of body measurement; e_{ijk} = effect of random error.

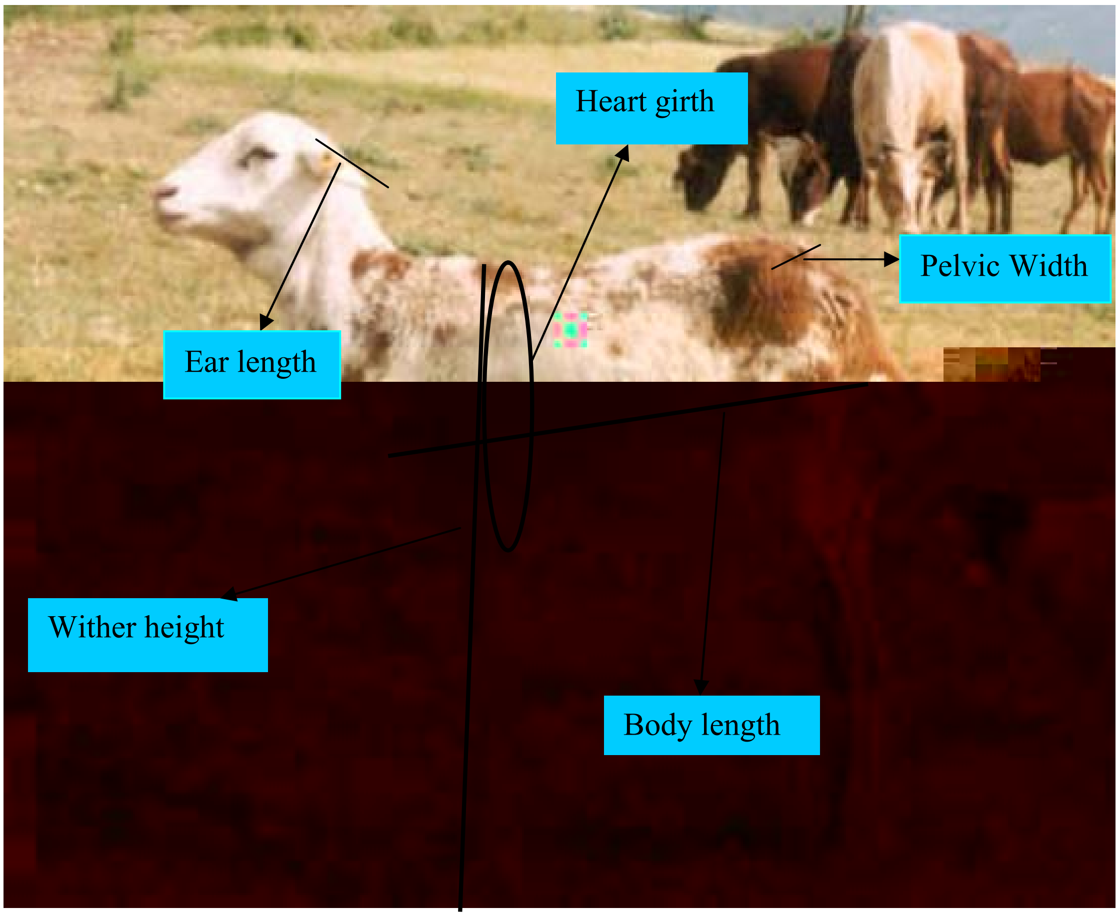

Figure 1. Washera ewe showing the exact points at which the measurements were taken.

For the analysis of fixed effects of linear body measurements model 1 was used. For all linear measurements dentition was grouped as 0-sheep with milk teeth (above 9 months); 1-sheep with one pair of permanent incisor (PPI); 2-sheep with two PPI; 3-sheep with three PPI; 4-sheep with four PPI and above. For the prediction equation of weight using body measurements, models 2 (linear) and 3 (multiple linear) were used. The statistical analysis was carried out using SPSS (SPSS version 13.0) linear regression procedures. Live weight was regressed on body measurements separately for different age groups and for overall. In the multiple regression equation, prediction equations were developed for live weight using a stepwise multiple regression procedure in which the number of predictors to be selected and the order of entry are both decided by statistical criteria (Field, 2005).

Results and discussion

Description of the production system

The agricultural production system in the study area was mixed crop-livestock. Crop production was the main agricultural activity in both study areas. The major crops grown include teff, maize, chickpea, barley, grass pea, field pea, faba bean and wheat. Cattle, sheep, donkey and poultry were main livestock species reared by the farm household. Some people practiced apiary. Cattle were mainly kept for draft power (ploughing) from oxen and production of oxen and small milk from cows. Sheep and poultry were kept for cash income (sale) and for home consumption. Livestock production and crop production complement each other in such a way that livestock are used as a source for draft and manure for crop production and from crop production the crop residues, straws and aftermath serve as main components of livestock feeds in the study areas. This type of complementarities in mixed crop-livestock production systems is well stated in the literature (Getahun, 2008).

Livestock graze on a communal grazing land which is owned by about 10 farmers (the area of land and number of households varies from area to area) and on crop aftermath. Most farmers own private grazing land for morning and afternoon grazing. Shrinkage of the communal grazing land from time to time due to cultivation and increased population pressure are the critical and major threats in addition to land slide and erosion (gully) in the highlands of Ethiopia (Getahun, 2008; Mengistie, 2008).

Though sheep production contributes in the household income to a great extent, it has long been taken as a side activity. However, the trend is that due to the decreasing grazing land and increasing population pressure, sheep are becoming very important and increasing from time to time. During focus group discussion, the key informants did mention that because of their suitability to produce and reproduce under feed shortage and with the increased market value, sheep are getting more attention in the present days.

Sheep production and management

Feeding: Sheep are herded together with other livestock species during the day. Like other parts of the highlands of the country, the main feed source is communal grazing land, crop residue and crop aftermath (Abebe, 1999; Getahun, 2008; Tesfaye, 2008). During crop harvesting season and in the afternoon, farmers remove their animals from the group-flock and graze them in their respective private grazing land and crop aftermath. Sheep had no access to hay and straw collected for dry season feeding. Now-a-days some farmers in the study areas are recognizing the difference of supplementing or not supplementing during feed shortage times. Priorities are given to pregnant, suckling and castrated animals when supplementing. The supplements are grass-pea straw, sprouted bean, local brewery byproduct "*atela*" and salt.

Housing: Farmers in the study area house their sheep throughout the year to protect them from cold and rain, predators and theft. The housing is usually together with other livestock to which it is separated by a fence. But some farmers with large flock size constructed separate house for their sheep. In both cases it is usually built adjacent to the family house. Some farmers with small flock size tie their sheep to a peg. According to the respondents, there is a difference in the productivity of sheep between those tied and housed freely where tied animals were healthier and productive than those housed freely. Farmers explained this as sheep housed freely lay one over each other because of their social behaviour and also in need of the warmth from huddling. Pregnant animals, young lambs and weak animals are the most vulnerable groups. In addition, animals may not get enough rest at night.

Newborn lambs in the first week of birth are separated from their dam and cared for at home during the day when sheep are taken to grazing and before they get into their house upon their return in the afternoon. This is a common practice in other parts of the country (Mengistie, 2008; Tesfaye, 2008; Abebe, 1999). Farmers use large baskets to keep newborn lambs; allow lambs to be kept dry, clean and warm. Suckling is in the morning before the dam leaves for grazing and when the flocks are back from grazing in the afternoon. Some farmers do separate even the dams for at least the first week of parturition and provide care for both lambs and dams indoors. These increase the dam-lamb relationship and help to protect the lamb from chill, sun and other environmental stresses thereby increase lamb survival (Mukasa-Mugerwa *et al*., 2000).

Disease prevalence and control: There is less disease load in the study areas. Nonetheless, occasionally there might be disease outbreak during which many sheep would die because of lack of health support. Some of the symptoms of diseases in the area mentioned were death, shivering, coughing, diarrhea, bloating, haemorrhage and wound around ear and mouth and legs, loss of appetite, mucus and frowsy mouth, dropping ear and head. Apart from taking to health clinics, farmers treat their animals by drenching the juice of different herbs, bleeding on its ear and ironing and puncturing the abdomen when bloating. But, most of the time they die. Abortion was an important problem of sheep production. Fearing of these, many farmers are reluctant to keep as many sheep as they need.

Reproduction: Reproduction is year-round to which most lambing concentrate in some of the months (August and February). This is true for any other breeds of sheep in Ethiopia (Getahun, 2008; Girma, 2008). Mating was uncontrolled: any ram in the flock would mate with any in-heat ewe. There is a problem of breeding ram; ram lambs were sold before reaching puberty. If any, those are of poor conformation to be sold at the market. In fact, some farmers had their own ram tied at home and a farmer does not allow his ram to mate other farmers' ewes.

Docking: Cutting the fat tail of female sheep is a common practice in both study areas. Sisay (2002) reported that more than half of the breeding females in the Western highland sheep were docked. There is no standardized specific site of cutting. The practice is that almost all of the fat tail would be cut (Figure 2). This is intended to ease mating and improve conception rate, improve body condition and not least to use the cut tail for consumption while the sheep are still alive. The cutting is done at the age of 2–3 months of age, after weaning. Farmers use hot sharp knife to avoid bleeding and infection.

Figure 2. Docked ewe lamb (left), weaning method (right) in the study areas.

Weaning: There is no formal weaning and weaning age. But when suckling is prolonged and if lambs are of good body condition, farmers wean their sheep by covering the udder of the dam with a piece of cloth (Figure 2), smearing the teat with dung and separating the dam from the lamb. This is usually done after three months of age of the lamb.

Culling: Culling is not common in the study area. Old ewes are maintained for long period of time even to the 12th parity. Ewes can be kept with no production for years. Farmers do not want to sell or slaughter those sheep that serve the family. But today, this type of sheep management is changing.

Castration: Castration of sheep is not a common practice in the study areas. Some farmers with better wealth status, however, castrate and fatten two to three castrates for long period (1-2 years) for home consumption as well as for market. The method of castration is traditional by repeatedly crushing the cord above the testis using a smooth river-stone and wood. The age of castration is not fixed, but it is usually after the one pair of permanent incisors is seen. This is because farmers believed that the rams will mature and finish growth at this age.

Marketing: Though sheep are sold anytime in a year and as cash needed, most are sold during holidays. Most ewe and ram lambs are sold just at weaning before they lose condition because of weaning shock. It is the ram lambs that are usually sold for meat at the market. Ewe lambs are sold for reproduction at the village level. Ewe lambs of healthy and better producing flock can be sold (pre-paid with better price) even earlier than two weeks of age by convention between the owner and buyer to take at weaning. This is to have better producing genotype. Through this they are selecting the flock for good. But, un-deliberately they are selecting the flock negatively through the drain of fast-growing good genotype ram lambs. This is because those good looking with high growth ram lambs are sold out from the flock before they reach breeding age. Since there is no controlled breeding, ram lambs which are not sold because of poor growth and conformation has chance to mate the flock.

In both areas, there is a nearby market to sell their sheep and there is a trend of marketing within the village (especially for breeding purpose). Market access was not mentioned as a problem in the study areas.

Flock size and demography

The average flock size per household and flock composition by age and sex in the study is presented in Table 1. The average flock size per household obtained in the present study was 9.58 sheep. Flock size ranged from 1 to 29 heads of sheep. A similar result was reported for the same sheep at Quarit (Chipman, 2003). The average holding of sheep (9.58) was higher than the 5.0 sheep/household reported from Alaba areas (Tsedeke, 2007) and the 6.97 sheep/household around Dire Dawa (Aden, 2003). However, it is lower than the 16.02 sheep/household in Gumuz sheep (Solomon, 2007), and 24 sheep/household in Lallo Mama Midir in the central highland of Ethiopia (Abebe, 1999).

Flock composition in terms of sex and age classes has been taken as an indicator of the management system that reflects to some degree the management objective, flock productivity and constraints on the system (Ibrahim, 1998). In the present study, the total flock composition (%) was 52.2, 9.9, 8.3, 5.2 and 24.3, young stock with milk teeth, sheep with 1 PPI, 2 PPI, 3 PPI and 4 PPI and above, respectively (Table 1). From the young stock, 60.2% were females, 38.7% males and the rest 1.1% were castrates. This suggests that since a 1:1 male to female ratio is expected, more ram lambs were already sold from this age group.

Of the total flock, 76.4% were females of which 58.8% were breeding ewes with at least one PPI and 31.6% were old ewes with four PPI and above. This higher proportion of old breeding ewes indicates that farmers in study area maintain breeding ewes for long period of time and the importance of culling. Males and castrates constitute 21.8% and 1.8%, respectively. More than 92% of the non-castrated males and 32% of the castrates were with milk teeth. The present study is in close agreement with the CSA (2003) report obtained in the Amhara region with 74.1% females and 25.9% males from the total flock. Sisay (2002), who studied sheep flocks under the traditional systems in Amhara region reported exactly similar results of 76.39% females and 23.61% males.

Table 1. Average flock size and flock composition by sex and dentition groups.

	Dentition group [1]										Total	
	0		1		2		3		4			
Sex	No	%	No	%	No	%	No	%	No	%	No	%
Male	208	20.2	4	0.4	4	0.4	7	0.8	2	0.2	225	21.8
Female	324	31.4	89	8.6	79	7.4	46	4.5	249	24.2	787	76.3
Castrate	6	0.6	9	1	3	0.4	1	0.0	0.0	0.0	19	1.8
Overall	538	52.2	102	9.9	86	8.3	54	5.2	251	24.3	1031	100

[1] *Dentition: 0 = sheep with milk teeth, 1 = sheep with 1 PPI, 2 = sheep with 2 PPI, 3 = sheep with 3 PPI, 4 = sheep with 4 PPI and above.*

Linear body measurements

Body measurements of Washera sheep are presented in Table 2. The overall body weight, wither height, body length, heart girth, pelvic width and ear length obtained were 26.69±0.45 kg, 68.96±0.36 cm, 57.66±0.33 cm, 74.37±0.49 cm, 14.34±0.12 cm and 9.73±0.08 cm, respectively.

Table 2. Linear body measurements of Washera sheep by district, sex and dentition.

Variable	N	Weight (kg)	Wither height (cm)	Body length (cm)	Heart girth (cm)	Pelvic width (cm)	Ear length (cm)
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	650	26.69±0.45	68.96±0.36	57.66±0.33	74.37±0.49	14.34±0.12	9.73±0.08
District		***	***	NS	**	***	NS
Yilmanadensa	377	26.03±0.47	69.59±0.38	57.55±0.35	73.87±0.51	14.21±0.12	9.76±0.08
Quarti	273	27.34±0.47	68.34±0.38	57.76±0.35	74.87±0.51	14.47±0.12	9.71±0.08
Sex		***	***	*	**	NS	NS
Male	58	28.33±0.88	70.79±0.71	58.34±0.65	75.65±0.95	14.24±0.23	9.67±0.15
Female	592	25.04±0.18	67.14±0.14	56.98±0.13	73.09±0.19	14.44±0.05	9.80±0.03
Dentition		***	***	***	***	***	NS
0	146	19.79±0.33[c]	63.99±0.27 [b]	52.72±0.25[c]	66.28±0.36[d]	12.59±0.09[d]	9.61±0.06
1	105	25.56±1.09[b]	69.71±0.88[a]	56.96±0.81[b]	72.82±1.19[c]	14.05±0.29[c]	9.88±0.19
2	95	27.45±1.09[ab]	70.1±0.88[a]	58.69±0.81[ab]	75.08±1.19[bc]	14.47±0.29[bc]	9.73±0.19
3	55	30.19±0.87[a]	71.43±0.70[a]	59.40±0.65[a]	77.88±0.95[ab]	15.17±0.23[ab]	9.49±0.15
4	249	30.43±1.32[a]	69.58±1.07[a]	60.52±0.98[a]	79.79±1.44[a]	15.42±0.35[a]	9.97±0.23
Sex xDentition		**	***	*	***	NS	NS
Male x 0	45	19.52±0.56[e]	63.74±0.45[c]	52.24±0.41[c]	65.22±0.60[e]	12.22±0.15	9.55±0.10
Male x 1	3	27.61±2.16[bcd]	73.07±1.74[a]	57.90±1.60[ab]	74.28±2.34[bc]	13.98±0.56	10.08±0.38
Male x 2	3	29.18±2.15[abc]	72.63±1.73[a]	59.65±1.60[a]	76.17±2.34[ab]	14.27±0.56	9.63±0.38
Male x 3	5	33.05±1.67[a]	74.51±1.34[a]	60.41±1.24[a]	80.33±1.81[a]	15.24±0.44	9.09±0.29
Male x 4	2	32.30±2.64[ab]	70.00±2.12[ab]	61.50±1.96[a]	82.25±2.86[a]	15.50±0.69	10.00±0.47
Female x 0	101	20.06±0.37[e]	64.25±0.30[c]	53.20±0.28[c]	67.34±0.40[d]	12.96±0.10	9.66±0.07
Female x 1	102	23.51±0.37[d]	66.35±0.30[b]	56.03±0.27[b]	71.35±0.40[c]	14.13±0.10	9.68±0.07
Female x 2	92	25.73±0.39[cd]	67.61±0.31[b]	57.74±0.29[ab]	73.99±0.42[bc]	14.68±0.10	9.82±0.07
Female x 3	50	27.34±0.53[bcd]	68.34±0.43[b]	58.39±0.39[a]	75.43±0.57[b]	15.10±0.14	9.90±0.09
Female x 4	247	28.56±0.24[bc]	69.16±0.19[b]	59.53±0.18[a]	77.33±0.26[a]	15.34±0.06	9.94±0.04

*[1]Dentition is same as in Table 1. NS, *, **, ***, and **** denote non significant and significant differences at p<0.05, p<0.01, p<0.001, and p<0.0001 probability levels, respectively.*

The overall body weight (26.69±0.45 kg) obtained were smaller than the report for the mature Western highland sheep by Sisay (2002), while it was in close agreement with Horro and Menz sheep at 12 and 24 months of age (Tibbo *et al*., 2004). Fixed effects district, sex and dentition were significant (p<0.001) sources of variation for body weights. Sheep from Quarit, male sheep and old aged sheep were superior in weight than Yilmanadensa sheep, female sheep and young aged sheep (with dentition <2 PPI), respectively. The effect of district may be because of the differences in the management of sheep between the districts. The superiority in the weight of males over females could be because of the hormonal differences in their endocrinological and physiological functions

(Ebangi *et al*., 1996). Tibbo *et al*. (2004) also reported the effect of sex on the weight of Horro and Menz sheep. The interaction effect of sex with dentition significantly ($p<0.01$) affected body weight where male and old aged (dentition 2, 3, 4) sheep were heavier than other groups of sheep.

Height at wither (68.96±0.36 cm) was significantly ($p<0.001$) affected by district, sex, dentition and the interaction between sex and dentition. Yilmanadensa sheep were superior in height at wither over their Quarit counterparts. Males with dentition above 1 PPI were taller than other sex and dentition groups. This might be because growth continues to a certain age until bone growth stops. The value obtained is in comparison with the value reported Sisay (2002) for mature western highland sheep. However, it is greater than that of Horro and Menz sheep at 12 and 24 months of age (Tibbo *et al*., 2004).

Sex, dentition and the interaction effect of sex with dentition were important sources of variation in body length. Females and sheep with dentition 0 were shorter ($p<0.05$) in body length than males and sheep with higher dentition groups.

Sheep at Quarit were superior ($p<0.01$) in heart girth than Yilmanadensa sheep. Sex also affected heart girth that males had higher ($p<0.01$) heart girth than their female counterparts. With respect to the effect of age, sheep with dentition 4 were superior ($p<0.001$) over their dentition 0 counterparts. Similarly, the interaction effect of sex with dentition was highly significant ($p<0.001$) where females with four PPI and males with four, three and two PPI were superior over other sex and dentition interaction groups. Pelvic width was also variable among districts. Quarit sheep had wider ($p<0.001$) pelvis than Yilmanadensa sheep. Dentition group significantly influenced pelvic width where pelvic width increased with age of sheep.

Prediction of body weight

The Pearson's correlation of linear body measurements with weight and with each other is presented in Table 3. The observed positive and significant ($p<0.01$) correlations between weight and other body measurements were in agreement with literature (Kassahun, 2000;

Thiruvenkadan, 2005; Afolayan *et al*., 2006; Sowande and Sobola, 2007; Hamayun *et al*., 2006).

Table 3. Phenotypic correlations between body weight and other body measurements in Washera sheep.

Dentition[1]		BW[£]	WH	BL	HG	PW
	WH	0.672**				
	BL	0.775**	0.761**			
0 PPI	HG	0.857**	0.786**	0.791**		
	PW	0.690*	0.695**	0.689*	0.803*	
	EL	0.065 NS	0.239**	0.155 NS	0.175*	0.309**
	WH	0.494**				
	BL	0.585**	0.641**			
1 PPI	HG	0.783**	0.523**	0.617**		
	PW	0.486**	0.281**	0.473**	0.527**	
	EL	0.197*	0.334**	0.171 NS	0.201*	0.231*
	WH	0.518**				
	BL	0.653**	0.498**			
2 PPI	HG	0.754**	0.543**	0.462**		
	PW	0.515**	0.192 NS	0.493**	0.311**	
	EL	-0.084 NS	0.052 NS	0.135 NS	-0.077 NS	0.207*
	WH	0.581**				
	BL	0.453**	0.403**			
3 PPI	HG	0.828**	0.628**	0.323*		
	PW	0.513**	0.391**	0.110	0.548**	
	EL	-0.129NS	-0.047 NS	0.059 NS	-0.092 NS	0.010 NS
	WH	0.421**				
	BL	0.492**	0.372**			
4 PPI	HG	0.798**	0.445**	0.399**		
	PW	0.448**	0.353**	0.300**	0.501**	
	EL	0.103 NS	0.127*	0.149*	0.125*	0.200**

*[1]Dentition is same as in Table 1. [£]BW = Body weight, HG = Heart girth, PW = Pelvic width, BL = Body length, WH = Height at wither, EL = Ear length. NS, *, and ** denot non significant difference and significant difference at p<0.05 and p<0.01, respectively.*

Among the body measurements heart girth had the highest correlation coefficient with weight at all dentition groups. The correlation coefficient between weight and heart girth was highest at dentition group 0 PPI. Similarly, the highest correlation between weight and wither height, body length and pelvic width was found at dentition group 0 PPI. The high correlation coefficients observed between body weight and heart girth for all dentition groups suggest that heart girth alone or in combination with other body measurements could provide a good estimate of predicting live weight of Washera sheep at different dentition groups.

Parameter estimates of linear and multiple linear regression equations predicting live weight from body measurements of Washera sheep are presented in Table 4. It was found that all the fitted equations were good at estimating weight from body measurements (R^2 = 0.58 to 0.82). Heart girth alone was better in estimating weight (R^2 = 0.58 to 0.73).

Table 4. Regression models for predicting body weight of Washera sheep at different age groups.

Dentition[1]	Model[2]	*a*	b_1	b_2	b_3	R^2	R^2 Change	Std error
0	$a \pm b_1$HG*	-23.160	0.646			0.735	0.000	1.913
	$a \pm b_1$HG$\pm b_2$BL	-27.620	0.492	0.278		0.759	0.025	1.828
1	$a \pm b_1$HG	-30.493	0.756			0.613	0.000	2.305
	$a \pm b_1$HG$\pm b_2$BL	-36.071	0.658	0.224		0.629	0.017	2.266
	$a \pm b_1$HG	-31.405	0.771			0.578	0.000	2.368
2	$a \pm b_1$HG$\pm b_2$BL	-47.734	0.592	0.513		0.694	0.116	2.028
	$a \pm b_1$HG$\pm b_2$BL$\pm b2$PW	-52.066	0.571	0.398	0.855	0.722	0.028	1.944
3	$a \pm b_1$HG	-33.091	0.803			0.685	0.000	2.371
	$a \pm b_1$HG$\pm b_2$BL	-49.267	0.738	0.360		0.723	0.038	2.243
4	$a \pm b_1$HG	-35.183	0.824			0.637	0.637	2.415
	$a \pm b_1$HG$\pm b_2$BL	-48.468	0.738	0.334		0.673	0.036	2.297
Overall	$a \pm b_1$HG	-32.264	0.784			0.798	0.798	2.305
	$a \pm b_1$HG$\pm b_2$BL	-38.027	0.643	0.282		0.815	0.018	2.204

*[1]Dentition is same as in Table 1. *HG = Heart girth, PW = Pelvic width, BL = Body length, WH = Height at wither. [2]Dependent Variable: Wt (Body weight).*

Kassahun (2000) found out that heart girth alone explained 83% and 81% of weight of Menz and Horro ram lambs. The higher association of body weight with heart girth was possibly due to relatively larger contribution in body weight by heart girth (Thiruvenkadan, 2005).The highest coefficient of determination ($R^2 = 0.82$) was obtained when the equations were fitted for the pool (for all dentition groups). Comparing for dentition groups, the highest coefficient of determination was depicted at age group 0 (75.9% of the variation in weight was explained by the equation). The differences in the coefficient of determination of equations between different dentition groups indicated that weight can be estimated using different equations for different age groups with different accuracies. Kassahun (2000) estimated different fitted models for different age groups. Within dentition groups, the coefficient of determination (it increases) revealed that weight was better predicted when two or more measurements were included in the equation.

Conclusion

The agricultural production system in the study area is mixed crop-livestock which complement each other in such a way that livestock are used as a source for draft and manure for crop production and from crop production the crop residues, straws and aftermath serve as main components of livestock feeds in the study areas.

Due to the increasing attention given to sheep production, because of the decreasing grazing land as a result of increasing population pressure, land slide and gully erosion and because of their suitability to produce and reproduce under feed shortage and the current increasing market value, production problems identified needs to be improved. The traditional management practices such as the weaning, docking and use of traditional herbal medications need to be encouraged and supported by scientific knowledge. The flock composition identified is within the range of many studies in Ethiopia. The higher proportion of old breeding ewes in the flock indicates that farmers in study area maintain breeding ewes for long period of time and the importance of culling.

The fixed effects of district, sex, dentition and the interaction between sex and dentition were sources of variation for the most of the response variables (linear body measurements). The high correlation coefficients observed between body weight and heart girth for all dentition groups suggest that heart girth alone or in combination with other body measurements could provide a good estimate of predicting live weight of Washera sheep at different dentition groups. 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. For ease of use and higher coefficient of determination, equations fitted for the pool (all age groups) or heart girth alone could be used in the field.

Acknowledgment

We are indebted to the Amhara Regional Agricultural Research Institute (ARARI) for fully financing the field research. We are also grateful to the International Livestock Research Institute (ILRI) for providing graduate fellowship to the first author while undertaking his MSc research thesis. The authors are greatly indebted to Mr Zerihun Taddese for his meticulous biometrics support during analyzing the data. We are grateful to the staff of Andassa Research Centre, particularly to Asresu Yitayew and Habtemariam Assefa for their support during the field work.

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