Sjournals
Scientific Journals
Scientific Journal of Animal Science (2013) 2(1) 15-25
ISSN 2322-1704

Contents lists available at Sjournals
Scientific Journal of Animal Science
Journal homepage: www.Sjournals.com

Original article

Variations in linear body measurements and establishing prediction equations for live weight of indigenous sheep populations of southern Ethiopia

A. Melesse[a,*], S. Banerjee[a], A. Lakew[b], F. Mersha[c], F. Hailemariam[d], S. Tsegaye[e], T. Makebo[f]

[a]*Hawassa University, School of Animal and Range Sciences, Hawassa, Ethiopia.*
[b]*Mekele University, Department of Animal Range and Wilde Life Sciences, Mekele, Ethiopia.*
[c]*Ministry of Agriculture and Rural Development, Guraghe Zone, Ethiopia.*
[d]*Axum University, Department of Animal Science and Eco-tourism Management, Axum, Ethiopia.*
[e]*Gambela ATVET College, Gambella Regional State, Ethiopia.*
[f]*Ministry of Agriculture and Rural Development, Kembata-Tembaro Zone, Ethiopia.*

[*]Corresponding author; Hawassa University, School of Animal and Range Sciences, Hawassa, Ethiopia.

A R T I C L E I N F O

Article history:
Received 05 January 2013
Accepted 18 January 2013
Available online 31 January 2013

Keywords:
Morphometrical characters
Body weight estimation
Indigenous sheep
Southern Ethiopia

A B S T R A C T

This study was conducted to describe variations in morphometrical traits and determine the usefulness of some linear body measurements in predicting body weight (BW) of indigenous sheep populations reared in KmabataTembaro-Hadiya (KTH), Wolaita (WOL), Gamogofa (GAG), Gurage-Silti (GUS) and Sidama-Gedeo (SIG) zones of Southern Region of Ethiopia. Data were obtained from 2712 sheep that were drawn from 928 households. The BW and height at withers (HW) in WOL and SIG ewes aged 1-2 years was significantly high compared to others. High chest girth (CG) values were obtained from SIG, GAG, and GUS ewes. Ewes of SIG, WOL, KTH and GAG had significantly high body length (BL). Significantly high CG values were obtained from SIG and GAG ewes. Rams of WOL, KTH and GUS had significantly high BW, BL and HW. Body weight of KTH, WOL and GAG ewes aged 1 year and above 2 years and rams is better estimated using CG alone. However, the best predictor for KTH, WOL and GAG ewes aged 1-2 years old were CG, HW and BL. In conclusion, CG was the primary variable to explain most of the variations in BW and can be used as reliable predictor for studied sheep types. SIG and WOL sheep had a relatively large body frame and emphasis may be given for their improvement.

© 2013 Sjournals. All rights reserved.

1. Introduction

Ethiopia is believed to be one of the major gateways for domestic sheep migration from Asia to Africa (Devendra and McLeroy, 1982). Sheep are among the most important livestock species in Ethiopia. They are often kept for multipurpose uses by resource-poor farmers in traditional family-based production systems. With 25.5 million sheep (Central Statistics Authority [CSA], 2011) and 14 traditional populations (Gizaw, Van Arendonk et al., 2007), there are highly diversified indigenous sheep populations in the country parallel to its diversity in ecology (Galal, 1983), ethnic communities and production systems. Sheep types in Ethiopia as observed by Gizaw (2008) are highly affiliated to specific ethnic communities. Several traditional breeds are reared by and named after specific communities. A breed reared by a community may be isolated from other breeds because of isolation of communities due to cultural barriers. Some communities attach special cultural values to their sheep and exclude use of breeding stock from other populations, resulting in cultural barrier to gene flow (Gizaw et al., 2007). Out of an estimated 25.5 million heads of sheep in the country (CSA, 2011), nearly 18% are reared in the Southern Regional State of Ethiopia, which is characterized by multicultural diversity along with its great variation in climate and topography representing a good reservoir of sheep genotypes.

The most common measure of animal performance is live weight which provides reliable and informative measure for selection, feeding requirements, health management (Thiruvenkanden, 2005), and decision on selling price. In Ethiopia, sheep breeding is generally performed in extensive conditions. Particularly, in these production conditions, live weights of animals can only be determined in livestock farms with appropriate infrastructure. For this reason, live weight parameter, which is an important selection criterion, cannot be effectively used at an adequate level. Where weighing scale is not available, especially in the rural communities of Ethiopia, the best method is to regress live weight on certain body characteristics which can be easily measured (Benyi, 1997). This is possible because there is a balanced relationship between body measurements and live weight in animals. Moreover, estimating the live weight using body measurements is practical, faster, easier, and cheaper in the rural areas where the sources are insufficient for the breeder (Gizaw, 1995; Nsoso, Aganga et al., 2003; Atta and El-khidir, 2004).

The importance of linear body measurements in estimation of body weight of small ruminants have been addressed for studying the breed standards (Riva et al., 2003). The methods are further important to study the morphological standards which vary with age, sex and other genetically and environmentally influenced traits (Gizaw, 1995; Pesmen and Yardimci, 2008). The regressions equations are unique for every category of livestock and vary according to area, sex, age and breed.

Studies relating live weight to body measurement and their possible use in estimating live weight on local sheep populations of Ethiopia are limited except those reported by Gizaw (1995) and Taye et al. (2012). Moreover, there is no study conducted in the Southern Regional State of Ethiopia to estimate the live weight of indigenous sheep using these quantitative measurements. Furthermore, previous works dealing with prediction equations were not area, age and sex specific. Therefore, the present study was conducted with the objective of assessing the variations in morphometrical characters and using these traits in estimating the live weight of indigenous sheep populations at different rearing areas, sex and age categories in the Southern Ethiopia.

2. Materials and methods

2.1. Description of the study areas and sampling procedures

The study was conducted from December 2010 to July 2011 in eight administrative zones of Southern Nations, Nationalities and Peoples Regional State of Ethiopia. Among the eight administrative zones in which Sidama and Gedeo, KembataTembaro and Hadiya as well as Gurage and Silte were clustered into three and described as Sidama-Gedeo (SIG), KembataTembaro-Hadiya (KTH) and Gurage-Silte (GUS) zones, respectively. The clustering was based on their closeness in geographical terrain and similarity in social and cultural values of the human population. The other two administrative zones namely Wolaita (WOL) and Gamogofa (GAG) were not clustered together because of differences in size and diversity of the environment and the vegetation.

Stepwise purposive selection procedure was carried out in the study area where the districts and the Kebeles (villages) were purposively selected based on the sheep population prevalent in each study zone. This was followed by identification of the households who owned at least four sheep and had prior experience in sheep husbandry. Amongst the identified households, 180 to 200 of them were then randomly selected from each zone to obtain the quantitative sample data. All the sheep in the sampled households were included in the current study.

2.2. Data collection procedures

Data on the assessment of quantitative traits were obtained from 2712 sheep populations of both sexes (1747 ewes and 965 rams) that were drawn from 928 households. The age of the animals were assessed according to the methods suggested by Charray et al. (1992). The quantitative morphometrical traits included in the study were height at withers (HW, the height from the bottom of the front foot to the highest point of the shoulder between the withers), chest girth (CG, the circumference behind the forelegs), body length (BL, the distance from the point of shoulder to the pin bone), pelvic width (PW, the distance between the pelvic bones, across dorsum), shoulder width (SW, the width of the chest between the briskets), head width (HdW, the width of the front head from the base of the left and right ear), head length (HdL, the length of the front head from the middle of the top head to the end of the nose), tail length (TL, the length of tail from the base to the tip), tail circumference (TC, the circumference of the tail at its widest part), ear length (EL, the length on the back side of ear from the root to the tip), fore canon length (CL, the length of the lower part of the leg extending from the hock to the fetlock), fore canon circumference (CC, the circumference of the lower part fore canon bone), horn length (HL, measured from root of horn to the tip along the outer curvature) and scrotal circumference (SC, the circumference of the testis at the widest part). The traits were measured using self devised equipments and as suggested by Macjowski and Zieba (1982). Body weight (BW) of the animals were taken early in the morning with an overnight fasting with a suspending balance with an error margin of ± 100 grams. The age of animals was estimated from dentition according to Wilson and Durkin (1984) for African sheep breed.

2.3. Statistical analysis

Body weight and morphometrical traits were analysed using the Generalized Linear Model Procedures of Statistical Package for Social Sciences (SPSS, 2006). Administrative zones were fitted as fixed independent variables while body weight and linear body measurements were fitted as dependent variables. Means were separated using Duncan's Multiple Range Test procedure and values were considered significant at *P* < 0.05. Stepwise regression procedure was used to regress body weight for both sexes within each studied zone to determine the best fitting regression equations for the prediction of live body weight. Regression equations were calculated and the adjusted coefficient of determination (R^2_{adj}) was used to establish the accuracy of the equations. The following regression model was used for estimation body weight from linear body measurements.

$Y_i = \beta o + \beta_i X_i + e_i$

Y_i = The response variable (live body weight)

β_o = The intercept

X_i = The explanatory variables (chest girth, height at withers, body length, pelvic width, head width, canon length, canon circumference, tail length)

β_i = Regression coefficients of the variables X_i

e_i = The random error

3. Results

3.1. Variations in morphometrical characters

3.1.1. Ewes below 1 year old

As shown in Table 1, the average HW of the ewes raised in KTH, WOL and SIG zones were similar being significantly (P < 0.05) higher than that of ewes from GAG and GUS. The BW of the ewes reared in the different zones was comparable with each other. The study further indicated that the ewes raised in GUS had significantly lower BL values when compared to those of other study zones. Ewes from GAG and SIG had (P < 0.05) higher values of CG and SW than those of other zones. The BW value was highest in ewes raised in WOL but lowest in those of GUS. The PW value was similar among all zones except in ewes reared in GUS which had significantly lower value for the trait. Ewes from WOL and GAG had (P < 0.05) lower HdW values when compared to those from the other studied areas. Ewes raised in WOL had (P < 0.05) higher HdL values than those of other zones which had comparable values.

Table 1
Quantitative variations in morphometrical measurements (cm) and body weight (kg) of ewes below one year old (Means ± SD; N = 566).

Quantitative traits	KTH	WOL	GAG	GUS	SIG
Body weight	24.6±3.6	25.5±4.2	24.2±4.2	23.0±2.4	24.5±1.2
Chest girth	68.2±3.6^{b}	65.3±0.5^{c}	71.3±5.5^{a}	68.4±4.3^{b}	71.1±1.4^{a}
Height at withers	63.6±3.0^{a}	63.4±3.0^{a}	56.1±3.4^{c}	59.5±3.0^{b}	64.2±0.8^{a}
Body length	64.6±3.6^{a}	63.3±3.9^{a}	62.6±4.2^{a}	43.5±3.3^{b}	63.2±0.8^{a}
Pelvic width	15.4±1.2^{a}	15.0±2.1^{a}	13.1±1.3^{b}	9.69±1.0^{c}	15.4±0.4^{a}
Shoulder width	13.1±1.2^{b}	12.6±1.4^{b}	15.2±2.2^{a}	13.5±1.5^{b}	15.7±0.4^{a}
Head width	10.8±0.5^{a}	7.08±1.0^{c}	8.59±1.0^{b}	9.83±0.5^{a}	9.80±0.2^{a}
Head length	16.8±0.9^{b}	17.9±1.2^{a}	16.5±1.1^{b}	16.7±1.1^{b}	15.8±0.5^{b}
Tail length	26.4±5.4^{c}	34.7±3.5^{a}	24.3±3.1^{d}	31.0±3.5^{a}	29.3±11^{b}
Tail circumference	14.2±1.8^{c}	12.7±2.5^{d}	10.3±3.1^{e}	18.2±2.2^{a}	16.8±3.5^{b}
Ear length	11.6±1.0^{a}	10.9±1.2^{a}	8.72±2.0^{b}	10.8±0.7^{a}	10.0±0.6^{a}
Canon bone length	14.2±0.8^{a}	14.7±1.0^{a}	12.7±1.2^{c}	11.6±0.5^{c}	13.7±0.4^{b}
Canon bone circumference	6.51±.0.4^{b}	6.52±0.5^{b}	6.55±0.7^{b}	7.63±0.5^{a}	6.64±0.4^{b}

$^{a-e}$ Means across rows between zones with different superscript letters are significantly (*P* < 0.05) different.
KTH = KembataTembaro-Hadiya; WOL = Wolaita; GAG = Gamogofa; GUS = Gurage-Silte; SIG = Sidama-Gedeo.

Ewes with longest TL were observed in the WOL and GUS whereas the shortest in GAG and were significantly different than those reared in other zones. The ewes with large TC were observed in GUS, followed by SIG, KTH, WOL and GAG and were significantly different from each other. The average values for EL of the ewes reared in the study areas were comparable except in those of GAG where the values were (P < 0.05) lower than the other zones. The CL was (P < 0.05) longer in ewes reared in KTH and WOL than those of other zones. The highest CC value was observed in the ewes raised in GUS zone when compared to the other zones which had similar values.

3.1.2. Ewes between 1 and 2 years old

The different quantitative morphometical traits in ewes (aged between 1 and 2 years) reared in the different study zones are presented in Table 2. Ewes reared in WOL and SIG had significantly higher BW and HW values than those of other zones. Ewes from GAG, GUS and SIG had significantly (P < 0.05) higher values of CG and SW than those of KTH and WOL which had similar values. No significance difference was observed in BL between ewes of all zones except GUS who had the lowest value. The HdW and CL values were significantly (P < 0.05) higher in ewes reared in KTH, WOL and SIG than those of GAG and GUS. Ewes from WOL and GUS had significantly longer TL than those of other zones. The TC value in GUS and SIG ewes was significantly higher than those of KTH and WOL which had comparable values. The lowest TC was observed in ewes of GAG.

3.1.3. Ewes above 2 years old

The average values for different morphometrical traits in ewes above 2 years old is presented in Table 3. Ewes reared in SIG had significantly higher BW than those of KTH and WOL which had similar values. On the other hand, the lowest BW values were recorded from ewes reared in GAG and GUS. The HW values were significantly higher in ewes reared in SIG and WOL than those of other zones. Ewes reared in KTH, WOL, GAG and SIG had significantly (P < 0.05) higher BL and PW values than those of GUS which had the lowest values for the traits. Significantly high values of CG and SW were observed in GAG and SIG ewes.

Values of HdW were significantly higher in ewes reared KTH, GUS and SIG than those of GAG and WOL zones. The HdL values were comparable between WOL, GAG and GUS but significantly higher than those of SIG and KTH which had similar values. The longest TL was obtained from ewes of WOL followed by GUS, SIG, KTH and GAG which differed significantly from each other. Ewes with the highest TC were observed in SIG and GUS whilst the lowest from GAG. The CL values were significantly (P < 0.05) higher in ewes of KTH, WOL and SIG than those of SIG and GAG. Ewes reared in GUS and SIG had significantly (P < 0.05) higher CC values than those of other zones.

Table 2

Quantitative variations in morphometrical measurements (cm) and body weight (kg) of ewes between one and two years age (Means ± SD; N = 950).

Quantitative traits	KTH	WOL	GAG	GUS	SIG
Body weight	25.6±4.1[b]	28.5±5.1[a]	25.3±4.3[b]	25.8±4.1[b]	27.5±2.3[a]
Chest girth	69.5±3.8[b]	70.5±4.2[b]	72.6±5.3[a]	71.8±4.7[a]	72.5±1.3[a]
Height at withers	63.3±3.3[a]	64.1±3.3[a]	56.6±3.0[c]	61.4±3.6[b]	64.6±0.7[a]
Body length	64.2±3.9[a]	64.8±4.1[a]	63.3±3.2[a]	46.3±2.5[b]	63.2±0.9[a]
Pelvic width	15.7±1.1[a]	15.3±1.1[a]	14.4±1.2[b]	10.8±1.0[c]	16.4±1.3[a]
Shoulder width	13.1±1.1[b]	12.9±1.6[b]	16.0±2.3[a]	14.2±0.8[b]	16.1±0.6[a]
Head width	11.1±1.1[a]	7.58±1.2[c]	9.01±1.4[b]	10.1±0.5[a]	9.89±0.3[b]
Head length	17.3±0.6[a]	18.2±1.3[a]	16.6±1.2[ab]	17.1±0.6[a]	16.1±0.5[b]
Tail length	25.4±6.2[c]	34.9±3.3[a]	23.5±3.5[d]	31.2±2.0[b]	24.2±1.3[c]
Tail circumference	14.1±3.4[b]	13.1±3.7[b]	8.69±3.0[c]	18.2±2.0[a]	17.5±3.0[a]
Ear length	11.4±0.9[a]	10.8±1.3[a]	8.89±2.0[c]	10.9±0.8[a]	10.3±0.6 [b]
Canon bone length	14.2±0.9[a]	14.8±1.1[a]	13.2±1.1[b]	11.8±0.4[c]	14.4±0.4[a]
Canon bone circumference	6.59±0.5	6.60±0.7	6.52±0.7	7.49±0.4	6.98±0.0

[a,b,c] Means across rows between zones with different superscript letters are significantly (*P* < 0.05) different.
KTH = KembataTembaro-Hadiya; WOL = Wolaita; GAG = Gamogofa; GUS = Gurage-Silte; SIG = Sidama-Gedeo.

Table 3

Quantitative variations in morphometrical measurements (cm) and body weight (kg) of ewes above 2 years of age (Means ± SD; N = 531).

Quantitative traits	KTH	WOL	GAG	GUS	SIG
Body weight	27.2±4.1[b]	28.3±3.8[b]	26.7±3.7[c]	26.4±3.1[c]	30.4±2.3[a]
Chest girth	70.5±3.5[c]	71.5±4.1[b]	74.6±4.6[a]	72.2±3.4[b]	73.2±2.8[a]
Height at withers	63.5±3.5[b]	64.4±3.0[a]	57.9±3.7[d]	60.6±3.0[c]	65.7±0.9[a]
Body length	64.1±7.0[a]	64.9±4.0[a]	64.9±3.6[a]	47.5±2.8[b]	63.9±0.9[a]
Pelvic width	16.3±1.2[a]	15.3±1.1[a]	15.5±1.0[a]	11.1±0.7[b]	16.1±0.5[a]
Shoulder width	13.7±1.2[b]	13.9±1.2[b]	15.8±2.4[a]	14.2±0.7[b]	16.3±0.5[a]
Head width	11.2±1.2[a]	7.59±1.1[c]	9.29±1.3[b]	10.2±0.5[a]	10.2±0.3[a]
Head length	16.8±0.7[b]	18.4±1.2[a]	16.9±1.1[a]	17.2±0.7[a]	16.3±0.5[b]
Tail length	27.0±6.4[d]	35.1±3.7[a]	23.6±3.2[e]	32.5±2.4[b]	29.5±5.5[c]
Tail circumference	13.9±3.9[b]	13.0±3.0[b]	8.92±4.0[c]	18.1±2.0[a]	17.9±2.5[a]
Ear length	11.2±1.0[a]	11.0±1.0[a]	8.88±1.1[b]	11.1±0.6[a]	10.4±0.4[b]
Canon bone length	14.7±2.2[a]	14.8±1.0[a]	13.0±1.4[b]	11.8±0.5[c]	14.1±0.3[a]
Canon bone circumference	6.79±0.5[b]	6.58±0.6[b]	6.61±0.8[b]	7.75±0.5[a]	7.16±0.4[a]

[a-e] Means across rows between zones with different superscript letters are significantly (*P* < 0.05) different.
KTH = KembataTembaro-Hadiya; WOL = Wolaita; GAG = Gamogofa; GUS = Gurage-Silte; SIG = Sidama-Gedeo.

3.1.4. Rams

The results pertaining to the morphometrical measurements in rams (full mouthed) have been presented in Table 4. Rams of KTH, WOL and GUS had significantly ($P < 0.05$) higher BW than those of SIG and GAG. The HW values were significantly ($P < 0.05$) higher in KTH, GUS and SIG rams than those of GAG and WOL. The highest ($P < 0.05$) BL and CG values were observed in rams of WOL and GUS, respectively. Rams of KTH and WOL had significantly ($P < 0.05$) higher SC than those of other zones which had comparable values. The SW value was significantly higher in rams raised in GAG and SIG than those of other zones which had comparable values. Rams of SIG had significantly higher PW value than those reared in other zones. The highest HdW was obtained from KTH rams while the lowest from WOL being significantly different from other zones.

The HdL values obtained from rams reared in KTH, WOL, GAG and GUS were comparable but significantly higher than those of SIG. Comparable CL value was also obtained from rams of KTH, WOL and SIG which were significantly higher than that of GAG and GUS. No significance difference was noted in CC value in rams reared in all five zones. The longest TL was observed in KTH rams which differed significantly from those of other zones. The TC values were significantly higher in rams reared in KTH, GUS and SIG than those of WOL and GAG. The longest HL was observed in KTH and GUS rams which differed significantly from those of other zones.

Table 4
Mean values (±SD) of quantitative morphometrical measurements (cm) and body weight (kg) of full mouthed rams (N = 965)

Quantitative traits	KTH	WOL	GAG	GUS	SIG
Body weight	29.4±3.5[a]	31.6±6.6[a]	26.1±5.4[c]	30.1±4.4[a]	27.5±2.3[b]
Chest girth	70.9±1.6[c]	72.8±7.1[b]	73.0±6.5[b]	75.0±5.3[a]	72.1±1.5[b]
Height at withers	65.8±2.3[a]	63.2±7.3[b]	57.4±3.7[c]	64.8±4.5[a]	65.4±1.3[a]
Body length	66.1±3.6[b]	68.0±5.5[a]	63.9±4.4[c]	48.0±3.0[d]	63.8±1.0[c]
Pelvic width	15.7±0.6[b]	15.4±1.4[b]	14.0±1.3[c]	10.9±1.2[d]	16.5±1.1[a]
Shoulder width	14.3±1.1[b]	14.8±1.7[b]	15.6±3.0[a]	14.8±1.2[b]	16.0±.5.3[a]
Head width	12.6±2.2[a]	8.17±1.1[c]	9.08±1.4[b]	10.4±0.5[b]	9.97±0.4[b]
Head length	16.9±0.8[a]	17.8±1.3[a]	17.2±1.3[a]	17.2±1.0[a]	16.1±0.6[b]
Tail length	38.3±2.7[a]	24.5±6.6[c]	25.4±3.2[c]	33.6±2.5[b]	34.6±4.1[b]
Tail circumference	24.7±1.1[a]	19.4±4.0[b]	11.3±5.7[c]	26.4±1.5[a]	25.0±1.0[a]
Scrotal circumference	22.5±2.5[a]	23.5±2.3[a]	20.5±3.4[b]	21.3±3.0[b]	20.6±3.0[b]
Ear length	10.6±0.8[a]	10.1±1.2[a]	8.88±2.0[b]	11.1±1.0[a]	9.95±0.5[a]
Canon bone length	14.5±1.3[a]	14.1±1.9[a]	13.1±1.4[b]	12.2±.6.0[c]	14.3±.6.2[a]
Canon bone circumference	7.38±0.6	7.49±0.7	6.71±1.0	7.97±0.6	6.98±0.5
Horn length	24.5±7.3[a]	18.1±8.3[b]	13.6±9.3[c]	21.5±5.1[a]	10.8±3.7[d]

[a-d] Means across rows between zones with different superscript letters are significantly ($P < 0.05$) different.
KTH = KembataTembaro-Hadiya; WOL = Wolaita; GAG = Gamogofa; GUS = Gurage-Silte; SIG = Sidama-Gedeo.

3.1. Estimating Live Weight of Sheep from Linear Measurements

As presented in Table 5, the best predictor (R^2_{adj}) for KTH, WOL and GAG ewes aged below 1 year old was found to be CG alone. The prediction results were best assessed by including CG, HW and PW values in morphometrical traits from ewes raised in GUS zone. In ewes aged between 1 and 2 years (Table 5), the best estimators for assessing the BW in ewes raised in all zones were CG, HW and BL. In KTH, CG was considered as best estimator along with CC and BL.

The study further shows that for prediction of BW in ewes above 2 years old, the trait included for the ewes raised in KTH, WOL, GAG and GUS zones was CG alone while for those in SIG were combinations of CG and BL. As shown in Table 5, in rams raised in KTH, WOL and GAG zones a single measurement of CG sufficed for the BW estimation. However, the body weight of GUS rams is best predicted by fitting measurements of CG and BL. Although the accuracy of estimation is lowest among all zones studied, the body weight of SIG rams can be assessed by taking into account the measurements of HW and CG variables.

Table 5
Stepwise multiple regression equations for estimation of body weight of indigenous sheep from different study zones by fitting quantitative morphometrical measurements in relation to sex and age.

Study zones	R^2_{adj}	Fitted stepwise multiple regression equations
Ewes below one year old		
KembataTembaro-Hadiya	0.82	-38.4 + 0.92 (CG)
Wolaita	0.72	-29.9 + 0.81 (CG)
Gamogofa	0.81	-24.3 + 0.68 (CG)
	0.83	-28.0 + 0.64 (CG) + 0.05 (PW)
Gurage-Silte	0.48	-20.5 + 0.43 (CG)
	0.55	-19.9 + 0.50 (CG) + 0.08 (PW)
	0.63	-21.7 + 0.38 (CG) + 0.05 (PW) + 0.03 (HW)
Sidama-Gedeo	0.11	-33.5 + 0.30 (CG)
	0.17	-40.8 + 0.26 (CG) + 0.07 (HW)
Ewes between 1 and 2 years old		
KembataTembaro-Hadiya	0.76	-39.2 + 0.93 (CG)
	0.82	-40.2 + 0.72 (CG) + 0.24 (CC)
	0.85	-47.0 + 0.66 (CG) + 0.21 (CC) + 0.19 (BL)
Wolaita	0.54	-35.4 + 0.91 (CG)
	0.60	-49.8 + 0.73 (CG) + 0.42 (HW)
Gamogofa	0.82	-28.0 + 0.73 (CG)
	0.84	-37.3 + 0.60 (CG) + 0.30 (BL)
Gurage-Silte	0.85	-31.6 + 0.80 (CG)
	0.86	-36.2 + 0.75 (CG) + 0.17 (BL)
Sidama-Gedeo	0.52	-15.9 + 0.13 (CG)
	0.63	-13.1 + 0.89 (CG) + 0.13 (HW)
	0.65	-13.0 + 0.85 (CG) + 0.10 (HW) + 0.05 (BL)
Ewes above 2 years old		
KembataTembaro-Hadiya	0.58	-35.0 + 0.88 (CG)
Wolaita	0.69	-26.4 + 0.77 (CG)
Gamogofa	0.70	-24.5 + 0.69 (CG)
Gurage-Silte	0.68	-25.8 + 0.72 (CG)
Sidama-Gedeo	0.47	-13.1 + 0.59 (CG)
	0.60	-14.6 + 0.51 (CG) + 0.11 (BL)
Full mouthed rams		
KembataTembaro-Hadiya	0.76	-10.9 + 1.95 (CG)
Wolaita	0.94	-28.8 + 0.65 (CG)
Gamogofa	0.83	-28.4 + 0.75 (CG)
Gurage-Silte	0.80	-26.7 + 0.76 (CG)
	0.82	-31.3 + 0.68 (CG) + 0.21 (BL)
Sidama-Gedeo	0.29	-40.1 + 1.03 (HW)
	0.36	-55.8 + 0.73 (HW) + 0.50 (CG)

R^2_{adj} = adjusted coefficient of determination; HW = height at withers; CG = chest girth; BL = body length; PW = pelvic width; CC = cannon circumference

4. Discussion

4.1. Quantitative morphometrical traits

The BW of rams is comparable with the observations of Taye et al. (2010) and Abegaz et al. (2011 and that of the ewes (across different age groups) is similar to those of Bonga and Horro ewes as reported by Edea et al.

(2009). On the other hand, these values were higher than those reported by Tibbo et al. (2004) for both Menz and Horro ewes and rams and Abebe et al. (2010) for yearling Arsi Bale sheep populations. However, the values are lower than those of other sheep types of Ethiopian origin reported by Galal (1983) for Horro and Menz sheep.

The HW values of ewes in the current study are similar to those reported by Galal (1983) for Somali black head and Menz and Abegaz et al. (2011) for Gumuz ewes. However, the HW values in the current study are lower than those reported by Galal (1983) for Horro sheep, Taye et al. (2010) for Washera sheep, Lemma (2002) for mature Western highland sheep of Ethiopia, but higher than the Abergelle sheep reported by Tajebe et al. (2011) and Menz and Afar sheep reported by Getachew et al. (2009). The HW values as reported by Edea et al. (2009) for Bonga and Horro ewes and rams of 1-2 years and above 2 years is higher than the values obtained from the present study. Similarly, Tibbo et al. (2004) also reported higher HW values in Horro ewes and rams.

The CG values of the rams and ewes (across the age groups studied) are comparable to those of Taye et al. (2010), Abegaz et al. (2011) and Tajebe et al. (2011) for various sheep types of Ethiopia. However, the values in ewes are lower than those reported by Edea et al. (2009), Taye et al. (2010), Abegaz et al. (2011) and Tajebe et al. (2011) for various sheep types of Ethiopia.

The BL values in the present study were similar to those of Lemma (2002), Traoré et al. (2008), Taye et al. (2010) and Abegaz et al. (2011). Higher value for BL was reported by Edea et al. (2009) for Bonga and Horro sheep of Ethiopia. However, lower BL values were reported from Afar and Menz rams and ewes by Getachew et al. (2009) and Tibbo et al. (2009) for Menz and Horro ewes and rams. These variations could be due to the effect of the complex genotype by environmental interactions of the studied areas. It has been reported by Hammond, Mason and Robinson (1971) that animals raised in the mountains and region facing high rainfall tend to be shorter than those reared in the dry areas due to leaching of certain macro and micro minerals in the high rainfall areas.

The result for PW in the present study finds similarity with that of Taye et al. (2010) for the Washera ewes and Tibbo et al. (2009) for Menz and Horro ewes. However, the PW values observed in the ewes of GUS and GAG were lower than those reported by Edea et al. (2009) for Bonga and Horro ewes. The SC values as assessed in this study are lower than those reported by Tibbo et al. (2009) and Edea et al. (2009). The heritability values for SC is reported to be quite high and the values have been taken into account the fertility status of livestock (Söderquist and Hulten, 2006). However, like all traits, SC values varied between breeds and the range is also a breed specific trait.

The results of TL and TC values in the present study were in good agreement with those of Traoré et al. (2008) and Abegaz et al. (2011). However, these values were higher than those reported by Tajebe et al. (2011). The values for EL in ewes and rams of the present study were similar to those of Edea et al. (2009), Taye et al. (2010) and Abegaz et al. (2011). However, these values are higher than those reported for Abergelle ewes (Tajebe et al., 2011) and Washera sheep of both sexes (Taye et al., 2010). The CL and CC values in the present study could not be compared due to lack of sufficient information in the literature. However, as observed by Hammond et al. (1971) and Hasan et al. (2009), the study of long bones provides an insight of the interspecies and intra species differences.

4.2. Prediction of live weight

Regression analysis is commonly used in animal research to describe quantitative relationships between a response variable and one or more explanatory variables such as body weight and body measurements (chest girth, chest girth, body length, height at wither etc.), especially when there is no access to weighing equipment. The high and significant correlation coefficients between body weight and linear body measurements for all age groups suggest that either of these variables or their combination could provide a good estimate for predicting live weight of the studied sheep types (data not shown). Chest girth had the highest correlation coefficient values with body weight in both sexes followed by HW and BL suggesting the suitability of these variables in predicting body weight of local sheep.

As shown in Table 5, chest girth was the primary variable to explain most of the variations followed by body length, height at withers and in rare case pelvic width in both male and female sheep. With regard to sex, the adjusted coefficients of determination (R^2_{adj}) for prediction equations were almost similar and are consistent with the reports of Taye et al. (2012). The low coefficient of determination for the ewes and rams in SIG may be attributed to the age of the sheep assessed. The fact that at an early age of sheep, the growth of the bones are significantly higher than that of the muscles and fat, while at a later stage of development the bones grow very slowly and stop growing at all and the growth of the muscles and later fat deposition occurs which leads to lower accuracy and these observations are similar to those reported by Hammond et al. (1971). The observations as presented in Table 5 for ewes for KTH and GAG zones aged below one year old indicated higher R_{adj}^2 at an early age when compared to the ones at later stages of the animal and is in good agreement with that of Semakula et al. (2010). However, the reverse was true when it came to estimating the live weight of the ewes raised in GUS zone, where the R_{adj}^2 values were estimated to be highest in the age category of 1-2 years, which may be attributed to poor management of the ewes. Moreover, fluctuations in nutrition and disease prevalence in the area could additional challenges thereby resulting in low correlation values between the morphometrical traits and body weight of the assessed sheep populations.

The study also indicated that the R^2_{adj} values could be improved further by taking other allied measurements other than taking chest girth values alone. These observations are similar to those of Ulaganathan et al. (1992), Topal et al. (2003) and Topal and Macit (2004) for estimation of body weight of Beetal goats and their crossbreds. Similar results were also reported by Bhattacharya et al. (1984) for bucks of Bengal breed and Prasad et al. (1990) for rams of Nellore breed. The importance of chest girth followed by other linear measurements in prediction of the body weight of sheep has also been reported by Afolayan et al. (2006). However, they were also in opinion that under field conditions it becomes difficult to take multiple measurements on an animal as restraining the animal becomes a problem and hence becomes uneconomical. The importance of CC, HW and PW in estimating live weight of small ruminant animals finds similarity with the observations of Hammond et al. (1971). They suggested that the bones of improved meat breeds are relatively thicker than those of the unimproved types and indicated that the CC and PW of the meat type breeds are broader than those of other types. However, it was also observed that the expression of the genetic potential of an animal is largely dependent on the nutrition it receives during the early stages of growth; hence those raised on poor nutrition would have thinner and slender skeletal structure.

5. Conclusions

Significant variations were observed in all studied quantitative morphometrical parameters of sheep among the studied zones. Accordingly, the sheep of Sidama-Gedeo and Wolaita can be classified as comparatively better sheep type with a relatively large body frame and emphasis may be given for their improvement. Moreover, the regression study indicated that chest girth was the primary variable to explain most of the variations in body weight. Hence, this morphometrical trait alone or in combination with body length and height at withers could be used as reliable predictors of live weight for all age groups of both sexes across the studied zones. However, as the sheep in the present study were raised under varying agro ecological conditions and under different nutritional regimes, it would be logical to expect variation in estimators and accuracy for body weight using different linear measurements.

Acknowledgements

The authors acknowledge the financial assistance received from the Southern Agricultural Research Institute (SARI). We express our heartfelt gratitude to all sheep owners in the study zones for allowing us to use their animals for taking linear measurements and for devoting their precious time in providing the required information.

References

Abebe, G., Kannan, G., Goetsch, A.L., 2010. Effects of small ruminant species and origin (highland and lowland) and length of rest and feeding period on harvest measurements in Ethiopia. *Afr. J. Agric. Res.* 5(9), 834-847.

Abegaz S., Hegde, B.P., Taye, M., 2011. Growth and physical body characteristics of Gumuz sheep under traditional management systems in Amhara Regional State, Ethiopia. *Livest. Res. Rural Dev.* 23 (117), http://www.lrrd.org/lrrd23/5/abeg23117.htm.

Afolayan, R.A., Adeyinka, I.A., Lakpini, C.A.M., 2006. The estimation of live weight from body measurement in Yankasa sheep. *J. Anim. Sci.* 8, 343-348.

Atta, M., El khidir, O.A., 2004. Use of heart girth, wither height and scapuloischial length for prediction of live weight of Nilotic sheep. *Small Ruminant Res.* 55, 233-237.

Benyi, K., 1997. Estimation of live weight from chest girth in pure and crossbred West African goats. *Trop. Anim. Health Prod.* 29, 124-128.

Bhattacharya, B., Ghosh, T.K., Duttagupta, R., Moitra, D.N., 1984. Estimation of body weight in Black Bengal goats from body measurements. *Indian Vet. J.* 61, 406-408.

CSA (Central Statistics Authority), 2011. Ethiopian Agricultural Sample Enumeration for the year 2010/2011. Statistical Report on Farm Management Practices, Livestock and Farm Implements. Central Statistical Authority, Addis Ababa, Ethiopia.

Charray, J., Humbert, J.M., Leif, J., 1992. Manual of sheep production in humid tropics of Africa. CAB International. U.K.

Devendra, C., McLeroy, G.B., 1982. Goat and Sheep Production in the Tropics. Intermediate Tropical Agriculture Series, 271 pp. Longman, London.

Edea Z., Haile A., Tibbo M., Sharma, A.K., Assefa, D., Sölkner, J., Wurzinger, M., 2009. Morphological Characterization of Bonga and Horro Indigenous Sheep Breeds under Smallholder conditions in Ethiopia*. Eth. J. Anim. Prod.* 9 (1), 99-115.

Galal, E.S.E., 1983. Sheep Germplasm in Ethiopia. Animal Genetic Resources Information, 1/83. Food and Agriculture Organization of the United Nations, Rome, Italy.

Getachew, T., Haile, A., Tibbo, M., Sharma, A.K., Kifle, A., Terefe, E., Wurzinger, M., Sölkner, J., 2009 Morphological characters and body weight of Menz and Afar sheep within their production system. *Eth. J. Anim. Prod.* 9(1), 99-115.

Gizaw, S., 1995. Estimation of bodyweight from linear body measurements and the influence of body condition and age on the accuracy of body weight estimation in Ethiopian Horro sheep. *Small Ruminant Network Newsletter*, 31, 5-9.

Gizaw, S., 2008. Sheep resources of Ethiopia: genetic diversity and breeding strategy. PhD. thesis, Wageningen University, The Netherlands.

Gizaw S., Van-Arendonk, J.A.M., Komen, H., Windig, J.J., Hanotte, O., 2007. Population structure, genetic variation and morphological diversity in indigenous sheep of Ethiopia. *Anim. Genet. 38*, 621-628.

Hammond, J. Jr., Mason, I.L., Robinson, T.J., 1971. Hammond's Farm Animals. Edward Arnold. U.K. pp. 293.

Hasan, A., Onar, V., Mutus, R., 2009. The relationship between morphometric and long bone measurements of the Morkaraman sheep. *Turk. J. Vet. Anim. Sci.* 33(3), 199-207.

Lemma, S., 2002. Phenotypic classification and description of indigenous sheep types in the Amhara National Regional State of Ethiopia. M.Sc. University of Natal.

Macjowski, J., Zieba, J., 1982. Genetics and Animal Breeding Part-A. Biological and genetic foundations of animal breeding. Polish Scientific Publishers. Warszawa, pp. 30-37.

Nsoso, S.J., Aganga, A.A., Moganetsi, B.P., Tshwenyane, S.O., 2003. Body weight, body condition score and hearth girth in indigenous Tswana goats during the dry and wet seasons in southeast Bostwana. *Livest. Res. Rural Dev.* (15) 4. http://www.lrrd.org/lrrd15/4/nsos154.htm.

Pesmen, G., Yardimci, M., 2008. Estimating the live weight using some body measurements in Saanen goats. *Archiva Zootechnica* 11(4), 30-40.

Prasad, R.D.D., Madhava, R.T., Charyulu, E.K., Maniratham, D., 1990. Note on the prediction of body measurements in Nelore sheep. *Cheiron,* 19 (6), 275-277.

Riva, J., Rizza, R., Marelli, S., Cavachini, L.G., 2003. Body measurements in Bergamasca sheep. *Small Ruminant Res.* 55, 221-227.

Semakula, J., Mutetikka, D., Kugonza, R.D., Mpairwe, D., 2010. Variability in body morphometric measurements and their application in predicting live body weight of Mubende and Small East African goat breeds in Uganda. *Middle East J. Sci. Res.* 5(2), 98-105.

Söderquist, L., Hulten, F., 2006. Normal values for the scrotal circumference in rams of Gotlandic Breed. *Reprod. Domest. Anim.* 41, 61-62.

SPSS (Statistical Package for Social Sciences), 2006. SPSS User's guide version 16.0 for Windows, Chicago, SPSS Inc.

Tajebe, S., Gangwar, S.K., Kebede, K., 2011. Performance and physical body measurement of Abergell sheep breed in traditional management system of Tigray regional state, Northern Ethiopia. *Int. J. Sci. Nature* 2(2), 225-230.

Taye, M., Abebe, G., Gizaw, S., Lemma, S., Mekoya, A., Tibbo, M., 2010. Traditional management systems and linear body measurements of Washera sheep in the western highlands of the Amhara National Regional State, Ethiopia. *Livest. Res. Rural Dev.* 22 (169). http://www.lrrd.org/lrrd22/9/taye22169.htm.

Taye, M., Bimerow, T., Yitayew, A., Mekuriaw, S., Mekuriaw, G., 2012. Estimation of live body weight from linear body measurements for Farta sheep. *Online J. Anim. Feed Res.* 2 (1), 98-103.

Thiruvenkanden, A.K., 2005. Determination of best fitted regression model for estimation of body weight in Kanni Adu kids under farmers' management systems. *Livest. Res. Rural Dev.* 17 (85). http://www.lrrd.org/lrrd17/7/thir17085.htm.

Tibbo, M., Ayalew, W., Awgichew, K., Ermias, E., Rege, J.E.O., 2004. On station characterisation of Menz and Horro sheep breeds in the Central highlands of Ethiopia. *Anim. Genet. Resources Info. Bulletin* 35, 61-74.

Topal, M., Macit, M., 2004. Prediction of body weight from body measurements in Morkaraman sheep. *J. Appl. Anim. Res.* 25, 97-100.

Topal, M., Yildiz, N., Esenbuga, N., Aksakal, V., Macit, M., Ozdemir, M., 2003. Determination of best fitted regression model for estimation of body weight in Awassi sheep. *J. Appl. Anim. Res.* 23 (2), 201-208.

Traoré, A., Tamboura, H.H., Kaboré, A., Royo, L.J., Fernández, I., Álvarez, I., Sangaré, M., Bouchel, D., Poivey, J.P., Francois, D., Toguyeni, A., Sawadogo, L.,Goyache, F., 2008. Multivariate characterization of morphological traits in Burkina Faso sheep. *Small Ruminant Res.* 80, 62-67.

Ulaganathan, V., Krishnappa, K., Shanmugasundaram, S., 1992. Prediction of body weight from linear body measurements in local goats. *Indian J. Anim. Genet. Breeding* 14 (2), 31-32.

Wilson, R.T., Durkin, J.W., 1984. Age at permanent incisor eruption in indigenous goats and sheep in semi-arid Africa. *Livest. Prod. Sci.* 11, 451-455.