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Using morphometric traits for live body weight estimation and multivariate analysis in Central Highland and Woyto-Guji Goat Breeds, Ethiopia

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The study was conducted to differentiate the Woyto-Guji and Central Highland goat breeds of Ethiopia and derive the most accurate linear regression equation for live body weight prediction. Morphological measurements were taken on randomly selected 531 adult female goats (263 from Woyto-Guji and 268 from Central Highland). Positive and highly significant (P<0.001) correlations were observed between body weight and most independent body measurement variables in both breeds. The highest relationship between chest girth and body weight were illustrated in both breeds (r=0.85 for Woyto-Guji and r=0.82 for Central Highland). The multiple regressions found five parameters to be significant (P<0.05) for Woyto-Guji (chest girth, body length, pelvic width, chest width and ramp length) and Central Highland (chest girth, body length, ramp length, horn and ear length) with R^2 values of 84% and 79%, respectively. Body weight, body length, height at wither, chest width, ramp length, pelvic width, horn length and ear length had a significant (P<0.15) discriminating power on the breeds. Nearest neighbor discriminating function analysis shows that 93.23% of Woyto-Guji and 92.96% of Central Highland breeds were classified into their source population. The morphological variations obtained in this study should be consolidated with more evidence drawn from genetic analysis.

Key words: Central Highland, goat, multivariate, morphometric traits, Woyto-Guji.

INTRODUCTION

The ultimate goal of the livestock and meat industry is to have an accurate and objective measurement method for assessing the economically important traits of animals and to determine the value and merit of the carcass while the animal is still alive (Boggs and Merkel, 1993). The use of morphometric traits to predict live body weight (LBW) can be important to make a selection and cull decisions for the local farmers as it can be a relatively low cost, high accuracy and consistency (Musa et al., 2012). Morphometric traits in some cases can be more reliable than modern weighing machines as the latter can give biased measurements caused by gut fullness (Obike et

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al., 2010). Body measurements that are used to predict LBW may affect its determination directly and indirectly (Yakubu and Mohammod, 2012).

Understanding the diversity, distribution, basic characteristics, comparative performance and the current status of each country's animal genetic resources are essential for their efficient and sustainable use, development and conservation. Complete national inventories, supported by periodic monitoring of trends and associated risks, are a basic requirement for the effective management of animal genetic resources. Without such information, some breed populations and unique characteristics they contain may decline significantly, or be lost, before their value is recognized and measures taken to conserve them (FAO, 2007).

Different univariate models and multivariate approaches have been used to determine relationships among body weight and several body measurements. Other studies have utilized correlations to express the relationship between body measurement variables, body weight and carcass traits. Regression equations have been established to estimate body weight from body dimensions (Singh and Mishra, 2004; Gorgulu et al., 2005; Oke and Ogbonnaya, 2011). Therefore, the purpose of this paper is to find out and study the morphometric traits of Woyto-Guji and Central Highland goats in order to differentiate the breeds and derive the most accurate linear regression equation for LBW prediction.

MATERIALS AND METHODS

Environmental setting of the study locations and goat populations

Sampling of Central Highland and Woyto-Guji goat breeds was from Meta-Robi and Konso districts, respectively. Data were conducted from April to May 2013 in Meta-Robi and March to April 2013 in Konso district. Meta-Robi is located at 100 km north-west from the capital Addis Ababa. The district lies in a hilly land scope at elevations from 1,200 to 2,900 m.a.s.l and located at 9°20' N latitude and 38°10' E longitude. The mean annual temperature and rainfall ranges from 23 to 31°C and 750 to 1100 mm, respectively. Over 95% of the population, practices mixed crop-livestock production system (Emmenegger, 2012). Konso is located at 595 km away from Addis Ababa in the southwest of Ethiopia; it is located at 5° 17' 36'' N latitude and 37° 29' 05'' E longitude and lies between 600 and 2100 m.a.s.l (Konso District Agricultural Office, 2008, unpublished data). The average total annual rainfall is 550 mm; the temperature ranges between 12 and 33°C (Tesfaye, 2003). The annual rainfall variation is between 400 and 1000 mm (Cheung et al., 2008). The production system is integrated crop-livestock system (Forch, 2003).

Morphological variables measured

Morphological measurements were taken on randomly selected 531 adult (= 4PPI) female goats (263 from Woyto-Guji and 268 from Central Highland goat breeds). The nine morphometric traits measured were body weight (BW), body length (BL), height at wither (HW), chest girth (CG), chest width (CW), ramp length (RL), pelvic width (PW), ear length (EL) and horn length (HL). Linear body measurements were taken using graduated measuring tape, but wither height measurement (cm) was done using calibrated metal caliper. Body weight was measured using suspended spring balance in kg. Measurements were done in the morning before the animals were released for grazing. All measurements were carried out by the same person, in order to avoid inter-individual variations.

Data analysis

Statistical analysis was carried out using the Statistical Analysis System (SAS Version 9.2, 2008). Discriminant analysis was used to classify the sampled populations into homogenous groups on the basis of the measured variables. Stepwise discriminant analysis procedure (PROC STEPDISC) was employed to identify the relative importance of variables in discriminating identified goat breeds. The CANDISC procedure was used to generate the univariate test of the selected traits, canonical functions and the plots of breed membership. The PROC DISCRIM was employed to obtain the Mahalanobis distances and linear discriminant functions.

Correlation (Pearson's correlation coefficient) between body weight and the linear body measurements were computed for the goat breeds. The stepwise REG procedure of SAS (2005) was used to determine the relative importance of live-animal body measurements in a model designed to predict body weight. Variables that best fitted the model were selected using C(*p*) statistic, Alkaike's Information Criteria (AIC), Schwarz Bayesian Criteria (SBC), R^2 (R-square) and MSE (Mean square of error).

Multiple linear regression model

The multiple linear regression model is as follow:

$$Yj = \beta0 + \beta1X1 + \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6X6 + \beta7X7 + \beta8X8 + ej$$

where Yj = the dependent variable body weight; β0 = the intercept; X1, X2, X3, X4, X5, X6, X7 and X8 are the independent variables as body length, chest girth, height at wither, chest width, pelvic width, rump length, horn length and ear length, respectively; β1, β2, β3, β4, β5, β6, β7 and β8 are the regression coefficient of the variables X1, X2, X3, X4, X5, X6, X7 and X8, respectively; ej= residual error.

RESULTS

Correlation between body weight and linear body measurements

Positive and highly significant (P<0.001) correlations were observed between body weight and the majority of independent variables of the breeds (Table 1). The highest relationship between chest girth with body weight were illustrated in both breeds (r=0.85 for Woyto-Guji and r=0.82 for Central Highland).

Body length, height at wither, chest girth, chest width, ramp length, pelvic width, horn length and ear length had a small to high positive correlations with one another, but there was a negative correlation between horn and ear length in Woyto-Guji goats. In Central Highland goats,

Table 1. Coefficient of correlation between body weight and linear body measurements (above diagonal for Central Highland and below for Woyto-Guji goats).

Correlation	BW	BL	HW	CG	CW	RL	PW	HL	EL
BW		0.62***	0.20***	0.82***	0.39***	0.56***	0.52***	0.30***	0.05*
BL	0.84***		0.25***	0.55***	0.14*	0.56***	0.45***	0.28***	0.08^{NS}
HW	0.66***	0.68***		0.22***	0.13*	0.26***	0.21***	0.10^{NS}	0.10^{NS}
CG	0.85***	0.73***	0.63***		0.52***	0.56***	0.54***	0.40***	0.001^{NS}
CW	0.45***	0.32***	0.21***	0.45***		0.28***	0.25***	0.27***	-0.04
RL	0.62***	0.57***	0.54***	0.56***	0.24***		0.48***	0.23***	0.15*
PW	0.68***	0.63***	0.51***	0.59***	0.29***	0.53***		0.28***	-0.03
HL	0.33***	0.35***	0.24***	0.30***	0.15*	0.26***	0.25***		0.04
EL	0.24***	0.24***	0.31***	0.19**	0.14*	0.19**	0.25***	-0.07	

BW=Body Weight; BL=Body Length; HW=Height at Wither; CG=Chest Girth; CW=Chest Width; RL=Ramp Length; PW=Pelvic Width; HL=Horn Length; EL=Ear Length; NS=non-significant; *P<0.05;**P<0.01; ***P<0.001

Table 2. Multiple regression analysis of live body weight on different body measurements of Woyto-Guji and Central Highland goats.

Breed	Equations	β0	β1	β2	β3	β4	β5	R2	C (p)	AIC	RMSE	SBC
	CG	-36.88	0.9					0.72	201.4	395.56	2.13	402.68
	CG+BL	-38.31	0.52	0.48				0.82	35.53	278.54	1.7	289.23
Woyto-Guji	CG+BL+PW	-38.12	0.48	0.42	0.47			0.83	18.18	262.54	1.64	276.81
	CG+BL+PW+CW	-38.77	0.44	0.42	0.45	0.28		0.84	10.37	254.93	1.61	272.76
	CG+BL+PW+CW+RL	-39.95	0.42	0.4	0.39	0.29	0.28	0.84	4.47	248.92	1.59	270.3
	CG	-46.35	1.04					0.73	77.86	450.68	2.33	457.84
	CG+BL	-60.48	0.85	0.45				0.79	5.95	387.47	2.07	398.21
CHL	CG+BL+RL	-61.63	0.81	0.41	0.3			0.79	4.11	385.61	2.05	399.93
	CG+BL+RL+HL	-62.48	0.84	0.42	0.3	-0.08		0.79	3.69	385.14	2.05	403.03
	CG+BL+RL+HL+EL	-64.59	0.84	0.42	0.26	-0.09	0.17	0.79	3.54	384.93	2.04	406.41

BL=Body Length CG=Chest Girth; CW=Chest Width; RL=Ramp Length; PW=Pelvic Width; HL=Horn Length; EL=Ear Length; CHL= Central Highland.

body length, height at wither, chest girth, chest width, ramp length, pelvic width, horn length and ear length had a small to high positive correlation with one another, but the ear length had a negative correlation with chest width, pelvic width and horn length.

Prediction of body weight from linear body measurements

In the prediction of body weight, the multiple regressions found five parameters to be significant (P<0.05) for Woyto-Guji (chest girth, body length, pelvic width, chest width and ramp length) and Central Highland goats (chest girth, body length, ramp length, horn and ear length) with R^2 values of 84 and 79%, respectively (Table 2).

Discriminant analysis

The discriminant analysis was carried out using nine quantitative variables (body weight, body length, height at withered, chest girth, chest width, ramp length, pelvic width, horn length and ear length) to identify as best discriminating variables on stepwise selection summery (Table 3). Based on the significance (P<0.15), all but chest girth did not have significant discriminating powers on the two goat breeds and was removed.

Discriminant function analysis

Table 4 represents the percent classification rate (hit rate) of female sample populations into each district. Most (93.23%) of Woyto-Guji and 92.96% of Central Highland goats were classified into their source population.

Canonical discriminant analysis

The pairwise squared Mahalanobis' distance among the district's population for females were highly significant

Table 3. Significant traits that discriminated the two goat breeds.

Step	Variables	Partial R^2	F-value	P-value	Wilk's Lambda	ASCC
1	Ramp length	0.5263	593.35	<0.0001	0.4737	0.5263
2	Pelvic width	0.1291	79.04	<0.0001	0.4125	0.5875
3	Horn length	0.1379	85.07	<0.0001	0.3556	0.6444
4	Ear length	0.1044	61.87	<0.0001	0.3185	0.6815
5	Height at withers	0.0505	28.19	<0.0001	0.3024	0.6976
6	Chest width	0.0177	9.53	0.0021	0.2971	0.7029
7	Body length	0.0050	2.66	0.1036	0.2956	0.7044
8	Body weight	0.0101	5.35	0.0211	0.2926	0.7074

The P-values for both Wilks' Lambda and ASCC were highly significant (P<0.0001)

Table 4. Percent classified into each district (hit rate) of female populations.

From District	Konso	Meta-Robi	Total
Konso	248 (93.23)	18 (6.77)	266 (100)
Meta-Robi	19 (7.04)	251 (92.96)	270 (100)
Total	267 (49.81)	269 (50.19)	536 (100)
Priors	0.4963	0.5037	
Rate	0.0677	0.0704	0.069

Numbers before the parenthesis indicates the number of observations

Table 5. Square Mahalanobis distance between sites for the female sample populations.

District	Konso	Meta-Robi
Konso	0	10.26787
Meta-Robi	***	0

***P<0.0001

Table 6. Multivariate statistics.

Statistics	Value	F value	Num DF	Den DF	Pr>F
Wilks' lambda	0.2926	159.24	8	527	<0.0001
Pillai's trace	0.7074	159.24	8	527	<0.0001
Hotelling-Lawley trace	2.4173	159.24	8	527	<0.0001
Roy's greatest root	2.4173	159.24	8	527	<0.0001

(P<0.0001). This shows the existence of measurable group differences between sampled populations from each site (Table 6). Larger differentiation (10.27) was observed between the two districts sampled goat populations (Table 5). All multivariate statistics for the differences between the districts was also significant (P<0.0001) in all of the four multivariate tests (Wilks' lambda, Pillai's trace, Hotelling-Lawley trace and Roy's greatest root; Table 6).

Univariate analysis of variance (ANOVA) revealed highly significant (P<0.0001) difference in all the morphometric measurements except pelvic width (Table 7). By comparing the F-value and highest amount of significant discriminating potential, chest width has the least amount to discriminate the two breeds.

The standardized canonical coefficients indicate the partial contribution of each variable to the discriminant function, controlling for other attributes entered in the equation. Accordingly, the total standardized canonical coefficients given in the Table 8 indicate that the explanatory variables, ramp length, horn length, ear length, height at wither and body length significantly

Table 7. Univariate Test statistics.

S/N	Variable	Pooled STD	Between STD	F Value	P-Value
1	Body weight	0.8796	0.6743	157.53	***
2	Body length	0.8165	0.8173	268.56	***
3	Height at withers	0.7958	0.857	310.82	***
4	Chest width	0.8938	0.6359	135.67	***
5	Ramp length	0.6889	1.025	593.35	***
6	Pelvic width	0.9992	0.0842	1.9	Ns
7	Horn length	0.7938	0.8606	314.98	***
8	Ear length	0.8329	0.7835	237.16	***

***P<0.0001; Ns= non-significant.

Table 8. Total-sample standardized canonical coefficient.

Variable	CAN1
Body weight	-0.2221
Body length	0.2519
Height at wither	0.3352
Chest width	0.2292
Ramp length	0.9817
Pelvic width	-0.606
Horn length	0.5078
Ear length	0.3999

Table 9. Total-Sample standardized class means.

District	Variable							
	BW	BL	HW	CW	RL	PW	HL	EL
Konso	-0.4804	-0.5823	-0.6105	-0.453	-0.7302	-0.06	-0.6131	-0.5582
Meta-Robi	0.4733	0.5736	0.6015	0.4463	0.7194	0.0591	0.604	0.5499

BW=Body Weight; BL=Body Length; HW=Height at Wither; CG=Chest Girth; CW=Chest Width; RL=Ramp Length; PW=Pelvic Width; HL=Horn Length; EL=Ear Length.

contributed to the first canonical variable (*CAN1*). The correlation between *CAN1* and the goat populations sampled from the two districts was high (0.84).

The standardized class means values of the eight quantitative variables are presented in Table 9. The morphometric variables of Central Highland goat population were relatively higher than the Woyto-Guji counterparts.

DISCUSSION

The correlation is one of the most common and most useful statistical tools that describe the degree of relationship between two variables. The current result on the coefficients of correlation between body weight and the majority of independent variables were positive, strong and significant. However, this study has disclosed the highest relationship between chest girth with body weight in both breeds. Similarly, the highest correlation of chest girth with body weight than other body measurements was reported by several authors (Dereje, 2012, unpublished data; Biruh, 2013, unpublished data; Feki, 2013, unpublished data). Thus, the association may also be useful as a selection criterion, since positive correlations of traits suggest that the traits may be under the same genetic influences (Jimmy et al., 2010). The strong relationship existing between body weight and body measurements in the present study in both breeds suggests that either or the combination of these morphological traits could be used to estimate live weight in goats fairly well in the situation where weighbridges or scales are not available. The possibility of using simple body measurements that can be carried out in the field to

predict important economic traits have been demonstrated by (Vargas et al., 2007; Ozkaya and Bozkurt, 2009).

Genetic variation is vital for the populations to adapt to varying environments and to respond to artificial selection; therefore, any conservation and development scheme should start from assessing the state of variation in the population (Toro et al., 2011). The discriminant analysis based on significant F-values indicated body weight, body length, height at withered, chest width, ramp length, pelvic width, horn length and ear length as the linear measures permitting discrimination between the Woyto-Guji and Central Highland goats. Some of these discriminating variables are similar to those reported by other researchers in sheep (Carneiro et al., 2010; Yakubu and Ibrahim, 2011) and goats (Yakubu et al., 2011). The higher the overall percent classification rate (hit rate) is also an indication of the fact that, the two breeds belong to different breeds. The high correct assignment to source genetic groups. Similarly, Yakubu et al. (2010) was able to correctly allocate more than 99% into their different groups. Additionally, Wilks' Lambda, the ratio of within-group variability to total variability on the discriminating variables, is an inverse measure of the importance of the discriminant functions (Brown and Tinsley, 1983; Betz, 1987; Huberty, 1994). In this case, the value of Wilks' Lambda was 0.29. This shows that most (70.7%) of the variability in the discriminating variables were because the difference was between rather than within the breeds.

Conclusion

The study revealed that the coefficients of correlation between body weight and the majority of independent variables were positive, strong and significant. Moreover, the high correlations between chest girth and body weight would imply that the live weight could be predicted fairly accurately from chest girth rather than other variables. Body weight, body length, height at withered, chest width, ramp length, pelvic width, horn length and ear length were found as the most discriminating variables to separate Woyto-Guji and Central Highland goats. Most of the animals were correctly assigned into their breeds of origin. The morphological variations obtained in this study should be consolidated with more evidence drawn from genetic analysis.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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