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APPLICATION OF LINEAR BODY MEASUREMENTS FOR PREDICTING BODY WEIGHT OF ABERGELLE GOAT BREED IN TIGRAY REGION, NORTHERN-ETHIOPIA

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ABSTRACT
The study was conducted to predict the live body weight of Abergelle goat breed using linear body measurements in Tigray region, Northern-Ethiopia. The data was collected for 297 goats (96 males and 201 females). The animals were grouped into four age groups of 0 PPI, 1 PPI, 2 PPI and 3 PPI. Abergelle goat breed had an average live weight of 17.30 ± 4.26 kg for male and 18.77 ± 3.72 kg for female. The heart girth (HG), body length (BL) and height at wither (HAW) were noted as 54 – 69, 44 – 53, and 52 – 66 cm for male and 55 – 65, 45 – 52, and 53 – 59 cm for female, respectively. The live body weight was highly correlated ($P < 0.001$) with the body measurements. Body weight (BW) had relatively high relationship with heart girth (0.73 – 0.89) as compared with the other body measurements of body length (0.46 – 0.82) and wither height (0.53 – 0.83). The regression equation was established with regardless of sex and age factors as BW= -20.89 + 0.65 HG ($R^2 = 0.80$), BW= -23.66 + 0.50 HG + 0.23 BL ($R^2 = 0.84$), and BW= -26.26 + 0.43 HG + 0.19 BL + 0.15 HAW ($R^2 = 0.85$). It can be concluded that considering of all these three linear body measurements produced the best prediction equation for body weight. However, heart girth parameter is the easiest way to use for live weight prediction in field conditions especially under the small holder farmers.

KEYWORDS: Heart girth, body length, height at withers, correlation coefficient, prediction equation.

INTRODUCTION

Goat rearing is a venture which has been practiced by a large rural population of the Tigray region, North Ethiopia. As per the CSA (2007) livestock survey report about 2.77 million of goats are found in the region estimated as 15 % of the country's goat population (18.56 million). Goat is a multi- functional animal and plays a significant role in the economy and nutrition of landless, small and marginal farmers. In spite of its great importance, little research and development attention is offered to the species for its improvements in the country in general and the region in particular. Nowadays, small ruminant fattening activities are being promoted under the smallholder farmers to enhance meat supply. However, there is difficulty in animal marketing in relation to price setting. The market price is usually set by subjective measurements (*i.e.* visual judgment and loin-eye-area palpation). Estimating the market price based on live weight is quite important in reducing the bargaining practices. Due to lack of weighing scale in the remote rural areas of the region, it is almost impossible to obtain any accurate measurement of this very important trait. Estimating the live weight of small ruminants is quite important for good animal management, including understanding medication doses, adjusting feed supply, monitoring growth and choosing replacement males and females (Mahieu *etal*., 2011).Weighing, as a method for assessing the condition of animals is labour intensive and costly for the farmers.

Therefore, there is need for a method that will be fast, cheap and easy to use for small-scale resource poor farmers (Nsoso *et al*., 2003). Many research works have been reported the use of linear body measurements in estimating live weight of animals (Khan *et al*., 2006; Adeyinka *et al*., 2006; Pesmen and Yardimci, 2008; Mahieu *et al*., 2011). They established regression equation model that could be used as predictor of body weight based on body measurements. The current research work was aimed to investigate the correlation of live weight with the linear body measurements and to establish the regression equation model that could be potentially used to predict body weight.

MATERIALS AND METHODS

Study area

The study was carried out in Begasheka watershed of Tigray region, Northern Ethiopia. It is located about 108 km west of Mekelle, the administrative capital city of Tigray region. It has an altitude of 1670 meter above sea level and the mean annual rainfall is 475 mm. The people in the study areas are dependent of crop-livestock production. The major crops of the area are maize, sorghum and finger millet and to some extent teff. Livestock species are part and parcel of the farming system providing many functions. Cattle, sheep and goat population are found largely. There are various types of vegetation distributed throughout the whole lands of the areas. Trees, shrubs and herbs in most ground surfaces are commonly found vegetation types.

Data collection methods

A total of 297 Abergelle goat (201 females and 96 males) were examined for their linear body measurements such as heart girth (HG), body length (BL) and height at wither (HAW). They were also investigated for their live body weight (BW). Age and sex were considered as

independent variable that could substantially determine these body traits. The animals were classified into two sex groups as male and female and four age groups as 0PPI, 1PPI, 2PPI and 3PPI which refer for no pair of permanent incisor (under 1 year), one pair of permanent incisors (1-2 years), two pairs of permanent incisors (2-3 years), and three pairs of permanent incisors (3-4 years), respectively. The age category was determined according their permanent incisors dentition as outlined in ESGPIP (2009). The animals were measured in their standing position under field conditions using plastic measuring tape and measuring stick and at the same time the body weight was taken using a 50 kg size spring balance early in the morning before allowing the animals for grazing. All the measured male animals were intact. Male and female animals were measured separately. The following linear body measurements were taken as per the procedures of ESGPIP (2009). The data collected for body length (the distance from the base of the tails to the base of neck (first thoracic vertebrae), heart girth (the circumferential measure taken around the chest just behind the front legs and withers) & wither height (the distance from the surface of a platform on which the animal stands to the wither).

Data analysis

JMP5 Software (SAS Institute 2002) was used for data analysis. The relationships between the various body measurements were calculated using Pearson's correlation coefficient. The multiple regressions was used for determination of the most suitable model in prediction of the live weight using various body measurements and this enabled to establish regression equations. In the analysis process both sex and age group were considered as independent variables.

RESULTS AND DISCUSSION

Body weight and body measurements

The live body weight and body measurements (body length, heart girth and height at wither) are presented in Table 1.The average live body weight of male in the four age category (0PPI, 1PPI, 2PPI and 3PPI) were noted to be 13.92 ± 2.6, 16.46 ± 3.45, 20.79 ± 3.76, and 23.78 ± 1.60 kg, respectively while for females with the same age group recorded as 14.58 ± 5.71, 16.80 ± 3.53, 18.87 ± 2.87, and 21.00 ± 2.65, respectively. For the pooled without considering the age, the live weight was obtained as 17.30 ± 4.26 kg for male and 18.77 ± 3.72 kg for female. In the early age the body weight for both male and female was observed to be almost similar but with age advancement males performed more weight than their counterpart females. The relative large weight seen in female as compared to male in the pooled analysis seems to be due to high number of female goats in the late ages while males have more number in the early ages in which less live weight scored. In the field it was seen that relatively less proportion of male are kept for breeding, and sufficient mature number of females retained for breeding purpose in a given goat flock. The same situation was reported in other research works (ILRI, 1996). The male goats are usually used for breeding purpose in their early age (1- 2 years). Male goats aged beyond 2 years are commonly castrated either for breeding control or meat function. In this study only intact male goats were considered in the measurements.

TABLE 1. Live body weight and body measurements (mean ±SD) for Abergelle goat breed, Tigray, Northern Ethiopia

Age	Sex	No. of Observation	Heart girth (cm)	Body length (cm)	Height at wither (cm)	Body weight (kg)
0 PPI	F	8	55.00 ± 8.42	45.75 ± 5.87	53.38 ± 5.48	14.58 ± 5.71
	M	18	54.11 ± 4.79	44.83 ± 4.20	52.44 ± 3.71	13.92 ± 2.6
	F & M	26	54.38 ± 5.97	45.12 ± 4.68	52.73 ± 4.24	14.12 ± 3.71
1 PPI	F	68	59.19 ± 4.85	48.44 ± 4.19	55.29 ± 4.36	16.80 ± 3.53
	M	53	57.15 ± 4.41	47.36 ± 4.41	55.94 ± 4.1	16.46 ± 3.45
	F & M	121	58.30 ± 4.75	47.97 ± 4.30	55.58 ± 4.24	16.65 ± 3.48
2 PPI	F	52	61.21 ± 4.02	51.00 ± 4.13	57.37 ± 3.15	18.87 ± 2.87
	M	19	62.89 ± 4.53	51.32 ± 3.83	61.05 ± 3.34	20.79 ± 3.76
	F & M	71	61.66 ± 4.2	51.08 ± 4.02	58.35 ± 3.58	19.39 ± 3.22
3 PPI	F	73	64.44 ± 3.30	52.03 ± 3.33	59.44 ± 3.31	21.00 ± 2.65
	M	6	68.67 ± 2.50	53.00 ± 3.74	65.17 ± 2.56	23.78 ± 1.60
	F & M	79	64.76 ± 3.43	52.11 ± 3.35	59.87 ± 3.59	21.21 ± 2.69
All age group	F	201	61.45 ± 5.01	50.30 ± 4.32	57.26 ± 4.19	18.77 ± 3.72
(0 and above	M	96	58.44 ± 5.83	48.02 ± 4.82	56.88 ± 5.11	17.30 ± 4.26
PPI)	F & M	297	60.48 ± 5.46	49.56 ± 4.60	57.13 ± 4.50	18.29 ± 3.95

PPI = Pair(s) of Permanent Incisors; SD = Standard deviation; F= female; M= male

TABLE 2. Correlation coefficient (r = -1 to 1) between the variables in Abergelle goat breed, Tigray, Northern Ethiopia

Age	Variables	HG	BL	HAW	BW
0 PPI	HG	1.00	0.78***	0.72***	0.84***
	BL		1.00	0.60***	0.82***
	HAW			1.00	0.83***
	BW				1.00
1 PPI	HG	1.00	0.77***	0.72***	0.89***
	BL		1.00	0.70***	0.82***
	HAW			1.00	0.75***
	BW				1.00
2 PPI	HG	1.00	0.56***	0.59***	0.83***
	BL		1.00	0.48***	0.65***
	HAW			1.00	0.58***
	BW				1.00
3 PPI	HG	1.00	0.34**	0.46***	0.73***
	BL		1.00	0.31**	0.46***
	HAW			1.00	0.53***
	BW				1.00
All age group (0 and above PPI)	HG	1.00	0.74***	0.74***	0.90***
	BL		1.00	0.67***	0.79***
	HAW			1.00	0.77***
	BW				1.00

PPI = Pair(s) of Permanent Incisors; HG= heart girth; BL= body length; HAW= height at wither; BW= body weight;
* = P<0.05; **= P<0.01; ***= P<0.001; ns = Non-signifiant

TABLE 3. Correlation coefficient (r) between body weight and linear body measurements in Abergelle goat breed, Tigray, Northern Ethiopia

Age	Sex	No. of Observation	HG	BL	HAW
0 PPI	F	8	0.90**	0.98***	0.96***
	M	18	0.76***	0.67**	0.70***
	F & M	26	0.84***	0.82***	0.83***
1 PPI	F	68	0.90***	0.77***	0.74***
	M	53	0.92***	0.88***	0.80***
	F & M	121	0.89***	0.82***	0.75***
2 PPI	F	52	0.84***	0.62***	0.50***
	M	19	0.81***	0.77***	0.64**
	F & M	71	0.83***	0.65***	0.58***
3 PPI	F	73	0.71***	0.44**	0.47***
	M	6	0.46 ns	0.78 ns	0.55 ns
	F & M	79	0.73***	0.46***	0.53***
All age group (0 and above PPI)	F	201	0.88***	0.73***	0.72***
	M	96	0.91***	0.86***	0.85***
	F & M	297	0.90***	0.79***	0.77***

PPI = Pair(s) of Permanent Incisors; HG= heart girth; BL= body length; HAW= height at wither; F= female; M= male;
* = P<0.05; **= P<0.01; ***= P<0.001; ns = Non-signifiant

TABLE 4. Models for prediction of live weight from different linear body measurement and their R^2 values for Abergelle goat breed, Tigray, Northern Ethiopia

Age	Sex	No. of Observation	Models	R^2	P-value
0 PPI	F	8	-19.11 + 0.61 HG	0.82	<0.002
			-29.58 - 0.06 HG + 1.04 BL	0.97	<0.0001
			33.60 – 0.02 HG + 0.71 BL + 0.31 HAW	0.98	0.0006
	M	18	-8.31 + 0.41 HG	0.57	0.0003
			-11.19 + 0.30 HG + 0.19 BL	0.63	0.0005
			-19.64 + 0.15 HG + 0.22 BL + 0.29 HAW	0.75	0.0002
	F & M	26	-14.41898 + 0.52 HG	0.71	<0.0001
			-18.49 + 0.32 HG + 0.34 BL	0.78	<0.0001
			-27.61 + 0.14 HG + 0.31 BL + 0.38 HAW	0.87	<0.0001
1 PPI	F	68	-21.95 + 0.65 HG	0.81	<0.0001
			-23.59 + 0.54 HG + 0.17 BL	0.82	<0.0001
			-25.52 + 0.49 HG + 0.12 BL + 0.13 HAW	0.84	<0.0001
	M	53	-24.54 + 0.72 HG	0.84	<0.0001
			-25.25 + 0.46 HG + 0.33 BL	0.91	<0.0001
			-24.76 + 0.48 HG + 0.34 BL – 0.04 HAW	0.91	<0.0001
	F & M	121	-21.58 + 0.66 HG	0.80	<0.0001
			-23.37 + 0.48 HG + 0.25 BL	0.84	<0.0001
			-25.36 + 0.43 HG + 0.21 BL + 0.13 HAW	0.85	<0.0001
2 PPI	F	52	-17.73 + 0.60 HG	0.70	<0.0001
			-21.85 + 0.50 HG + 0.20 BL	0.76	<0.0001
			-22.27 + 0.49 HG + 0.20 BL + 0.01 HAW	0.76	<0.0001
	M	19	-21.56 + 0.67 HG	0.66	<0.0001
			-25.02 + 0.44 HG + 0.35 WH	0.71	<0.0001
			-23.40 + 0.47 HG + 0.37 BL – 0.07 HAW	0.71	<0.0003
	F & M	71	-19.95 + 0.64 HG	0.69	<0.0001
			-23.77 + 0.52 HG + 0.21 BL	0.74	<0.0001
			-25.61 + 0.49 HG + 0.20 BL + 0.08 HAW	0.74	<0.0001
3 PPI	F	73	-15.72 + 0.57 HG	0.50	<0.0001
			-21.34 + 0.51 HG + 0.19 BL	0.55	<0.0001
			-25.39 + 0.46 HG + 0.15 BL + 0.15 HAW	0.58	<0.0001
	M	6	3.4755319 + 0.2957447 HG	0.21	0.3548
			-1.88 +0.14 HG + 0.30 BL	0.65	<0.0001
			-28.91 + 0.22 HG + 0.26 BL + 0.36 HAW	0.96	<0.0001
	F & M	79	-15.70 + 0.57 HG	0.53	<0.0001
			-21.55 + 0.51 HG + 0.19 BL	0.58	<0.0001
			-25.17 + 0.44 HG + 0.16 BL + 0.16 HAW	0.61	<0.0001
All age group (0 and above PPI)	F	201	-21.42 + 0.65 HG	0.78	<0.0001
			-24.50 + 0.53 HG + 0.21 BL	0.81	<0.0001
			-26.99 + 0.47 HG + 0.16 BL + 0.14 HAW	0.82	<0.0001
	M	96	-21.72 + 0.67 HG	0.83	<0.0001
			-24.57 + 0.46 HG + 0.31BL	0.88	<0.0001
			26.24 + 0.36 HG + 0.29 BL + 0.15 HAW	0.89	<0.0001
	F & M	297	-20.89 + 0.65 HG	0.80	<0.0001
			-23.66 + 0.50 HG + 0.23 BL	0.84	<0.0001
			-26.26 + 0.43 HG + 0.19 BL + 0.15 HAW	0.85	<0.0001

PPI = Pair(s) of Permanent Incisors; HG = heart girth; BL= body length; HAW = height at wither; F = female; M = male

The body length (BL) of the animals in the same age category (0PPI, 1PPI, 2PPI and 3PPI) were obtained to be 44.83 ± 4.20, 47.36 ± 4.41, 51.32 ± 3.83, and 53.00 ± 3.74 cm, respectively for males and 45.75 ± 5.87, 48.44 ± 4.19, 51.00 ± 4.13 and 52.03 ± 3.33 cm, respectively for females. The mean heart girth (HG) of the male goats in these age group were found to be as 54.11 ± 4.79, 57.15 ± 4.41, 62.89 ± 4.53, and 68.67 ± 2.50 cm, respectively while for female goats was 55.00 ± 8.42, 59.19 ± 4.85, 61.21 ± 4.02 and 64.44 ± 3.30, respectively. Likewise, the mean and standard deviation for height at wither (HAW) was measured as 52.44 ± 3.71, 55.94 ± 4.10, 61.05 ± 3.34, and 65.17 ± 2.56 cm, respectively for males and 53.38 ± 5.48, 55.29 ± 4.36, 57.37 ± 3.15 and 59.44 ± 3.31, respectively for females.

The current study on Abergelle goat showed that males out measured females in both body weight and body measurements in the late age groups (2 PPI and 3 PPI). Male were obtained heavier and longer than female in these age groups. The male goats were bigger than their counterpart females. The same results were also reported by other studies (ILRI, 1996; Khan *et al*., 2006; Adeyinka *et al*., 2006) in which the males out performed females in both body weight and body measurements.

The body weight of this breed was found to be lower than other goat breeds as mentioned by other authors. It was reported as 55 kg for Saanen goat breed (Pesmen and Yardimci, 2008) and 30 – 40 kg for Pakistan goats (Khan *et al*., 2006). This could be due to the breed differences in which the local animals own small body size in their inherit nature.

Relationship of body weight and linear body measurements

The relationships of body weight with the three linear body measurements (body length, heart girth and height at wither) and amongst them are depicted in Table 2 in terms of correlation coefficient determination. There is a significant correlation ($P < 0.001$) of body weight with body length (r = 0.82, 0.82, 0.65 and 0.46), heart girth (r = 0.84, 0.89, 0.83 and 0.73) and height at wither (r =0.83, 0.75, 0.58 and 0.53) in the four age category (0PPI, 1PPI, 2PPI and 3PPI), respectively (Table 2). The results showed that body weight has relatively high relationship with heart girth (0.73 – 0.89) as compared with the other body measurements, body length (0.46 – 0.82) and height at wither (0.53 – 0.83).

The higher correlation coefficient of body weight with a given body measurement demonstrates that on the basis of the dimension of various body measurements the body weight could be predicted more accurately. The findings also demonstrated a decreasing trend in the correlation as the age advanced indicating that better prediction of body weight could be obtained in the early age. Similarly the larger correlation coefficient observed in male tells that the live body weight could be estimated with great precision in male as compared to their counterpart female. The r value was 0.91, 0.86 and 0.85 in male and 0.88 and 0.73 and 0.72 in female for heart girth, body length and height at wither, respectively.

Similar situation was reported in other research works (Khan *et al*., 2006; Adeyinka *et al*., 2006) in which a significant difference observed in the relationship of body weight with body measurements in both sexes (male and female). The difference was explained to be due to the fat deposition variation between male and female. Khan *et al*. (2006) found a coefficient correlation of 0.62 – 0.70 between heart girth and body weight and increased with age advancement in goats. In other studies (Adeyinka *et al*., 2006) seasonal variation in the relationship between body weight and body measurement was reported. This could be in relation with the body condition of the animals that oscillate with season in relation with availability of feeds and water. Here in this study the seasonal effect was not considered.

Prediction of body weight using body measurements

The prediction equation for live body weight based on the body measurements are presented in Table 4. It indicates a trend of increment in R^2 value as the number of variables increase. R^2 is widely used to determine how well a regression fits as the coefficient of determination. As per the present study high correlation was determined between live weight and heart girth in both sexes and all age groups. For pooled analysis with regardless of both sex and age by considering heart girth as independent variable the regression equation become BW= -20.89 + 0.65 HG (R^2 = 0.80). When heart girth and body length considered together the R^2 value increased to 0.84 and the equation was established as BW= -23.66 + 0.50 HG + 0.23 BL. Similarly, when all body measurements (heart girth, body measurement and wither height) considered the R^2 value is changed to 0.85 and the prediction equation was developed as BW= -26.26 + 0.43 HG + 0.19 BL + 0.15 HAW.

The most appropriate parameters were determined to be heart girth and body length to predict the live weight in the established regression equations. Considering both heart girth and body length the equation could be used with higher estimation precision. However, heart girth parameter is the easiest way to use for live weight prediction in field conditions especially under the small holder farmers. Many researchers stated heart girth to be the most appropriate and confident parameter in live weight estimations for farm animals. Those who seek better precision they can consider the other linear body measurements (body length and wither height) in the prediction equation.

CONCLUSION

As per the present study it seems better to conclude that live body weight of goats could be predicted using linear body measurements in Abergelle goat breed. Heart girth parameter is the easiest way to use for live weight prediction in field conditions especially under the small holder farmers. However, combining it with other body measurements (body length and height at wither) would produce the best prediction equation for body weight. Better prediction could be obtained in male than female. This could be used for various purposes such as selection, breeding, marketing, growth evaluation and thus to make appropriate management decisions. The same research efforts need to be undertaken in other breeds of goats. Further research is needed to investigate the relation between the body weight and linear body measurements with carcass composition in the same breed and other

breeds of animals considering the age and body conditions with maximum number of observations.

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