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Article *in* Livestock Research for Rural Development · July 2018

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Abstract

The goal of the current study was to develop simple regression-based equations that allow small-scale producers to use simple body measurements to accurately predict live weight of typical African goats. The data used in this study were recorded in five African countries, and was composed of 814 individuals of 40 indigenous breeds or populations and crosses that included 158 males and 656 females. Records included the live weight measured with a hanging scale, linear body measurements, country, breed, owner, and age. Country, breed, age, chest girth, height at withers, body length, and shoulder width had large effects ($p<0.05$) on live weight. One linear model and two quadratic models were developed to predict weight from body measurements. The mean of the absolute value of the differences (mean absolute difference) between predicted and observed weights were compared to a standard body measurement (BM) method live weight predictions. Based on the improved fit of the predictions, animals were divided into three chest girth classes. For the animals with chest girth of <55 cm the prediction model with linear terms for chest girth, body length, shoulder width and height at withers and chest girth and body length as a quadratic term was selected as the most accurate. For animals with chest girths of 56-75 cm and >76 cm, the prediction model selected that included linear terms for chest girth, body length, shoulder width and height at withers plus a quadratic term for chest girth was selected as the most accurate. When analyzed within country from Uganda and Zimbabwe, animals with chest girth < 55cm the linear model with additional quadratic terms for chest girth and body length was selected. For animals with chest girth 55-75cm the linear model with the added quadratic terms for chest girth and body length was selected for animals from Malawi and Zimbabwe while the linear model with a quadratic term for chest girth was selected for Mozambique, Tanzania and Uganda. For animals with chest girth of >76 cm the linear model with a quadratic term for chest girth was chosen for Tanzania, while for the other countries the linear model with quadratic terms for chest girth and body length was most accurate. In all cases, the models produced smaller mean prediction errors than the BM method.

Key Words: *Africa, body measurements, food security, goats, live weight, small ruminants*

Introduction

Livestock plays a key role in food security of smallholders in eastern and southern African countries. In these countries, the vast majority of people in rural areas, especially women, rely on investment in their livestock, with small ruminants serving as "current accounts" and larger species as "saving accounts" (Lebbie 2004). Of the small ruminants, goats represent an important livestock component across all agro-ecological zones in sub-Saharan Africa and goats exist in all production systems (Lebbie 2004). Native African breeds of livestock are known for their hardiness (Kouakou et al 2008), breeding capacity under harsh conditions (Simela and Merkel 2008), and most importantly their capacity to perform well under adverse conditions with minimal input of resources (Olivier et al 2002). While it is generally appreciated that they perform relatively well under harsh conditions, rural goat production in Africa faces challenges that include high disease and parasite prevalence, low levels of management, limited forage availability and poor marketing management (Gwaze et al 2009) that are responsible for poor overall productivity.

Of the 223 million goats in Sub Saharan Africa (SSA), about 64% are found in arid (38%) and semi-arid (26%) agro-ecological zones (Lebbie and Ramsay 1999) with more than 90% being owned by smallholder farmers (Gwaze et al 2009; Lebbie and Ramsay 1999).

Marketing and trade of goats in Africa is based on subjective estimates of body weight because the access to livestock scales is very limited. Because of this, traders often underestimate body weight to lower the price of the animals, which adversely affects farmers because they receive less money for their animals than they are really worth (Walugembe et al 2014).

A key issue may arise when trying to use weight prediction methods developed for large breeds, or for animals managed in higher-input systems from the developed world. These weight equations may not be equivalent to smaller breed animals raised under poor management conditions. We hypothesized that African goats will rarely fit the growth curves used in developed countries to predict live weight and that these will prove inaccurate and often unreliable for conditions and breeds found in developing countries. Popular methods often used in developed countries like the BM method that uses the formula *body weight in pounds = ((chest girth inches^2 x body length inches)/300* ((Horner 2013), or the caprine weight tape, which is a cloth measuring tape that is either designed for sewing or designed specifically as a goat weigh tape with predicted weights (based on chest girth) printed on the tape are likely to be inaccurate in developing countries. Conversion tables are available online for producers to predict body weights based on chest girth (Campbell 2014) and these will prove inaccurate and often unreliable for conditions and breeds found in developing countries. Based on this dilemma, the objective of this project was to develop a manual weight prediction method that can accurately be used on African goats.

Materials and methods

The data used in this study were recorded in five African countries: Uganda, Zimbabwe, Tanzania, Malawi and Mozambique. The data set included 814 individuals of 40 indigenous breeds and crosses that consisted of 158 males and 656 females. Records included the live weight of the individual taken with portable, hanging (sling) scales (with what precision?), and body measurements were taken by cloth measuring tape. Chest girth was measured as body circumference at the heart, just behind the elbows. Height at the withers was measured at the highest point of back at the anterior thoracic spinal process between the lateral scapular cartilage and measuring perpendicular from there to the ground). Body length was measured from point of shoulder (anterior point of humerus) to pin bone (ischiatic tuber) and pin width was the distance between left and right lateral ischiatic tuber bones. Shoulder width was the distance between the left and right lateral points of shoulder (greater tubercles). Additionally, country, breed, owner and age were recorded. Breed determination was questionable and was confounded with country of origin most likely so was ignored for the analyses. Age was determined by records where available, and otherwise was estimated. Sampling teams varied by country, or within country. All measurements were taken following approved animal care procedures using the AdaptMap Photo Protocol and Sampling Kit (USDA 2014).

After deleting incomplete observations, three additional observations considered statistical outliers were removed. Pearson correlation coefficients between the available body measurements and live weight were determined using Proc Corr (SAS 2013). A preliminary analysis of variance was performed using Proc GLM (SAS 2013) and the model for this initial analysis of variance (ANOVA) included the fixed effects of breed, country, age, and sex along with the five body measurements as covariates and the response variable was live weight.

Given that smallholders cannot use complicated models with fixed effects, an initial linear regression model utilizing the measurements for chest girth, height at withers, body length, and shoulder width were employed. Two additional models that included quadratic terms were also developed. The first one included the same linear terms as the basic model with the addition of chest girth as a quadratic term. The second quadratic model used the same terms as the basic linear model plus chest girth and body length as quadratic terms. All models are presented in Table 1.

Initially the entire data set was used as a whole, but as expected large prediction errors were obtained, and it was decided to divide the data in three categories according to chest girth. Chest girth was used because it showed the highest correlation to live weight, also, under field conditions chest girth is easier to measure, relative to the other manual measurements. Furthermore, under field conditions live weight of the animal to be weighed would be unknown. After trying different chest girth categories, the largest R^2 values were obtained when the categories used were chest girth under 55 cm, from 55 to 75 cm and over 76 cm.

Table 1. Models used to predict live weights of live goats

Model name	Equation
The BM method*	LW = [(chest girth)^2 x length/300
Linear model**	LW = b(chest girth)+b (body length)+b (shoulder width)+b (height)+e
Quadratic chest girth**	LW = b(chest girth)+b (body length)+b (shoulder width)+b (height) + b(chest girth)^2+ e
Quadratic chest girth, body length**	LW = b(chest girth)+b (body length)+b (shoulder width)+b (height)+e + b(chest girth)^2 +b(body length)^2 +e

LW = live weight ; BM= body measurement approach
** English units – weights in pounds, lengths in inches*
*** Metric units – weights in kg, lengths in cm*

Once the data were categorized, Proc Reg with the /p option (SAS, 2013) was used to calculate regression equations and the predicted live weight for each observation on each category. The absolute value of the residuals was averaged to calculate the average prediction error produced by each model for each category. Finally, the prediction errors produced by each model were compared to those produced by the Body Measurement (BM) method. Additionally, each category was separated by country and the data were analyzed in a similar manner with the objective of determining the model that was most appropriate for each country.

Results

Minimum, maximum range and average of live weight, age and the body measurements used in this studied are shown in Table 2. The results of the preliminary analysis of variance are shown in Table 3.

Table 2. Descriptive statistics of biological parameters and body measurements.

Measurement	Minimum	Maximum	Range	Average	S. D.*
Age (months)	3.60	180.00	176.40	38.80	25.49
Live weight (kg)	3.00	63.00	60.00	28.86	9.81
Pin bone width (cm)	2.00	18.50	16.50	7.77	4.03
Shoulder width (cm)	5.00	26.00	21.00	13.14	3.01
Chest girth (cm)	33.00	104.00	71.00	69.51	9.13
Body length (cm)	23.00	86.00	63.00	60.53	8.42
Height at withers (cm)	29.00	85.00	56.00	60.12	6.99

**Standard Deviation*

Table 3. Preliminary ANOVA[a] of several effects on live weight

Source	DF	Sum of Squares	Mean Squares	F Value	P Value
Country	4	952.59	238.15	20.77	<.0001
Age	21	462.00	22.00	1.92	0.008
Sex	1	19.03	19.03	1.66	0.20
Breed	38	2395.81	63.05	5.5	<.0001
Chest girth[b]	1	3050.13	3050.13	266.01	<.0001
Height at withers[b]	1	257.68	257.68	22.47	<.0001
Body length[b]	1	1325.81	1325.81	115.63	<.0001
Shoulder width[b]	1	375.74	375.74	32.77	<.0001
Pin bone width[b]	1	67.30	67.30	5.87	0.02
Error	742	8463.49	11.41		

[a] *ANOVA = Analysis of Variance* [b]*covariate*

Country had an effect ($p<.0001$) on live weight along with breed and the covariates for chest girth, height at withers, body length and shoulder width. Age ($p= 0.008$) and the covariate for pin bone width ($p=0.016$) were also associated with weight. Surprisingly, sex was not important ($p=0.20$).

The Pearson correlation coefficients are shown in Table 4. All the body measurements used in this analysis were found significantly correlated to live weight. Chest girth and body length were the body measurements that showed the highest correlation to live weight, with coefficients of 0.85 and 0.83, respectively. Pin bone width showed a correlation of 0.19, being the body measurement showing the lowest correlation to live weight. Pin bone width also showed the lowest correlations to other body measurements, having showed a correlation coefficient of 0.18 with both chest girth and height at withers. The highest correlation between body measurements was found for height at withers and body length with correlation coefficients of 0.78.

Table 4. Pearson correlation coefficients for live weight and body measurements of African goats all P<.0.0001

	Live weight	Pin bone width	Shoulder width	Chest girth	Body length	Height at withers
Live weight	1.00	0.19	0.54	0.85	0.83	0.77
Pin bone width	0.19	1.00	0.31	0.18	0.22	0.18
Shoulder width	0.54	0.31	1.00	0.55	0.50	0.45
Chest girth	0.85	0.18	0.55	1.00	0.76	0.73
Body length	0.83	0.22	0.50	0.76	1.00	0.78
Height at withers	0.77	0.18	0.45	0.73	0.78	1.00

In Table 5 the R^2 and the mean difference between the recorded live weights and the predictions of each of the three models used for each chest girth category along with the differences for BM method are presented. The R^2 obtained for the linear models ranged for 0.61 to 0.74 and the category of chest girth under 55 cm showed the highest R^2 value. The model with the quadratic term for chest girth produced R^2 values ranging from 0.62 to 0.77, with the category of chest girth under 55 cm showing the highest value as well. The R^2values obtained for the model that included the quadratic terms for chest girth and body length ranged from 0.63 to 0.80.

Table 5. R^2 and mean absolute differences (MAD) between live and weight prediction models and the BM method

Chest Girth (cm)	Linear model*		Quadratic chest girth **		Quadratic chest girth and body length***		The BM method****	
	R^2	**MAD (kg)**	**R^2**	**MAD (kg)**	**R^2**	**MAD (kg)**	**R^2**	**MAD (kg)**
<55	0.74	1.54	0.77	1.45	**0.80**	**1.38**	0.21	2.01
55-75	0.72	2.46	**0.73**	**2.41**	0.73	2.41	0.59	2.63
76+	0.61	3.75	**0.67**	**3.14**	0.63	3.68	0.62	3.70

** Live Weight = b(chest girth)+b (body length)+b (shoulder width)+b (height)+e*
*** Live Weight = b(chest girth)+b (body length)+b (shoulder width)+b (height)+ b(chest girth)2 + e*
**** Live Weight = b(chest girth)+b (body length)+b (shoulder width)+b (height)+b (chest girth)2+b(body length)2 +e*
***** Live Weight = [(chest girth)2 x length]/300*

Interestingly, the model with the highest R^2 for each category was not the model with the smallest average absolute prediction error for each category. The live weight for observations with over 76 cm of chest girth was predicted most accurately by the model that included the quadric term for chest girth, this model produced a mean difference between predicted and actual live weights of 3.14kg with an R^2 of 0.62 while the model that included quadratic terms for chest girth and body length produced a mean difference of 3.68 kg between predicted and actual live weights but produced a higher R^2 of 0.63. For the 55-75 cm of chest girth category, the highest R^2 was 0.73 and it was produced by both quadratic models. Also, both models produced a mean difference between predicted and actual live weight of 2.41kg. For the <55 cm of chest girth category, the model with quadratic terms for quadratic chest and body length had both the highest R^2 with 0.80 and the smallest mean difference between predicted and measured live weights. Finally, the BM method, originally developed for goats in the developed world, produced mean differences of 2.01, 2.63 and 3.7 for the categories of <55 cm, 55 to 75 cm and over 75 cm of chest girth, respectively

Table 6. Country-specific R^2 and mean absolute differences (MAD) between live and weight prediction models and the BM me

Chest Girth (cm)	Country	N	Linear model*		Quadratic chest girth **		Quadratic chest girth and body length***		Th met
			R^2	**MAD (kg)**	**R^2**	**MAD (kg)**	**R^2**	**MAD (kg)**	**R^2**
<55*****	**Uganda**	23	0.90	1.35	0.93	1.18	**0.95**	**1.02**	0.14
	Zimbabwe	23	0.65	1.20	0.65	1.18	**0.67**	**1.17**	0.42
55-75	**Malawi**	125	0.85	1.33	0.85	1.40	**0.86**	**1.31**	0.85
	Mozambique	85	0.77	2.08	**0.78**	**2.04**	0.78	2.06	0.68
	Tanzania	114	0.71	2.01	**0.71**	**2.00**	0.72	2.00	0.67
	Uganda	147	0.67	2.62	**0.69**	**2.44**	0.69	2.44	0.64

	Zimbabwe	83	0.90	1.50	0.91	1.50	**0.91**	**1.48**	0.83
76+	**Malawi**	55	0.68	2.28	0.70	2.23	**0.70**	**2.22**	0.67
	Mozambique	19	0.79	3.04	0.81	2.68	**0.90**	**1.94**	0.68
	Tanzania	34	0.81	3.74	**0.82**	**3.67**	0.82	3.73	0.71
	Uganda	93	0.64	3.88	0.66	3.79	**0.66**	**3.78**	0.49
	Zimbabwe	21	0.79	2.13	0.81	2.03	**0.82**	**1.97**	0.73

*** Live Weight = b(chest girth)+b (body length)+b (shoulder width)+b (height)+ b(chest girth)2 + e*

**** Live Weight = b(chest girth)+b (body length)+b (shoulder width)+b (height)+ b(chest girth)2+b(body length)2 +e*

***** Live Weight = [(chest girth)2 x length]/300*

****** Due to low numbers of observations for this category, only Uganda and Zimbabwe were analyzed*

The R^2 and the mean difference between the recorded live weights and the predictions of each of the three models used for each chest girth category along with the BM method for each country are presented in Table 6. In all cases the mean absolute differences are smaller for the proposed prediction models than for the BM method. There were no observations from Malawi and Mozambique in the category of <55cm of chest girth while there was only one observation in this category for Tanzania, therefore these countries were excluded from this analysis. The linear model using additional quadratic terms for chest girth and body length showed the highest R^2 and the lowest mean average difference (MAD) for Uganda and Zimbabwe with R^2 values of 0.95 and 0.67 and MAD of 1.02 and 1.17, respectively. In the 55-75cm chest category, the model with additional quadratic chest and body length terms was the most accurate for Malawi and Zimbabwe producing R^2 of 0.86 and 0.91, respectively and MAD of 1.3kg for Malawi and 1.48kg for Zimbabwe. On contrary, the predictions for Mozambique were more accurate when the linear model included an additional quadratic term only for chest girth and the R^2 for this model was 0.78 and the MAD was 2.00kg. For observations from Tanzania and Uganda, both models with additional quadratic terms were equally accurate, therefore the model with only one quadratic term was selected to simplify analyses for the producers with MADs of 2.00kg and 2.44kg, respectively. For the 76+cm category, the model with one quadratic term produced the best predictions for Tanzania with a MAD of 3.67kg. While the linear model with two additional quadratic term produced the lowest MAD for Malawi (2.22kg), Mozambique (1.94kg), Uganda (3.78kg) and Zimbabwe (1.97kg). . Overall, at least one of the models proposed in this study produced smaller mean differences between the predicted and recorded live weights than the BM method on a within country basis. The final overall models selected for each chest girth category with the coefficients for each measurement are shown in Table 7 and the models selected for each country are shown in Table 8.

Table 7. Final overall models for live weight prediction of African goats for each category of chest girth

Chest Girth (cm)	Prediction Model
<55	LW = 16.31 - 0.17(chest girth) - 1.07(body length) - 0.14(shoulder width) + 0.3141(height)+ 0.0024(chest girth)^2 + 0.01671(body length)^2 +e

55-75	$LW = 40.89 - 2.07(\text{chest girth}) + 0.29(\text{body length}) - 0.05(\text{shoulder width}) + 0.31(\text{height}) + 0.02(\text{chest girth})^2 + e$
76+	$LW = -214.47 + 4.017(\text{chest girth}) + 0.69(\text{body length}) + 0.34(\text{shoulder width}) + 0.15(\text{height}) - 0.0(\text{chest girth})^2 + e$

Table 8. Final models for live weight prediction of African goats for each category of chest girth within country

Country	Chest Girth (cm)	Prediction Model
Malawi	**55-75**	$LW = -2.97 + 0.108(\text{chest girth}) - 0.64(\text{body length}) + 0.007(\text{shoulder width}) + 0.17(\text{height}) + 0.004(\text{chest girth})^2 + 0.008(\text{body length})^2 + e$
	76+	$LW = -310.28 + 6.54(\text{chest girth}) + 0.72(\text{body length}) + 0.11(\text{shoulder width}) + 0.21(\text{height}) - 0.036(\text{chest girth})^2 - 0.002(\text{shoulder width})^2 + e$
Mozambique	**55-75**	$LW = -14.69 - 36(\text{chest girth}) + 0.28(\text{body length}) + 0.004(\text{shoulder width}) + 0.072(\text{height}) + 0.008(\text{chest girth})^2 + e$
	76+	$LW = 445.94 - 10.04(\text{chest girth}) - 1.96(\text{body length}) + 0.32(\text{shoulder width}) + 0.64(\text{height}) + 0.04(\text{chest girth})^2 + 0.02(\text{body length})^2 + e$
Tanzania	**55-75**	$LW = -13.85 + 0.11(\text{chest girth}) + 0.26(\text{body length}) + 0.56(\text{shoulder width}) - 0.13(\text{height}) + 0.0047(\text{chest girth})^2 + e$
	76+	$LW = -185.06 + 3.82(\text{chest girth}) + 0.66(\text{body length}) + 1.08(\text{shoulder width}) - 0.45(\text{height}) - 0.02(\text{chest girth})^2 + e$
Uganda	**<55**	$LW = 15.00 - 0.49(\text{chest girth}) - 0.78(\text{body length}) - 0.05(\text{shoulder width}) + 0.35(\text{height}) + 0.005(\text{chest girth})^2 + 0.014(\text{body length})^2 + e$
	55-75	$LW = 103.81 - 3.96(\text{chest girth}) + 0.32(\text{body length}) + 0.15(\text{shoulder width}) + 0.24(\text{height}) + 0.03(\text{chest girth})^2 + e$
	76+	$LW = -293.24 + 5.5(\text{chest girth}) + 1.08(\text{body length}) + 0.58(\text{shoulder width}) + 0.26(\text{height}) - 0.03(\text{chest girth})^2 - 0.003(\text{body length})^2 + e$
Zimbabwe	**<55**	$LW = 93.26 + 2.9(\text{chest girth}) - 7.83(\text{body length}) + 0.57(\text{shoulder width}) + 0.28(\text{height}) - 0.02(\text{chest girth})^2 + 0.08(\text{body length})^2 + e$
	55-75	$LW = 100.7 - 4.09(\text{chest girth}) + 0.59(\text{body length}) + 0.14(\text{chest width}) + 0.25(\text{height}) + 0.03(\text{chest girth})^2 - 0.003(\text{body length})^2 + e$
	76+	$LW = 135.15 - 9.05(\text{chest girth}) + 6.16(\text{body length}) + 0.30(\text{shoulder width}) - 0.004(\text{height}) + 0.06(\text{chest girth})^2 - 0.04(\text{body length})^2 + e$

Discussion

Goats represent an important livestock component across all agro-ecological zones in sub-Saharan Africa. Moreover, goats are found in all production systems ranging from pastoral and agro-pastoral systems through ranching range systems to small holder mixed-crop-livestock systems (Lebbie 2004). However, in countries like South Africa, 50% of the country's goat population are kept under small-scale conditions (Shabalala and Mosima 2002). Smallholder farming systems in developing countries are characterized by minimal resources in terms of land and capital, low income, poor food security, diversified agriculture and informal labor arrangements derived from family members (de Sherbinin et al2008). Therefore, goats are an ideal vehicle for cash generation to improve food security and welfare among communal families (Gwaze et al 2009).

Three of the four fixed effects included in the preliminary analysis shown in Table 3 had significant effects on live weight of rural African goats. However, sex had no effect (p=0.20) and therefore it was decided that it was not needed to produce sex-specific models. Given that most comparisons of goats are within country and region when sold, it was decided to not correct the live weights recorded for the fixed effects of country, age and breed. Certainly, small holders could not make such adjustments so models including body measurements only were considered best.

The Pearson correlation coefficients shown in Table 4 are higher when compared to the ones obtained in a previous study that looked at the correlations between linear body measurements and body weight and how these changed with age and sex (Khan et al 2006). In that study, the body measurement with the highest overall correlation with body weight was body length for males older than 25 months old (r=0.82). This differs from the findings of the present study, where the highest correlation obtained was for chest girth (r=0.85). Our findings agree with those of a study on West African Dwarf (WAD) sheep (Sowande and Sobola 2008) that found chest girth had the highest correlation (r=0.94) with live weight. Furthermore, chest girth has been shown to be the body measurement with the highest correlation to live weight in other species like horses (Takaendengan et al 2012) and beef cattle (Ozkaya et al 2009). High correlations among body measurements as those found for body length and chest girth (r=0.76) and chest girth and height at withers (r =0.73) are similar to those obtained in a different study between chest girth and body length (r=0.74) and chest girth and height at the withers (r=0.81) for animals 19-24 months old (Khan et al 2006).

The BM method mean differences (Tables 5 and 6) between predicted and measured live weight were compared to the models developed in here. The models developed for each specific country (Table 8) show higher R^2 and lower MADs than models shown in Table 7, probably because environmental and managemental conditions are different among each country and using only observations of the same country reduces the noise in the data due to breed and other factors. Even though we developed country-specific models (Table 8), the models shown in Table 7 are still useful and more accurate than the BM method and can provide a better estimation of live weight of the animals with chest girth under 55cm in Malawi, Mozambique and Tanzania, when environmental and managemental conditions are similar to those of Uganda and Zimbabwe.

Overall, the models developed in this study showed smaller mean differences between predicted and measured live weights than the BM method, which is widely used by dairy goat farmers in the United States as a simple way to predict live weight of animals when there is no access to a livestock scale. However, in rural Africa, poor access to scales to weigh animals at the time of sale may undervalue goats, and limit smallholder income due to the common practice of traders visually estimating body weight, and potentially underestimating it (Walugembe et al 2014). Moreover, another challenge faced by African producers is poor performance of animals due to poor nutrition (Lebbie 2004). In addition to poor nutrition and management, conformation and size differences between breeds from these diverse regions are also likely to exist. Therefore, the BM method may lose accuracy when applied to goats from all over rural Africa where quadratic equations worked better at predicting live weights for these African goats.

Linear models using only the chest girth measurement have been used to predict weights of African goats (Alemu Yami et al 2009) and sheep (Sowande and Sobola 2008) previously. In the case of sheep, the linear models produced higher R^2 (0.91-0.94) than the quadratic models used in this study. However, other body measurements such as width of hindquarter were used. A valid option to improve the equations provided in this study may be to consider additional measurements that were not measured in this research such as head length, loin girth and width of hindquarters.

The full equations shown in Tables 7 and 8 could allow small producers in rural Africa to more accurately predict live weight of animals and potentially improve the income received at selling, as well as to potentially inform and improve management decisions about their animals that are based on body weight. It is important to note that the model selected for each category produced the smallest mean differences between live weight and predicted weight, independently of the R^2. However, for the animals in the category of chest girth measuring 55-75 cm, both quadratic models developed produced the same R^2 and the same mean differences, but the simpler quadratic model was chosen to simplify the usage for producers.

The goal of this research is to facilitate the accurate calculation of live weight of goats, as done in a similar study (Walugembe et al 2014). Such a calculation could be used in a cell phone application that will allow farmers to input their measurements and automatically apply these equations to predict the weights from simple body measurements. In case that there is no access to a calculator or a cellphone, another valid approach would be to develop a measuring tape that uses the high correlation between chest girth and live weight found in this and other studies, to accurately predict chest girth to live weight and imprint the associated values directly on the cloth tape similar to current tools available and developed on large framed dairy breeds in developed countries.

Conclusion

- This study confirms that using body measurements to predict live weight in goats is a valid strategy to improve the marketing management of rural African livestock producers.

Acknowledgements

This research has been supported by the United States Agency for International Development (USAID), Feed the Future Initiative Livestock Improvement Project and the African Goat Improvement Network (AGIN), and the USDA Agricultural Research Service, Office of International Research Programs, the Ensminger Fund, State of Iowa, and Hatch funds.

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Received 5 May 2018; Accepted 6 June 2018; Published 3 July 2018