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Variability in Body Morphometric Measurements and Their Application in Predicting Live Body Weight of Mubende and Small East African Goat Breeds in Uganda

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Abstract: A study was conducted in three districts (Sembabule, Soroti and Arua) to determine the variability in body morphometric measurements and their application in determining economic value of goats in Uganda. Data on live body weight (LBW), Corpus length (CL), Height at withers (WH), Height at rump (RH), Heart girth (HG), Shoulder width (SW), Hip bone width (HBW) and Chest depth (CD) were collected from (n=198) Mubende, (n=188) SEA/Teso and (n=188) SEA/Lugware goats kept by traditional farmers. Regression analysis was carried out for LBW with all the linear body measurements. The data were classified on the basis of breed, age, sex and coat colour pattern. Breed, Age and sex significantly ($P<0.05$) influenced all the body measurements. Coat colour had no significant ($P>0.05$) influence on any measurement. Older animals were superior ($P<0.05$) to young ones in all measurements. Across age, sex significantly ($P<0.05$) influenced live body weight and linear body measurements with males showing supremacy. All measurements were significantly higher for the Mubende goats ($P<0.05$) implying that this breed is bigger than the two contemporaries. All linear body measurements and live body weight were highly ($P<0.001$) and positively correlated for all ages except for the group with two pairs of permanent incisors. From the regression analysis, live body weight could be predicted with accuracy from linear body measurements especially; heart girth, height at wither, corpus length and rump height. Pooling of body measurements in a multiple regression, improved the R^2 value to 0.91. It was concluded that, there is variability in body measurements across sex, age and breed/ecotype and that these measurements can be exploited in predicting live body weight and hence the economic value of goats.

Key words: Live Body Weight · Linear · Traits

INTRODUCTION

Uganda is endowed with a number of goat breeds whose value of these breeds is in meat production and skin production [1, 2]. However, these are assumed to have low genetic potential [3]. In fact previous studies about indigenous goats have concentrated around improving productivity [4, 5], with little on characterization. For genetic improvement one may need to explore the possibility of selection before attempting to crossbreed or introgression. However the first step towards improvement and/or even conservation is characterisation of the breed [6, 7].

Increasing meat yield from these breeds requires genetic improvement of their live weights. Proper measurement of this trait, which is often hard in rural areas due to lack of weighing scales, is requisite for achieving this goal, moreover, there is a growing need to study variations among goat populations through breed characters so as to facilitate their efficient use [8]. The capacity of producers and buyers to relate the live animal measurements to growth parameters is necessary for optimum and sustainable production and value-based trading system. Linear body measurements can be used as a way of estimating weight and market value in terms of cost of the animals [9]. It is quite important to note that animals are valued basing on their weights in most of the commercial settings. There is a need for estimation of the trait from simple and more easily measurable variable such as linear body measurements. Studies regarding the linear body measurements of goats have been carried in other regions of the world, for their possible use for estimating the animals live weights [10, 11].

The present study was carried out to determine variability in body measurements and relate live weights to linear body measurements in Mubende, SEA/Teso and

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SEA/Lugware goats, considering the effects of age, sex and breed as a step towards employing such in body weight estimation for selection and other purposes. Results obtained in present study would also be useful to farmers and animal scientists who are involved in small ruminant research.

MATERIALS AND METHODS

Body measurements were taken from at least four female and four male goats from each of the surveyed household. Measurements were taken on a total of 575 goats comprising 197 male and 378 female goats (Table 1).

Sets of measurement were taken for the eight traits considered in this study as described by Brown *et al*. [12] and adopted [11, 13]. Body weight (BW) was taken using the Salter hanging spring type scale and measured to the nearest 0.5 kg. Heart girth (HG) was measured by taking the circumference of the chest using a tailor's tape calibrated in cm, taken as the circumference of the body immediately behind the shoulder blades in a vertical plane, perpendicular to the long axis of the body. A rigid tape measure was used to determine; Corpus length (CL), measured as the distance from the point at the top behind the scapular to the base of the tail, height at withers (HW), measured as the distance from the ground to the withers and height at rump (RH), measured as the distance from the ground to the rump.

Using callipers the following were measured; Hip bone width (HBW) was taken as the distance between the two pelvic bones (*Tubercoxae*), across the dorsum. Shoulder width (SW) was measured as distance between the shoulders, i.e. widest point of shoulders. Chest depth (CD) was measured as the distance between the top behind the scapular and the flow of the sternum (taken to be the depth of brisket) immediately behind forelegs. Plates 1-4 show some of the procedures taken.

The coat colour for each animal was scored using a standard colour descriptor manual (SADC/ILRI Animal Genetic Resources Survey Chart [14]. Each animal was identified by breed group, sex and estimated age class based on dentition [9, 15] using permanent teeth eruption. All measurement were taken early in the morning before the animals were fed, with the animals standing on a flat surface with head held up. Visibly pregnant animals were excluded from the study.

Statistical Analysis: The PROC GLM, PROCMEANS procedures of SAS [16] were used to analyse the data fitting breed, age, sex and coat colour pattern as main effects in the model. Mean (X) and standard errors were computed for each body measurement. The means were separated using Duncan's multiple range test (1955). The statistical model for the linear body measurements included; breed group, sex and age-group as fixed effects. The statistical model used took the form,

$$Y = u + b_i + s_j + a_k + (b_i * s_j) + (b_i * a_k) + (s_j * a_k) + e$$

Where y = the vector of N observations on an animal of a given breed, sex, age group and coat colour pattern for a given variable (BW, HG, CD, BL, etc); u = population mean; b_i = i^{th} breed; s_j = j thsex; a_k= k thage group; the interaction effects represent two-way combinations of these factors (e.g., i^{th} breed and j^{th} sex); and e = residual effect which is independently and evenly distributed with mean = 0 and variance = δ^2.

Relationship between live body weights and linear body measurements were estimated by simple correlation and regression using Pearson correlation method.

RESULTS AND DISCUSSION

The comparisons in the study were mainly across age group, breed and sex, on morphometric trait dimensions to provide evidence of breed type and existing relationship between live body weight and linear body measurements. A number of measurements like; wither height, rump height have been used for describing cattle in beef show classes, but with much preference for rump height [17, 18].

Skeletal measurements such as ulna length, body height and length and chest depth are less affected by nutrition and thus indicate inherent size better than dimensions related to deposition of fat and muscle, such as width and girth measurements and body weights [19]. The measurements related to deposition of fat and muscles are also affected by gut-fill and pregnancy in females. Larger effects of nutrition on length than on height were documented in beef cattle [20]. Coleman and Evans [21] reported that restricted nutrition suppressed the growth of height and body length during the growing phase in cattle.

Table 1 shows that more female animals than males were available for the exercise. The number of available males dwindled as age increased. This could be because farmers will want to keep females goats in preference to males to cut feeding costs and to increase production efficiency. Negative selection could be another possibility where bigger males are sold or consumed. Fajemilehin and Salako [22] reported that in the forest deciduous zone of South Western Nigeria, goat farmers kept more females than male goats because, majority of the males are preferably castrated or fattened for sale as meat and source of income to the owners in time of financial crisis

Table 1: Sample sizes by age group, breed group and sex for the goats studied

	Mubende			Teso			Lugware		
Dentition	Male	Female	Total	Male	Female	Total	Male	Female	Total
Milk	30	26	56	34	37	71	36	35	71
First Pair	24	32	56	15	29	44	14	28	42
Second pair	16	30	46	12	27	39	10	27	37
Third pair	03	20	23	01	13	14	01	18	19
Fouth pair	01	16	17	00	20	20	00	20	20
Total	74	124	198	62	126	88	61	128	188

Table 2: Analysis of variance for body measurements in the three Ugandan goat breeds

		Body measurement (cm)							
Source of variation	Df	Wither height (WH)	Rump height (RH)	Corpus length (CL)	Heart girth (HG)	Chest depth (CD)	Shoulder width (SW)	Hip bone width (HBW)	Live body weight (LBW) (kg)
Breed	2	1880.2[a]	1849.4[a]	493.8[a]	1288.7[a]	158.5[a]	77.9[a]	78.3[a]	1596.9[a]
Age	4	1861.9[a]	1957.2[a]	2024.4[a]	4029.6[a]	178.4[a]	150.9[a]	150.5[a]	3655.3[a]
Sex	1	670.3[a]	286.8[a]	254.2[a]	93.9[c]	27.4[b]	5.6[c]	176.5[a]	52.5[b]
Breed x Sex	2	273.3[b]	105.0[b]	61.5[c]	99.4[c]	7.3[c]	17.9[a]	17.8[a]	41.2[b]
Breed x age	8	36.4[d]	5.8[d]	26.4[d]	36.7[d]	2.9[c]	1.2[d]	1.1[d]	19.3[c]
Sex x age	4	162.1[c]	44.8[d]	31.4[c]	55.3[d]	46.0[c]	5.2[b]	3.9[b]	100.6[b]
Residual	551	17.1	17.0	15.1	27.1	1.3	1.3	1.3	17.7

Notes: 1. [a] significant at ($P < 0.001$); [b] Significant at ($P < 0.01$); [c] Significant at ($P < 0.05$); [d] not significant at ($P > 0.05$)

Table 3: Least square means for body weight and linear body measurements for goats (male + female) as affected by age group

	Measurement (cm)							
Age	WH	RH	CL	CD	SW	HBW	HG	LBW
Milk	46.96[c]	48.73[d]	38.35[d]	19.64[d]	9.32[d]	9.37[d]	52.20[d]	13.64[d]
First pair	52.54[b]	54.43[c]	43.54[c]	22.24[c]	10.52[c]	10.59[c]	59.00[c]	18.96[c]
Second pair	55.49[a]	57.39[b]	45.12[c]	23.88[b]	11.29[b]	11.32[b]	63.57[b]	23.62[b]
Third pair	57.00[a]	59.19[ab]	47.57[b]	25.51[a]	13.85[a]	12.46[a]	66.56[a]	26.77[a]
Fourth pair	57.13[a]	59.46[a]	49.97[a]	25.57[a]	13.93[a]	12.53[a]	66.60[a]	27.55[a]
LSD	1.30	1.33	1.12	0.69	0.38	0.40	1.45	1.48

[a], [b], [c], [d] Means carrying the same superscript within a column are not significantly different (P>0.05). LSD = Least Significant Difference

WH=Wither height, RH=Rump height, CL=Corpus length, CD=Chest depth, SW=Shoulder width, HBW=Hip bone width, LBW=Live body weight and HG=Heart girth

Table 4: Least square means for body weight and linear body measurements for goats above one year as affected by breed group in the study

	Breed group			
Trait/Measurement	Mubende	SEA/Teso	SEA/Lugware	LSD
WH	56.42[a]	50.08[b]	49.43[b]	1.29
RH	58.62[a]	51.50[b]	51.40[b]	1.37
CL	45.59[a]	42.28[b]	41.63[b]	1.25
CD	24.37[a]	21.38[b]	21.31[b]	0.71
SW	13.25[a]	12.76[b]	12.97[b]	0.34
HBW	12.77[a]	11.40[b]	11.19[b]	0.37
HG	62.68[a]	57.91[b]	56.58[b]	1.69
LBW	23.52[a]	18.75[b]	17.55[b]	1.48

[a], [b], [c], [d] Means carrying the same superscript within a column are not significantly different (P>0.05). LSD = Least Significant Difference

WH=Wither height, RH=Rump height, CL=Corpus length, CD=Chest depth, SW=Shoulder width, HBW=Hip bone width, LBW=Live body weight and HG=Heart girth

before celebrating their first or second birth day. The end result is that relatively fewer males are available at ages above 2 years.

A summary description of the analyses of variance is presented in Table 2 and the subclass least-squares means of age, breed group and sex for the body measurements studied are presented in Tables 3, 4 and 5, respectively. Tables 6, 7 and 8, indicate the correlation between live body weight and linear body weight in each breed type. While, Table 9 shows the regression

Table 5: Least square means with their associated standard errors for body weight and linear body measurements for goats above one year as affected by sex

	Sex		
Trait	Male	Female	LSD
WH	51.99[a]	49.97[b]	1.17
RH	53.92[a]	51.92[b]	1.20
CL	43.68[a]	42.40[b]	1.05
CD	22.39[a]	22.28[a]	0.62
SW	12.58[a]	12.50[a]	0.30
HBW	11.21[a]	10.09[b]	0.30
HG	59.80[a]	57.93[b]	1.45
LBW	20.55[a]	18.69[b]	1.29

[a], [b], [c], [d] Means carrying the same superscript within a row are not significantly different (P>0.05). LSD = Least Significant Difference

WH=Wither height, RH=Rump height, CL=Corpus length, CD=Chest depth, SW=Shoulder width, HBW=Hip bone width, LBW=Live body weight and HG=Heart girth

Table 6: Correlations coefficients between body weight (kg) and linear body measurements (cm) in Mubende goats

	Measurement							
Age group	Sex	WH	RH	CL	CD	SW	HBW	HG
Milk	F	0.75**	0.70**	0.86**	0.67*	0.51*	0.68**	0.92**
	M	0.77**	0.73**	0.79**	0.43	0.36	0.66*	0.87**
First pair	F	0.50*	0.63*	0.41	0.31	0.26	0.15	0.59*
	M	0.33	0.24	0.47	0.39	0.12	0.55*	0.24
Second pair	F	0.53*	0.36	0.56*	0.47	0.45	0.28	0.80**
	M	0.75**	0.77**	0.73**	0.56*	0.55*	0.46	0.79**
Third pair	F	0.78**	0.80**	0.60*	0.52*	0.53*	0.65*	0.42
Fourth pair	F	0.86**	0.79**	0.78**	0.76**	0.73**	0.63*	0.59*

** Significant at (P < 0.01); * Significant at (P < 0.05)

WH=Wither height, RH=Rump height, CL=Corpus length, CD=Chest depth, SW=Shoulder width, HBW=Hip bone width, LBW=Live body weight and HG=Heart girth

Table 7: Correlation coefficients between body weight (kg) and linear body measurements (cm) in SEA/Teso

	Measurement							
Age group	Sex	WH	RH	CL	CD	SW	HBW	HG
Milk	F	0.74**	0.87**	0.85**	0.54*	0.638*	0.782**	0.79**
	M	0.54*	0.69**	0.79**	0.77**	0.672*	0.571*	0.82**
First pair	F	0.48	0.61*	0.12	0.65*	0.45	0.433	0.73**
	M	0.617*	0.54*	0.44	0.18	0.010	0.325	0.92**
Second pair	F	0.75**	0.46	0.70**	0.03	0.552*	0.622*	0.68**
	M	0.72**	0.67*	0.67**	0.46	0.503*	0.340	0.75**
Third pair	F	0.60*	0.42	0.58*	0.66*	0.718**	0.761**	0.302
Fourth pair	F	0.56*	0.88**	0.65*	0.81**	0.794**	0.802**	0.52*

** Significant at (P < 0.01); * Significant at (P < 0.05)

WH=Wither height, RH=Rump height, CL=Corpus length, CD=Chest depth, SW=Shoulder width, HBW=Hip bone width, LBW=Live body weight and HG=Heart girth

Table 8: Correlation coefficients between body weight (kg) and linear body measurements (cm) in SEA/Lugware

	Measurement							
Dentition	Sex	WH	RH	CL	CD	SW	HBW	HG
Milk	F	0.92**	0.90**	0.96**	0.93**	0.90**	0.96**	0.91**
	M	0.83**	0.87**	0.85**	0.76**	0.86**	0.84**	0.87**
First pair	F	0.30	0.47	0.42	0.81**	0.46	0.37	0.76**
	M	0.63*	0.51*	0.77**	0.67*	0.60*	0.23	0.53*
Second pair	F	0.77**	0.76**	0.54*	0.24	0.32	0.58*	0.93**
	M	0.55*	0.73**	0.90**	0.37	0.46	0.37	0.59*
Third pair	F	0.60*	0.32	0.60*	0.62*	0.71**	0.85**	0.24
Fourth pair	F	0.66*	0.79**	0.59*	0.76**	0.73**	0.80**	0.41

** Significant at (P < 0.01); * Significant at (P < 0.05). WH=Wither height, RH=Rump height, CL=Corpus length, CD=Chest depth, SW=Shoulder width, HBW=Hip bone width, LBW=Live body weight and HG=Heart girth

Table 9: Prediction equations for overall live body weight from some linear body measurements in Mubende, SEA (Teso and Lugware) goats

Breed	Dependent	Independent	Regression equation	Significance	Adjusted R2
Mubende	LBW	WH	Y= - (39.48±3.35) + 1.12x	p<0.001	0.80
	LBW	RH	Y= - (40.42±3.50) + 1.09x	p<0.001	0.79
	LBW	CL	Y= - (27.63±3.41) +1.12x	p<0.001	0.72
	LBW	HG	Y= - (35.39±2.08) + 0.94x	p<0.001	0.90
SEA(Teso/Lugware)	LBW	WH	Y= - (28.85±2.15) + 0.94x	p<0.001	0.76
	LBW	RH	Y= - (30.56±2.09) + 0.94x	p<0.001	0.79
	LBW	CL	Y= - (23.08±1.75) + 0.98x	p<0.001	0.73
	LBW	HG	Y= - (25.85±1.19) + 0.76x	p<0.001	0.88

WH=Wither height, RH=Rump height, CL=Corpus length, LBW=Live body weight and HG=Heart girth

equations for predicting live body weights from linear body measurements. Linear measurements and live body weight were influenced significantly ($P < 0.05$) by breed, age and sex, but not coat colour class (Table 2). Hair coat colour is under the control of single or few genes acting in a simple Mendelian way and thus not expected to have significant influence on quantitative traits.

Effect of Age on Body Weight and Linear Body Measurements: Tables 3 summarize the least squares means for live body weight and linear body measurements in different age groups and sex for each breed of goat. Age strongly influenced ($P<0.05$) live body weight and ($P<0.01$) linear body measurements in all breeds of goats, depicted by the consistent increases in all the measurements as the age of the animal increased. This is expected since as the animal grows, size and shape are also expected to increase with age. There was variability in body measurements as the animal age increased especially in live body weight. This is in agreement with the earlier reports [11, 22]. The variability however, reduced sharply between 3 to 4 pairs of permanent incisor teeth in all the trait measurements examined most probably because the animals had almost attained full growth. Fajemilehin and Salako [22] reported similar findings and added that at maturity, linear body measurements are essentially a constant, there by reflecting heritable size of the skeleton. The fact that skeletal measurements like wither height and tissue measurements (Circumference) like girths were increasing consistently as the animal aged reflects that the studied animals could be said to have normal skeletal development and normal body condition. Reports indicate that, height at withers at any given time reflects the animal's skeletal size and that heart girth reflects body condition [22].

Effect of Breed on Body Weight and Linear Body Measurements: Table 4 summarizes the overall body weight and linear body measurements for goats above 1 year of age across breed type. The live body weight of Mubende was significantly ($p<0.05$) higher than for either SEA/Teso and/or SEA/Lugware at all age groups. Generally the body dimensions for Mubende were significantly ($p<0.05$) greater than those for both Teso and Lugware except ($P>0.05$) for SW and CL (50.48±0.87) where they didn't differ with SEA/Teso (49.57±0.82). This is indicative of a clear cut distinction between Mubende goat and the two other types in the study.

For both SEA/Teso and SEA/Lugware goats, there were no significant ($P<0.05$) breed differences in the body measurements. It is however, worth pointing out that although the differences were not statistically significant, generally the body measurements for Teso goats were slightly or marginary higher than those for Lugware goats. The observed between-breed and within breed variations in live body weight and linear body measurements clearly indicate the large genetic diversity which exists in the East African goats, with well defined breeds.

The magnitudes of linear body measurements for mature animals are indicated in Table 4. WH values for Mubende goats, are above (56.0cm) those stated (50.0 cm) for Mubende goats of Uganda [23]. SEA/Teso (50.08cm) and SEA/Lugware (49.43cm), however, had WH values approximating those reported for Mubende goats. The three breeds of Uganda are taller than the Red Sokoto (40.94 cm) and White Borno (43.94 cm) [13]. The three breeds are however, shorter than the Kigezi (65.0 cm) and Somali (62.0 cm) [23]. The values of both HG and BL for Teso and Lugware were slightly below those for Mubende, however, the three are superior to both Red Sokoto and White Borno of Nigeria whose HG and BL values were; 40.44cm, 43.73cm and 43.65cm, 46.69cm for Red Sokoto and White Borno, respectively.

All the three goats stood higher at the rump than wither, sloping forwards from the posterior and all are shown to be longer than shorter (i.e. body length versus height). The girths of the three breed groups were proportional to their size; however for the measurement, the accuracy of this generalization can be affected by gut-fill.

Effect of Sex on Body Weight and Linear Body Measurements: The results revealed (Table 5) that sex is an important source of variation for live body weight and linear body measurements at all the age groups. Goats have been reported to exhibit sexual dimorphism in body weight [13]. In the study measurements were generally heavier in males than females at all age groups. This is in consonance with Hamayun *et al.* [11], Adeyinka and Mohammed [13] and Akpa *et al.* [24]. Fajemilehin and Salako [22], while working on West African Dwarf goats on the other hand, reported findings which sharply contradicted the above findings when they said that females were superior in body weight and linear body measurements across all age groups. The sex-related differences might be partly a function of the between-sex differential hormonal effects on growth. However, Olutogun *et al.* [25] reported a non-significant effect of sex on body weight and linear body measurements except for girth in White Fulani and Gubali cattle in Nigeria. They further explained that the difference in girth was because animals measured were brought for sale and thus were probably made to appear robust by watering them and feeding them on grasses *adlib* before taking them to market for sale to attract good prices and because males usually have larger gut fill than the females, they then tend to assume false weight.

The highest significant correlation coefficient between live body weight and linear body measurements at milk teeth and first pair of permanent incisor age groups suggests that either of these variables, especially HG or their combination would provide a good estimate for predicting live body weight in Mubende and SEA goats at an early stage. Highly significant correlation values of body weight and heart girth were reported in brown Bengal does, Beetal goats, grey Bengal does [11, 26], in Red Sokoto and Borno goats [13, 27, 28]. At later stages three pairs and four pairs of permanent incisor teeth however, Wither height and corpus length consistently assumed more importance as an indicator of live body weight across all breed types. Hamayun *et al*. [11] working on Beetal goats reported that at later stages (from 19-24months and on ward) the body length assumed more importance as an indicator of live body weight.

The relationship between LBW and some linear body measurements for each breed-type is presented in Table 9. From the study, it can be shown that both SEA/Teso and SEA/Lugware were not significantly different in all the measurements, indicating the possibility of using a common prediction equation to estimate the live body weight measurements from some linear body measurements. The levels of significance ($p<0.001$) between the regression coefficients for the three breeds is indicative of sizable differences in live body weights and the linear measurements and hence of significant breed differences. The accuracy of estimation was further ameliorated when these traits are combined in multiple regression, $R^2 = 0.91$.

Tables 6, 7 and 8 show the correlation coefficients between live body weight and linear body measurements across each age group for Mubende, SEA/Teso and SEA/Lugware. The high correlation coefficient values between most linear body measurements and body weight, indicates that any of these traits could be measured easily to give an indication of the other, especially in body weight estimation in the fields without weigh bridges.

Conclusions and Recommendations: Linear measurements together with live body weight were influenced significantly by breed, age and sex, but not coat colour class. Hair coat colour is under the control of single or few genes acting in a simple Mendelian way thus was not expected to have significant influence on quantitative traits. Since the body measurements had high correlation with the body weight, this may be used as selection criteria. The study has showed that although a number of traits measured could be used to predict body weight accurately, heart girth would be the best estimator of body weight in goats. For more accurate and dependable estimate of body weight, however, a number of morphometric traits should be combined in a regression analysis. The higher correlation coefficient for Mubende goat shows that, body weight would be more accurately estimated using the morphometric measurements in Mubende than either in Teso and/or Lugware goats. The results seem to support the idea that Mubende goats seem to be a distinct breed from the other SEA goats under the study.

Further studies are needed to investigate the relationship between morphometric measurements in the same and other breeds of goats in different regions of the country with maximum number of observations. The effect of season and parity on the morphometric traits should also be established.

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