Trop Anim Health Prod (2008) 40:433–439
DOI 10.1007/s11250-007-9116-z

ORIGINAL PAPER

Body measurements of west African dwarf sheep as parameters for estimation of live weight

O. S. Sowande · O. S. Sobola

Accepted: 24 November 2007 / Published online: 6 December 2007

Abstract The relationships between live weight and eight body measurements of West African Dwarf (WAD) sheep were studied using 210 animals under on farm condition. Data obtained on height at withers (HW), heart girth (HG), body length (BL), head length (HL), head width (HDW), loin girth (LG), length of hindquarter (LHQ) and width of hindquarter (WHQ) were fitted into linear, allometric and multiple regression models to predict live weight from the body measurements. Results revealed that body measurements of WAD sheep were generally higher in the rams than in the ewes. Coefficient of determination (R^2) values computed for the body measurements were generally higher (0.87–0.99) using allometric regression model than linear regression model (0.44–0.94). Heart girth (HG) and WHQ depicted the highest relationship to live weight in linear and allometric models compared to other body measurements. Based on stepwise elimination procedure, HG, HL and WHQ were better in predicting live weight in multiple linear regression models. The magnitude of correlation coefficient (r) indicate that WHQ shows the highest correlation with live weight (r=0.96) compared to HG (r=0.94).

O. S. Sowande (✉)
Department of Animal Production and Health,
College of Animal Science and Livestock Production
University of Agriculture,
P. M. B. 2240 Abeokuta, Nigeria
e-mail: ezekielolusiji@yahoo.com

O. S. Sobola
Department of Animal Physiology,
College of Animal Science and Livestock Production
University of Agriculture,
P. M. B. 2240 Abeokuta, Nigeria

Keywords Body measurements · Live weight · Dwarf sheep · Regression equations

Abbreviations

BL	body length
BM	body measurements
Cm	centimeter
HDW	head width
HG	heart girth
HL	head length
HW	head width
LB	length of brisket
LG	loin girth
LHQ	length of hindquarter
WAD	West African Dwarf
WHQ	width of hindquarter

Introduction

West African Dwarf (WAD) breed of sheep is the most numerous in the humid southwestern part of Nigeria, a large proportion of which is under extensive management system. The breed is primarily reared for its meat. This animal species is yet to undergo any specialized breeding for higher meat yield. Genetic improvement of its live weight is required to increase meat yield from this breed. Body measurements (BM) are simple and easily measured variables for estimating live weight although it is unlikely to be more accurate than direct measurement of live weight due to error in location of reference points and anatomical distortions produced when animal change position or posture or muscle tone. In most cases the derived equations can only be useful on-station where such information are required for the purpose of selection and breeding. Despite these limitations, body measurements have been used to evaluate breed performance and to characterize breed of animals. In addition, it has been used as a means of selecting replacement animals and evaluating breed in a controlled environment (Shrestha et al. 1984) and yearling weight in sheep (Aziz et al. 1981).

Among West African small ruminants, strong linear and geometric relationship between live weight and chest girth have been reported in Djallonke, Sahel x Djallonke, Red Sokoto goats and Yankasa sheep (Antobam 1983; Benyi 1997; Fasae et al. 2005). There is paucity of information on the relationship between live weight and body measurements of WAD sheep as in cattle (Davis et al. 1961; Biogolo and Meregali 1972; Young 1972; Spencer and Eckert 1988; Mgbere et al. 2005), WAD goats and crosses (Ozoje 1997; Benyi 1997), and other breeds of sheep (Weiner and Hayter 1974; Bhadula et al. 1979; Bhad et al. 1980; Shrestha et al. 1984; Ibiwoye et al. 1993). Furthermore, in most of the studies only chest girth was considered in prediction equations. In a breeding programme where improved live weight is the overall breeding objective other body measurements having strong correlation to live weight must be considered. Measurement of height at withers and body length may indicate crossbreeding (Hall 1991). This study was undertaken to obtain prediction equations for estimating live weight of WAD sheep from eight body measurements for the purpose of breed characterization and selection for genetic improvement.

Materials and methods

Location and climate of the study area

Animals used for live weight and body measurements were sourced among the smallholder farming community in Ajegunle Abeokuta, Ogun State, Nigeria. The location falls within latitudes 7° 5.5′–7° 8.0′ N and longitudes 3° 11.2′–3° 12.5′ E. The climate is humid and is located in the derived savanna zone of South Western Nigeria. It receives a mean annual precipitation of 1,455 mm, mean annual temperature of 34.7 °C and mean relative humidity of 82%.

Management of animals

A total of 210 WAD sheep, 97 males and 113 females, were selected for live weight and body measurements among the flocks of smallholder farmers. There was no birth record therefore determination of age was by dentition (FAO 1994). The estimated age of the animals was between 13 and 36 months. The sheep were intensively managed. *Panicum maximum* was cut and carried to their pens in the morning and supplementation with concentrates was done in the evening.

Live weight and body measurement procedures

Data was collected over a three-month period. Live weight (kg) of individual animal was determined prior to morning supply of feed to avoid error due to gut-fill using Measuretec^{R} hanging scale. Body measurements were obtained by the use of measuring tape calibrated in centimeters (cm) after restraining and holding the animals in an unforced position. Reference points for the body measurements were determined according to the procedure of Searle et al. (1989). Height at withers (HW) was obtained as the highest point over the scapulae vertical to the ground. Heart girth (HG) was obtained as the smallest circumference just behind the foreleg. Body length (BL) was obtained as the distance from the head of the humerii to the distal end of the pubic bone. Head width (HDW) was obtained as the distance between the outer ends of both eyes. Head length (HL) refers to the distance between the horn site and the lower lip. Loin girth (LG) was determined as the circumference round the animal just before the hind leg. The reference point for Length of hindquarter (LHQ) was the distance located between the 10th rib and the ventral tuberosity of the tuber iscshii while Width of hindquarter (WHQ) was the circumference the animal around the 10th rib.

Statistical analyses

Statistical analyses were carried out using SPSS Software version 10.0 (SPSS 1999) linear and non-linear regression procedures. Live weight was regressed on the body measurements separately for males and females (sex-specific), and for the pool data (not sex-specific). In the multiple regression equation, prediction equations were developed for live weight using a stepwise elimination procedure. The following models were used.

$$W = a + bG \quad \text{..............................(linear)}$$

$$W = aG^b \quad \text{..................................(allometric)}$$

$$W = a + b_1G_1 + b_2G_2 + \ldots + b_nG_n \text{.........(multiple linear)}$$

where W=live weight; a=intercept; G=body measurement; b=regression coefficient of W on G; n=nth number of body measurement.

Results

Live weight and body measurements of WAD sheep

Table 1 shows the Least Square means of live weight and body measurements of WAD sheep. The males used in the experiment were of higher mean liveweight that the female although the highest individual weight was in the female. The male and female WAD sheep had a mean live weight of 16.99 kg and 15.20 kg, respectively. In all the body measurements, male WAD sheep had higher values compared to the females.

Linear regression model

Parameter estimates of linear regression equations predicting live weight from body measurements of WAD sheep are presented in Table 2. In this study all the body measurements were good in predicting the liveweight of the WAD sheep except HDW, which had coefficient of determination (R^2) below 50%. The highest R^2 was observed in WHQ of rams and HG of ewes while WHQ depicts the best overall. The low values of the standard deviations showed the closeness of the predicted to the actual values.

Table 1 Range and least square means of live weight (kg) and body measurements (cm) of WAD sheep

Parameters	Number	Range	Mean
Liveweight:			
Male	97	16.00–32.00	16.99
Female	113	12.00–35.00	15.20
Overall	210	12.00–35.00	16.03
HW:			
Male	97	44.00–69.00	56.19
Female	113	34.00–66.00	52.73
Overall	210	34.00–69.00	54.33
HG:			
Male	97	43.00–82.80	63.26
Female	113	35.00–86.00	59.69
Overall	210	35.00–86.00	61.34
BL:			
Male	97	37.00–63.00	49.34
Female	113	30.00–66.00	47.02
Overall	210	30.00–66.00	48.11
HDW:			
Male	97	9.00–15.00	12.19
Female	113	9.00–16.00	12.16
Overall	210	9.00–16.00	12.17
HL:			
Male	97	15.00–23.50	19.51
Female	113	12.00–23.00	18.24
Overall	210	12.00–23.50	18.82
LG:			
Male	97	5.00–85.00	63.78
Female	113	38.00–96.00	61.31
Overall	210	5.00–96.00	62.45
LHQ:			
Male	97	23.00–40.00	30.98
Female	113	18.00–42.50	29.09
Overall	210	18.00–42.50	29.97
WHQ:			
Male	97	51.00–97.00	71.38
Female	113	2.00–99.50	63.39
Overall	210	2.00–99.50	67.08

HW, height at withers; HG, heart girth; BL, body length; HDW, head width; HL, head length; LG, loin girth; LHQ, length of hindquarter; WHQ, width of hindquarter.

Allometric regression model

Table 3 shows the parameter estimates of allometric equations for predicting live weight from body

Table 2 Linear regression parameters for estimating live weight from body measurements of WAD sheep

Measurement	Constant[1]	Regression Coefficient[1]	Coefficient of determination (R^2)	Standard deviation[2]
HW:				
Male	−32.997	0.890	0.93	0.0112
Female	−27.403	0.808	0.71	0.0023
Overall	−28.879	0.827	0.79	0.0100
HG:				
Male	−27.539	0.704	0.89	0.0037
Female	−18.743	0.569	0.89	0.0078
Overall	−21.128	0.606	0.88	0.0070
BL:				
Male	−34.745	1.047	0.85	0.0119
Female	−22.530	0.803	0.83	0.0108
Overall	−25.724	0.868	0.83	0.0049
HDW:				
Male	−28.436	3.728	0.44	0.0022
Female	−30.131	3.727	0.44	0.0003
Overall	−29.410	3.723	0.43	0.0146
HL:				
Male	−32.509	2.538	0.79	0.1572
Female	−25.247	2.218	0.72	0.0033
Overall	−26.972	2.284	0.74	0.0146
LG:				
Male	−13.485	0.478	0.62	0.1572
Female	−21.696	0.602	0.92	0.0033
Overall	−18.535	0.553	0.79	0.0146
LHQ:				
Male	−25.403	1.368	0.89	0.0012
Female	−22.605	1.300	0.74	0.0063
Overall	−23.363	1.314	0.80	0.0061
WHQ:				
Male	−17.212	0.479	0.94	0.0059
Female	−12.583	0.438	0.77	0.0118
Overall	−16.826	0.487	0.93	0.0941

HW, height at withers; HG, heart girth; BL, body length; HDW, head width; HL, head length; LG, loin girth; LHQ, length of hindquarter; WHQ, width of hindquarter.

[1] All constants and regression coefficients are significant at P< 0.01

[2] Standard deviation between actual and predicted liveweight

measurements of WAD sheep. The R^2 values computed for the body measurements were generally higher (0.87–0.99) using allometric regression than linear regression (0.44–0.94). This yielded an average of 6% higher R^2 value than linear regression. Heart girth (HG) and WHQ depicted the highest relationship to live weight in allometric equations compared to other body measurements. Heart girth (HG) accounted for 99% of live weight in both rams and ewes while WHQ accounted for 99% of live weight in rams and 98% in the ewes.

Multiple linear regression model

The multiple linear equations for estimating live weight from body measurements of WAD sheep are presented in Table 4. All the eight body measurements were fitted into the model and through stepwise elimination procedure five of the body measurements were considered unfit in the model. The three body measurements that best fit the model are heart girth (HG), head length (HL) and width of hindquarters (WHQ) accounting for 95% of the live weight in the rams and 91% in the ewes.

Correlations of live weight and body measurements

Correlation coefficients obtained between the live weight and body measurements of WAD sheep are presented in Table 5. There was a high and positive correlation between the live weight and all body measurements. The highest correlation coefficient (r)

Table 3 Allometric regression parameters for estimating live weight from body measurements of WAD sheep

Measurements	Constant[1]	Regression Coefficient[1]	Coefficient of determination (R^2)	Standard deviation[2]
HW:				
Male	0.00014	2.894	0.99	0.3926
Female	0.00002	3.417	0.94	0.0557
Overall	0.00010	2.993	0.96	0.2188
HG:				
Male	0.00029	2.636	0.99	0.3821
Female	0.00040	2.557	0.99	0.6518
Overall	0.00036	2.584	0.99	0.5191
BL:				
Male	0.00017	2.945	0.98	0.2311
Female	0.00038	2.732	0.97	0.5650
Overall	0.00028	2.809	0.97	0.5736
HDW:				
Male	0.00729	3.087	0.93	0.2964
Female	0.01324	2.809	0.87	0.2090
Overall	0.01209	2.865	0.90	0.2312
HL:				
Male	0.00163	3.096	0.97	0.4505
Female	0.00218	3.020	0.94	0.5930
Overall	0.00212	3.020	0.96	0.5162
LG:				
Male	0.00143	2.246	0.96	0.4100
Female	0.00134	2.255	0.98	0.4092
Overall	0.00140	2.249	0.97	0.3716
LHQ:				
Male	0.00360	2.451	0.98	0.3615
Female	0.00384	2.443	0.94	0.3685
Overall	0.00389	2.434	0.96	0.3733
WHQ:				
Male	0.00395	1.952	0.99	0.2967
Female	0.00199	2.135	0.98	0.6023
Overall	0.00334	2.003	0.99	0.4055

HW, height at withers; HG, heart girth; BL, body length; HDW, head width; HL, head length; LG, loin girth; LHQ, length of hindquarter; WHQ, width of hindquarter.

[1] All constants and regression coefficients are significant at $P< 0.01$

[2] Standard deviation between actual and predicted liveweight

was depicted by WHQ (r=0.96) followed by HG (r=0.94). The lowest correlation was depicted by HDW (r=0.66). There was also a high and positive correlation among all the body measurements.

Discussion

Differences in live weight and body measurements of rams and ewes show that these parameters are sex dependent. Ewes has slower rate of growth and reaches a lower mature size due to the effect of estrogen in restricting the growth of the long bones of the body. The values of HW, HG and BL are close to values of 50.5, 61.7, 44.5 cm and 50.2, 60.5, 43.2 cm reported for WAD rams and ewes, respectively (Hall 1991). The slightly lower value of these parameters could be attributed to few numbers of animals (23) involved in his work. There are no published references on HDW, HL, LG, LHQ and WHQ in WAD sheep suggesting that this breed has not been properly characterized.

Width of hindquarter (WHQ) and HG better described the relationship between live weight and body measurements of WAD sheep. Both WHQ and HG gave the best R^2 in linear equation. Heart girth has been reported to be the most satisfactory single variable in estimating live weight (Ibiwoye et al. 1993) however, in this study, WHQ seems to compare favourably with HG in estimating live weight using linear equations. The lowest R^2 value was exhibited by the HDW (R^2=0.43) suggesting that HDW is not a

Table 4 Multiple linear regression equations for estimating live weight from body measurements of WAD sheep

Sex	Predictive equations[1]	(R^2)	Standard Deviation[2]
Male	−21.8607+0.2033HG+0.0911HL+0.3392WHQ	0.95	0.0002
Female	−15.0989+0.6244HG−0.6961HL+0.0904WHQ	0.91	0.0001
Overall	−17.7625+0.2533HG−0.2603HL+0.3436WHQ	0.94	0.0565

HG, heart girth; HL, head length; WHQ, width of hindquarter.

[1] All constants and regression coefficients are significant at $P<0.01$

[2] Standard deviation between actual and predicted liveweight

reliable body measurement in predicting the live-weight of WAD sheep.

The results obtained with allometric equations supports the assertion that live weight tends to be underestimated by linear regression equations in animals with large chest girth (Brown et al. 1983). This also confirms earlier findings that the relationship between live weight and chest girth in sheep and goats as in cattle is curvilinear (Davis et al. 1961; Pander et al. 1989 and Benyi 1997). Heart girth explained 99% of variation in live weight of WAD sheep by allometric and 89% by linear regression. This result is in line with previous reports where HG has been reported to be the most satisfactory single variable in estimating live weight (Davis 1961; Biogolo and Meregali 1972; Spencer and Eckert 1988; Ibiwoye et al. 1993, Benyi 1997). In Iranian Mehraban sheep (Bathaei 1995), HW, BL and HG were the most significantly associated with variation in weight using allometric equations. No published work is available on the relationship of WHQ to live weight. Areas around the WHQ also include the rump, which is one of the six-hindquarter cut of choice in carcass evaluation and therefore would be an important parameter in a selection and breeding programme.

Parameter estimates in multiple linear regression model shows that more than one body measurement may be required for predicting live weight especially in breeding programme for WAD sheep in which overall live weight is the breeding objective. In this study, HG, HL and WHQ are the most important body measurements required for selection and breeding in WAD sheep. Bamiro (1991) reported that the use of combination of HG, length of brisket (LB) and HW enhanced the efficiency of predicting the live weight of Yankassa sheep. This implies that body conformation varies in different species of sheep.

The positive correlation coefficient in this study is in agreement with Mgbere et al. (2005) who reported similar relationship between live weight and body measurement in N'Dama cattle. This indicates that an increase in any one body measurement would result in a corresponding increase in live weight.

Table 5 Pearson correlation matrix of live weight and linear body measurements of WAD sheep

	Liveweight	HW	HG	BL	HDW	HL	LG	LHQ	WHQ
Liveweight	1.000								
HW	0.890**	1.000							
HG	0.940**	0.971**	1.000						
BL	0.910**	0.911**	0.946**	1.000					
HDW	0.659**	0.736**	0.719**	0.703**	1.000				
HL	0.863**	0.903**	0.939**	0.873**	0.764**	1.000			
LG	0.891**	0.825**	0.886**	0.855**	0.668**	0.796**	1.000		
LHQ	0.893**	0.899**	0.911**	0.885**	0.711**	0.882**	0.854**	1.000	
WHQ	0.964**	0.911**	0.941**	0.921**	0.670**	0.871**	0.909**	0.922**	1.000

HW, height at withers; HG, heart girth; BL, body length; HDW, head width; HL, head length; LG, loin girth; LHQ, length of hindquarter; WHQ, width of hindquarter.

**Significant at $P<0.01$

Conclusion

The pattern of relationship observed in this study indicates that for a breeder or stockman to have a fairly good knowledge of the live weight of WAD sheep, measurement of HG and WHQ will be useful. Selection and breeding based on these two body measurements could result in improved live weight in WAD sheep. Such measurements would also aid in recognizing and describing the complex relationships that contribute to adaptation of WAD sheep to humid tropical environment and its functional efficiency.

References

Antobam, K., 1983. Estimation of weights of sheep from body measurements. (unpublished B.Sc. dissertation, University of Ghana)

Aziz, D. A., Alrawi, A. A. and Kazzal, N. T., 1981. Prediction of yearling weight and dimensions from weaning performance in Awassi sheep. *Mesopotamia Journal of Agriculture*, **16**, 29 – 36

Bamiro, A. O., 1991. Prediction of sheep live body weight from seven body measurements using Yankasa sheep. (unpublished B.Agric. dissertation, University of Agriculture, Abeokuta, Nigeria)

Bathaei, S. S., 1995. Growth and body development from birth to maturity in Iranian Mehraban sheep. *Revue d' Elevage et de Medecine Veterinaire des Pays Tropicaux*, **48,** 181–194

Benyi, K., 1997. Estimation of liveweight from chest girth in pure and crossbred West African goats. *Tropical Animal Health and Production*, **29,** 124–128

Bhadula, S. K., Bhat, P. and Garg, R. C., 1979. Prediction of body weight from body measurements in sheep. *Indian Journal of Animal Science*, **49,** 775–777

Bhad, P. N., Bhat, P. and Garg, R. C., 1980. Notes on prediction weight using linear body measurements in sheep. *Indian Journal of Animal Health,* **13,** 12–14

Biogolo, C. and Meregali, A., 1972. Relationship between body measurements, live weight and weight gain in young China bulls. *Revista de Zootecnia,* **45,** 121–135

Brown, J. E., Brown, C. J. and Butts, W. T., 1983. Evaluating relationships among immature measures of size, shape and performance of beef bulls: the relationship between post weaning test performance and size and shape at twelve months. *Journal of Animal Science*, **37,** 11–19

Davis, H. P., Sweet, W. W. and Harvey, W. R., 1961. Relation of heart girth to weight in Holsteins and Jerseys. Nebraka Agric. *Nebraka Agric. Expt. Stat. Bull* 194

FAO 1994. A manual for the primary animal health care workers. Food and Agriculture Organization of the United Nations. Rome, Italy. pp 28

Fasae, O. A., Chineke, A. C. and Alokan, J. A., 2005. Relationship between some physical parameters of grazing Yankasa ewes in the humid zone of Nigeria. *Archivos de Zootecnia*, **54,** 639–642

Hall, S. J. G., 1991. Body dimension of Nigerian cattle, sheep and goats. *Animal Production*, **53,** 61–69

Ibiwoye, T. I. I., Oyatogun, M. O. and Jolayemi, J., 1993. Yankasa sheep and West African dwarf goat production in the Kainji lake basin of Nigeria. *Tropical Agriculture (Trinidad)*, **70,** 165–168

Mgbere, O. O., Olutogun, O. and Orheruata, A. M., 2005. Evaluation of body weight as related to linear body measurements in N'Dama cattle under humid tropical environment. *Nigerian Journal of Animal Production*, **32,** 173–184

Ozoje, M. O., 1997. Correlation analysis in purebred and crossbred West African dwarf goats: growth and maturity patterns. *Tropical Agriculture (Trinidad)*, **74,** 303–307

Pander, B. L., Kanaujia, A. S. and Yadav, A. S., 1989. Growth performance and prediction of body weight from body measurements in Beetal and Black Bengal kids and their crosses maintained under feedlot conditions. *Indian Journal of Animal Production and Management*, **5,** 162–166.

Searle, T. W., McGraham, N. and Donnelly, J. B., 1989. Changes in skeletal dimensions during growth in sheep: the effect of nutrition. *Journal of Agricultural Sciences (Cambridge)*, **112,** 321–327

Shrestha, J. N. B., Heaway, D. P., Fisher, P. S. and Langroord, G. A., 1984. Influence of breed birthdate, age and body weight on linear measurements of growing rams maintained in controlled environment. *Canadian Journal of Animal Science*, **64,** 279–291

Spencer, W. P. and Eckert, J. B., 1988. Estimation of liveweight and carcass weight in Gambian N'Dama cattle. *World Animal Review* **1,** 1–10

SPSS 1999. Statistical Package for social sciences. Procedure and Facilities for release. McGraw-Hill Book Co. NY

Weiner, G. and Hayter, S., 1974. Body size and conformation in sheep from birth to maturity as affected by breed, crossbreeding maternal and other factors. *Animal Production*, **19,** 47–65

Young, D. L., 1972. The estimation of liveweight from heart girth within specified age/sex group of Kenya range cattle. *East African Agriculture and Forest Journal*, **38,** 193–200