

Age- and sex-dependent regression parameters for estimating live weight from body measurements of West African Dwarf sheep

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Abstract

The relationships between live weight and eight body measurements of West African Dwarf (WAD) sheep were studied using 300 animals under farm condition. The animals were categorized based on age and sex. Data obtained on height at withers (HW), heart girth (HG), body length (BL), head length (HL), length of hindquarter (LHQ), width of hindquarter (WHQ), head width(HDW), and loin girth (LG) were fitted into simple linear (change in body measurement is directly proportional to weight or body size), allometric (body measurements do not necessarily change in direct proportion to weight or body size), and multiple linear regression models to predict live weight from the body measurements according to age group and sex. Results showed that live weight and body measurements of ewe were higher than that of the ram. Live weight, HG, HW, WHQ, LG, BL, LHQ, HL, and HW increased with the age of the animals. In multiple linear regression model, WHQ, LHQ, HW, HL and HDW best fit the model for sheep aged ≤1; HG, LG, BL and HDW for 2 year -old sheep; HG, BL, and HL best fit the model for sheep 3 years age group; LHQ best fit the model for sheep of 4 years of age; while HL best fits sheep that were in 5 year age category. Coefficients of determination (R^2) values for linear and allometric models for predicting the live weight of WAD sheep increased with age in all the body measurements (HW, HG, BL, HL, LHQ, WHQ, HDW and LG). Sex had significant influence on the model with R^2 values consistently higher in females except the models for LHQ, WHQ, LG and BL were they the same with the males. Based on R^2 values, it wase concluded that both linear and allometric regression models could be used to predict live weight from body measurements of WAD sheep.

Keywords: Age, Body measurements, Live weight, Regression models, WAD sheep, Sex

Introduction

West African Dwarf (WAD) sheep is a short legged, small breed with notable physical and sexual vigour and a robustness that enables them withstand the stresses of the climate, diseases and irregular feeding (Charray *et al*., 1992). The body weight of live animals is the most reliable measure of growth and a good index for selection, determination of feed requirements and health management strategies (Thiruvenkanden 2005). Furthermore, decision on selling price per kilogramme of meat is usually based on animal's weight where weighing scale is available otherwise sales are based on visual appraisal of the animal and price haggling. Interests in generating data for the purpose of selection and breeding are recent developments as the breed is yet to undergo any specialized breeding for higher meat yield (Sowande and Sobola, 2008). Genetic improvement of its live weight is required to increase meat yield from this breed. Body measurements are simple and easily measured variables which could be regressed with live weight for selection and breeding purpose. The advantages and disadvantages of using this method had been highlighted in previous studies (Sowande and Sobola 2008). There is paucity of information on the relationship between live weight and body measurements of WAD sheep compared to other breeds of sheep (Bhad et al., 1980; Shrestha et al., 1984; Ibiwoye et al., 1993) and WAD goats and its crosses (Ozoje 1997; Benyi 1997). In most of the studies only chest girth was considered in prediction equations. In others (Sowande and Sobola, 2008) where other body measurements were employed, only sex was considered in the regression models. In addition, the relationship in most of these studies was based on correlation matrix, and prediction equations were limited to using simple linear regression model. Furthermore, prediction equations were not age and sex specific. Since changes in body size is dependent on age and sex of an animal (Sowande et al., 2010), this study was undertaken to obtain prediction models for estimating the live weight of WAD sheep from body measurements for the purpose of breed characterization and selection for possible genetic improvement using age- and sex-specific linear, multiple linear, and allometric regression models.

Material and Methods

Study Area and Experimental Animals

Animals used for live weight and body measurements were sourced among the smallholder farming community in Ago-Iwoye area of Ogun State. Ago-iwoye falls within latitude 3.5°S-7.5°N with an annual rainfall of 1455mm which is bimodal in nature with peaks in June and September. Temperature ranges between 27°C and 32°C.

A total of 300 animals were used for the study. The animals were grouped according to sex: male (97) and female (203) and age group ≤ 1 yr (119); 2yrs (57); 3yrs (42); 4 yrs (56) and 5yrs (26). Management system employed for the WAD sheep was semi-intensive; time of confinement was limited to nights and part of the day to avoid crop damage. The predominant grass species was Panicum maximum. When animals were resstricted feeding was based on cut and carry of P. maximum and supplementation with dried cassava peels. Routine health check on the animals was done by the community Veterinary Doctor.

Live weight and body measurement procedure

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 Searle *et al.* (1989). Heart girth (HG) was obtained as the 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. Length of hind quarter (LHQ) was the distance located between the 10^{th} rib and the ventral tuberosity of the tuber ischii. Height at withers (HW) was measured as the highest point over the scapulae vertical to the ground. Loin girth (LG) refers to the circumference round the animal just before the hind leg. Width of hindquarter (WHQ) was obtained as the circumference round the animal around the 10^{th} rib.

Statistical analyses

Statistical analyses were carried out using SPSS 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 different age groups (age-specific) and for the pooled data (non sex and age specific). The linear regression was used to determine whether change in body measurement is directly proportional to weight or body size. Allometric regression analysis was used to determine whether body measurements do not necessarily change in direct proportion to weight or body size. In the multiple regression equation, prediction equations were developed for liveweight using a stepwise elimination procedure. The following models were used.

$W=a+bG$.....................(linear)

$W=aG^b$.......................(allometric)

$W=a+b_1G_1+b_2G_2+....+b_nG_n$..... (multiple linear)

Where:

W= live weight;

a= intercept/constant;

G= body measurements;

b= regression coefficient/allometric exponent of W on G; n=n^{th} number of body measurements.

Results and Discussion

Least square means and standard error of the liveweight and body measurements of WAD sheep is presented in Table 1. Age and sex strongly influences the liveweight and body measurements of WAD sheep as there were consistent increase in all the traits studied as the animals' aged. This trend is not surprising as the size and shape of the animals is expected to increase with age. Rapid growth in the early growth phase as noted in this study is a time of great change in the skeletal and muscular systems. During this period, bones are continually being remolded or reshaped to meet the

Table 1: Least square means and standard error of liveweight (kg) and body measurements (cm) of WAD sheep

Factors	N	HG	WHQ	LHQ	LG	BL	HW	HL	HDW	WEIGHT
Sex:										
Ram	97	65.0±8.8	70.7±9.4	28.0±3.3	65.6±9.9	52.0±5.8	57.5±5.5	18.7±1.4	17.5±2.7	19.9±4.9
Ewe	203	69.2±5.3	76.8±6.4	28.3±2.9	71.1±5.7	55.2±3.6	58.3±4.2	19.4±11.9	16.1±1.3	21.4±4.1
Age (yrs):										
=1	119	62.9±6.5	69.4±8.7	26.9±2.9	64.2±8.1	51.1±4.5	55.2±4.4	19.5±15.6	16.2±1.9	17.3±3.3
2	57	69.8±5.9	77.8±5.7	28.5±3.6	71.9±6.5	55.4±3.5	59.4±4.1	18.8±1.2	16.7±2.0	21.9±2.6
3	42	69.8±4.2	78.7±4.2	28.8±2.1	72.2±4.9	56.1±4.3	60.6±3.9	19.7±0.9	17.1±2.1	22.9±3.5
4	56	71.5±3.0	76.7±4.2	28.8±2.5	72.5±4.4	56.8±2.8	60.8±3.5	18.9±1.2	16.8±2.2	23.8±2.8
5	26	75.5±3.9	82.5±4.3	30.7±2.4	75.7±4.3	56.9±3.4	59.4±2.9	19.3±0.8	16.5±0.8	26.0±3.9
Pooled Data	300	67.9±6.9	74.8±8.0	28.2±3.0	69.3±7.8	54.2±4.7	58.1±4.6	19.2±9.8	16.5±1.9	20.9±4.5

N=Number of observations
HG=Heart girth
BL=Body length
HDW=Head width
HL= Head length
LHQ=Length of hind quarter
HW=Height at withers
LG=Loin girth
WHQ=Width of hindquarter

Table 2: Linear and Allometric regresion parameters for predicting live weight of WAD sheep from Heart Girth

Factors	N	a	B	R^2	SD
		Linear			
Sex:					
Male	97	-5.090	0.385	0.97	0.006
Female	203	-15.962	0.539	0.98	0.006
Age(yrs):					
=1	119	0.645	0.264	0.97	0.004
2	57	11.256	0.153	0.99	0.021
3	42	-11.823	0.497	0.99	0.012
4	56	-0.846	0.345	0.99	0.024
5	26	10.422	0.206	0.98	0.014
Total	300	-9.103	0.442	0.98	0.003
		Allometric			
Sex:					
Male	97	0.078	1.327	0.97	0.051
Female	203	0.013	1.742	0.98	0.340
Age(yrs):					
=1	119	0.325	0.959	0.97	0.001
2	57	3.127	0.459	0.99	0.031
3	42	0.042	1.486	0.99	0.141
4	56	0.296	1.027	0.99	0.027
5	26	1.952	0.599	0.98	0.021
Total	300	0.033	1.532	0.98	0.154

stresses applied by the greater muscle mass and body weight (Trenkle and Marple, 1983). In this study, ewes were heavier than rams and the linear measurements were superior in the ewe except HDW. This is in line with the findings of Hall (1991) where a higher height at withers, heart girth and body length were reported in WAD ewes compared to the rams. Influence of sex on live weight and linear body measurements might be partly due to hormonal effect (Frandson and Elmer, 1981). in previous studies (Ogungbayi *et al.*, 2003) sex had no influence on body length, height at withers and heart girth of WAD lamb between 0-3 months. However at this age the ram lambs were heavier than the ewe lambs.

Parameter estimates of linear and allometric regression models for predicting live weight from heart girth of WAD sheep are presented in Table 2. Coefficients of determination (R^2) values for linear and allometric models were similar. Reliability of HG in predicting the live weight of WAD sheep increased with age up to 4 years from 97% in sheep of ≤ 1 year old to 99% in 4 year-old sheep but declined subsequently. This suggests that rate of growth in sheep is maximium at four years since HG is a function of the body condition score of the animal. In earlier study (Sowande and Sobola, 2008) reported R^2 values of 0.89 for both rams and ewes which is lower than values of 0.97 and 0.98 respectively for

Table 3: Linear and Allometric regresion parameters for predicting live weight of WAD sheep from Width of hindquarter.

Factors	N	Linear a	B	R^2	SD
		Linear			
Sex					
Male	97	-7.558	0.389	0.98	0.007
Female	203	-6.491	0.363	0.98	0.014
Age(yrs)					
=1	119	1.337	0.229	0.98	0.012
2	57	10.677	0.144	0.99	0.021
3	42	-1.885	0.314	0.98	0.020
4	56	9.960	0.181	0.99	0.027
5	26	20.219	0.070	0.98	0.006
Total	300	-5.859	0.358	0.98	0.014
		Allometric			
Sex					
Male	97	0.036	1.479	0.98	0.272
Female	203	0.080	1.287	0.98	0.021
Age(yrs)					
=1	119	0.350	0.920	0.98	0.041
2	57	2.553	0.494	0.99	0.021
3	42	0.215	1.068	0.98	0.800
4	56	1.882	0.585	0.99	0.030
5	26	9.934	0.218	0.98	0.004
Total	300	0.074	1.306	0.98	0.122

rams and ewes. This variation could be due to geographical location and management systems employed in rearing the animals. Live weight of WAD sheep therefore, could be reliably predicted using either of the two models for the different ages and sex using HG. Ibiwoye et al. (1993) reported that the most satisfactory single variable in estimating live weight is heart girth.

Linear and allometric regression parameters for predicting live weight from width of hindquarter of WAD sheep of different age groups and sex are presented in Table 3. Coefficients of determination (R^2) values for linear and allometric models were similar. Reliability of WHQ in predicting the live weight of WAD sheep was similar in both sexes (0.98) and ranged between 0.98 and 0.99 among the different age groups. Sowande and Sobola, 2008 reported R^2 value of 0.94 for rams and 0.77 ewes using linear equation and 0.99 for rams and 0.98 for ewes using allometric equation.

Linear and allometric equations for predicting liveweight from length of hindquarter are presented in Table 4. Coefficients of determination (R^2) values for both linear and allometric models were similar. 97% of change in live weight was accounted for by LHQ in both sexes whereas R^2 values for the different age category in both linear and allometric ranged from 98 to 99%. These values are higher than 0.88 to 0.94 obtained in WAD goats aged 1 to 3 years (Sowande et al., 2010).

Coefficients of determination (R^2) values for both linear and allometric models were similar for LG, BL and HW (Tables 5, 6 and 7) except the lower R^2 values of 0.96 and 0.97 obtained in males and sheep aged ≤ 1, respectively. Both linear and allometric regression equations had a R^2 value of 0.97% for both sexes and a range of 0.98 to 0.99 for the different age categories. There is paucity of information on the importance of LG and BL in predicting live weight in WAD\sheep. However, Sowande and Sobola (2008) obtained R^2 values of 0.85 and 0.62 for males; 0.83 and 0.92 for females in linear regression models respectively for BL and LG. in allometric models, values of 0.98 and 0.96 for males; and 0.97 and 0.98 for females respectively for BL and LG in WAD sheep. Height at withers reflects the animals' skeletal size. The findings in this study suggests that this measurement would be an importantant consideration in selecting animal for breeding purpose as the height of the male relative to the female determines the ease of mating.

In male WAD sheep, HL (Table 8) accounted for 95% variation in live weight using linear and allometric equations and 96 and 97% varation in live weight of females using linear and allometric equations respectively. Among the age

Table 4: Linear and Allometric regresion parameters for predicting live weight of WAD sheep from Length of hindquarter.

Factors	N	a	b	R^2	SD
		Linear			
Sex:					
Male	97	-10.212	1.077	0.97	0.004
Female	203	3.840	0.620	0.97	0.001
Age(yrs):					
=1	119	0.698	0.613	0.98	0.030
2	57	16.089	0.204	0.99	0.003
3	42	-3.855	0.928	0.99	0.006
4	56	6.170	0.613	0.99	0.004
5	26	14.409	0.378	0.98	0.004
Total	300	-1.530	0.796	0.97	0.540
		Allometric			
Sex:					
Male	97	0.116	1.542	0.97	0.120
Female	203	1.385	0.819	0.97	0.013
Age(yrs):					
=1	119	0.716	0.966	0.98	0.020
2	57	9.208	0.259	0.99	0.013
3	42	0.505	1.134	0.99	0.033
4	56	2.020	0.735	0.99	0.034
5	26	5.764	0.440	0.98	0.006
Total	300	0.573	1.077	0.98	0.016

Table 5: Linear and Allometric regresion parameters for predicting live weight of WAD sheep from Loin girth.

Factors	N	a	B	R^2	SD
		Linear			
Sex:					
Male	97	-2.985	0.349	0.97	0.020
Female	203	-6.025	0.385	0.97	0.003
Age(yrs):					
=1	119	1.477	0.246	0.98	0.020
2	57	13.738	0.114	0.99	0.020
3	42	13.339	0.132	0.98	0.013
4	56	22.071	0.024	0.99	0.010
5	26	14.025	0.158	0.98	0.015
Total	300	-3.518	0.352	0.99	0.008
		Allometric			
Sex:					
Male	97	0.130	1.203	0.97	0.001
Female	203	0.094	1.272	0.97	0.026
Age(yrs):					
=1	119	0.356	0.933	0.98	0.040
2	57	5.005	0.346	0.99	0.042
3	42	3.900	0.413	0.98	0.010
4	56	16.105	0.091	0.99	0.016
5	26	3.589	0.458	0.98	0.023
Total	300	0.126	1.205	0.97	0.050

Table 6: Linear and Allometric regresion parameters for predicting live weight of WAD sheep from Body Length.

Factors	N	Linear a	B	R^2	SD
		Linear			
Sex:					
Male	97	-11.330	0.601	0.97	0.000
Female	203	-8.731	0.545	0.97	0.004
Age(yrs):					
=1	119	-3.884	0.414	0.98	0.013
2	57	22.252	-0.006	0.99	0.006
3	42	0.247	0.403	0.98	0.020
4	56	32.299	-0.150	0.99	0.020
5	26	8.509	0.307	0.98	0.013
Total	300	-9.618	0.563	0.97	0.013
		Allometric			
Sex:					
Male	97	0.038	1.586	0.97	0.066
Female	203	0.087	1.372	0.97	0.004
Age(yrs):					
=1	119	0.130	1.243	0.98	0.018
2	57	22.271	-0.004	0.99	0.006
3	42	0.442	0.980	0.98	0.002
4	56	95.281	-0.344	0.99	0.043
5	26	1.784	0.663	0.98	0.010
Total	300	0.062	1.456	0.97	0.115

Table 7: Linear and Allometric regresion parameters for predicting live weight of WAD sheep from Height at withers.

Factors	N	a	B	R^2	SD
			Linear		
Sex:					
Male	97	-8.877	0.501	0.96	0.010
Female	203	-5.876	0.467	0.97	0.006
Age(yrs):					
=1	119	-0.318	0.318	0.97	0.016
2	57	15.529	0.108	0.99	0.020
3	42	2.679	0.336	0.98	0.001
4	56	19.228	0.075	0.99	0.013
5	26	36.719	-0.181	0.98	0.020
Total	300	-7.581	0.491	0.97	0.020
			Allometric		
Sex:					
Male	97	0.045	1.502	0.96	0.097
Female	203	0.129	1.258	0.97	0.343
Age(yrs):					
=1	119	0.307	1.004	0.97	0.030
2	57	7.441	0.265	0.99	0.034
3	42	0.587	0.894	0.98	0.012
4	56	11.561	0.176	0.99	1.520
5	26	143.031	-0.418	0.98	0.038
Total	300	0.081	1.366	0.97	0.080

groups, reliability of the two models increased with age except a decrease observed after 4 years of age and R^2 ranged between 0.97 to 0.99 in sheep aged from ≤1 to 4years. These values are higher than previously reported (Sowande and Sobola, 2008) for both sexes and among different age groups (Sowande et al., 2010) in WAD goats. Head width showed strong relationship with live weight (Table 9) and accounted for 95% and 97% variation in live weight respectively for male and female WAD sheep in both linear and allometric regression models. These values are at variance with reports of Sowande and Sobola (2008) who reported lower R^2 values in both sexes using linear and allometric regression models.

Multiple linear regression models for estimating liveweight from body measurements of WAD sheep are shown in Table 10. Heart girth, WHQ, LHQ, HW and HDW best fits the model for male WAD sheep and HG, LHQ and HW best fits the model for females with R^2 values of 0.65 and 0.56 respectively. This is an indication of differences in the conformation and growth pattern in male and female WAD sheep. The size of head is important in male animals than females to make allowance for growth of horns. Among the age groups, the highest R^2 value was recorded at 3yrs (0.60) while the least was recorded at 5yrs (0.22). WHQ, LHQ, HW, HL and HDW fits the

Table 8: Linear and Allometric regresion parameters for predicting live weight of WAD sheep from Head Length.

Factors	N	a	B	R^2	SD
		Linear			
Sex:					
Male	97	-2.744	1.211	0.95	1.030
Female	203	20.932	0.022	0.96	0.004
Age(yrs):					
=1	119	16.595	0.034	0.97	0.006
2	57	16.254	0.302	0.99	0.004
3	42	-17.746	2.129	0.99	0.004
4	56	13.571	0.541	0.99	0.004
5	26	-19.406	2.354	0.98	0.007
Total	300	20.277	0.033	0.96	0.010
		Allometric			
Sex:					
Male	97	0.754	1.118	0.95	0.989
Female	203	13.866	0.147	0.97	0.053
Age(yrs):					
=1	119	11.285	0.146	0.97	0.114
2	57	10.354	0.256	0.99	0.013
3	42	0.107	1.818	0.99	0.067
4	56	6.794	0.427	0.99	0.023
5	26	0.104	1.865	0.98	0.030
Total	300	12.154	0.185	0.96	0.062

model for age group ≤1 year, suggesting that increase in bone length is the main factor responsible for live weight increase. The model for 2-year old WAD sheep contained HG, LG, BL and HDW. Inclusion of HG in the model suggest that at this age the animal's conformation in terms of protein and fat accretion has commenced with some amount of bone growth responsible for live weight changes. At 3 years of age, HG, BL and HL accounted for 60% changes in live weight in linear multiple regression model and beyond this age multiple linear regression model might not be reliable in predicting the live weight of WAD sheep as only LHQ (4 years) and HL (5 years) were fitted into the model which had eliminated other body measurements. Bamiro (1991) in a study with Yankassa sheep reported that the use of combination of HG, length of brisket (LB) and HW as enhancing the efficiency of predicting the live weight using multiple linear regression model.

Conclusion

All the linear body measurements considered in this study had strong relationship with live weight. Age of the animal and sex were shown in linear and allometric regression models to be important factors when planning a breeding programme with overall live weight as the main objective. Multiple linear regression model revealed that beyond 3 years of age, this model might not be reliable in predicting the live weight of WAD sheep. Based on R^2 values, it could be concluded that both linear and allometric regression

Table 9: Linear and Allometric regresion parameters for predicting live weight of WAD sheep from Head Width.

Factors	N	a	B	R^2	SD
			Linear		
Sex:					
Male	97	8.919	0.628	0.95	1.062
Female	203	2.380	1.181	0.97	0.001
Age(yrs):					
=1	119	13.002	0.263	0.97	0.002
2	57	15.076	0.408	0.99	0.003
3	42	10.250	0.739	0.98	0.010
4	56	18.459	0.319	0.99	0.006
5	26	18.738	0.441	0.98	2.120
Total	300	11.190	0.587	0.96	0.000
			Allometric		
Sex:					
Male	97	0.4220	0.543	0.95	1.060
Female	203	1.775	0.896	0.97	0.110
Age(yrs):					
=1	119	8.404	0.259	0.97	0.021
2	57	9.352	0.303	0.99	0.041
3	42	4.742	0.555	0.98	0.030
4	56	12.740	0.222	0.99	0.020
5	26	11.551	0.290	0.98	0.024
Total	300	5.668	0.466	0.96	0.040

Table 10: Multiple Linear regresion models for predicting the live weight of WADsheep from body mesurements.

Factors	Predictive equations	R^2	SD
Sex:			
Male	-16.890 – 0.336HG + 0.523WHQ + 0.489LHQ + 0.235HW – 0.315HDW	0.65	5.680
Female	-28.554 + 0.413HG + 0.310LHQ + 0.216 HW	0.56	0.030
Age(yrs):			
=1	-6.332 + 0.167WHQ + 0.286LHQ + 0.148HW + 0.024HL – 0.273HDW	0.48	0.040
2	12.374 + 0.313HG – 0.164LG – 0.168BL + 0.527HDW	0.26	0.030
3	-37.396 + 0.226HG + 0.314BL + 1.410HL	0.60	0.004
4	6.170 + 0.613LHQ	0.29	0.004
5	-19.406 + 2.354HL	0.22	0.007
Total	-20.259 + 0.269HG + 0.311LHQ + 0.119BL + 0.133HW	0.54	0.022

models could be used to predict live weight from body measurements of WAD sheep.

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