AGRICULTURAL SCIENCE AND TECHNOLOGY, VOL. 13, No 2, pp 134-140, 2021
Published by Faculty of Agriculture, Trakia University, Bulgaria
ISSN 1313-8820 (print)
ISSN 1314-412X (online)
http://www.agriscitech.eu
DOI: 10.15547/ast.2021.02.022

Statistical models based on morphometric traits for live body weight estimation in goats

N.A. Ouchene-Khelifi*, N. Ouchene

Veterinary sciences institute, Saad Dahleb University, Blida 1, road of Soumaa, B.P. 270, Blida 09000, Algeria

(Manuscript received 24 September 2020; accepted for publication 31 March 2021)

Abstract. *The objective of this study was to develop statistical models to predict body weight from goat's body measurements. Data on 1702 goats for circumferences of chest (CG), abdominal circumference (AC) and spiral circumference (SC), height at withers (WH), body length (BL), and body weight (BW) were analysed to study the relationship between linear body measurements and body weight. The present study revealed that in the goats from all breeds studied (Arabia, Makatia, Kabyle, M'zabite, Saanen and Alpine), the weight evolved in the same direction and at the same rate as the linear measurements chosen. The linear measurements were all significantly correlated with animal weight ($p<0.001$). Results indicated that Arabia goats had the highest WH (71.07 cm) and CG (17.72 cm). The highest measurements were reported in Alpine goats for AC (97.73 cm), BL (78.05 cm), SC (106.29 cm) and BW (41.60 kg). The Kabyle breed were recorded with the lowest values for the WH (64.95 cm), BL (67.58 cm) and BW (29.52 kg). The average live weight was 38.15±10.90 kg with differences according to age, sex and breed (Arabia, Makatia, Kabyle and M'Zabite). Positive and highly significant ($p<0.001$) correlations were observed between BW and the majority of independent variables. The highest relationship was illustrated between CG with BW ($r=0.922$). Linear regression analyses were performed to develop the models. The simple regression analysis found all parameters to be significant ($p<0.001$) (WH, BL, CG, AC and CS) and CG gave more precision on the weight when using a single measurement parameter (R^2 varied between 0.950 and 0.967). Therefore, the following formula can be used to estimate the live weight of the animals using only the chest circumference ($P=75*CG$). The development of these equations would enable producers and researchers to predict the animal body weight and develop strategic plans for the relevant goat herds.*

Keywords: Algeria, correlations, goats, live body weight, prediction, regression

Abbreviations: AC- Abdominal circumference, BL- Body length, BW- Body weight, CG- Circumference of chest, SC- Spiral circumference, WH- Height at withers.

Introduction

Goat farming is an efficient agricultural enterprise for farmers with little land and other resources (Moela, 2014). In Algeria, the local goat population, mainly present in difficult regions (mountains, forests, steppes and the Sahara) (Ouchene-Khelifi et al., 2015), uses poor food resources to produce meat (Madani et al., 2015). Its population is estimated at 4.9 million in 2018 (FAOSTAT, 2018).

Body weight is a very important characteristic in meat animals due to its direct relation with income (Cam et al., 2010). It is supplemented with measurements which describes an individual or population more completely than conventional methods of weighing or grading (Ravimurugan et al., 2015). Body measurements are important to reflect breed norms and provide information on the morphological structure and developmental capacity of animals (Riva et al., 2002). They are indicators of growth in animal life and are also useful for predicting body weight and carcass characteristics (Ravimurugan et al., 2015; Kumar et al., 2018).

Estimating body weight using body measurements is advantageous for improving both the economic gain of operations and the efficiency of selection (Elmaz et al., 2008). When selecting goats, attention should be paid to age, growth rate, circumference of chest and body length. The prediction of live weight and its relationship with other morphological measures provides valuable knowledge for the study of animal husbandry with regard to meat production per animal (Iqbal et al., 2013). Many authors have used body measurements to predict the body weight of sheep (Tadesse and Gebremariam, 2010; Birteeb et al., 2012) and goats (Parés et al., 2012; Hopker et al., 2019; Abd-Allah et al., 2019b; Waheed et al., 2020) but to our knowledge, no studies have been carried out in Algeria on the determination of the live weight of goats using body measurements.

The present study was therefore carried out to establish the relationship between live weight and some linear body measurements in local Algerian breeds in order to derive a prediction equation to estimate the live weight of goats under field conditions without the use of scales.

*e-mail: khelifinaa@gmail.com

Material and methods

Study location and animal samples

Twenty-one regions of Algeria were selected including cradles of the local breeds (Figure 1). The data for this study were obtained among 1702 adult goats, comprising 329 males and 1373 females belonging to six different breeds (Arabia, Makatia, Kabyle, M'zabite, Saanen and Alpine). Of all of them 454 aged less than 24 months, and 1248 aged over 24 months (Table 1). These animals were evaluated by morphometric characteristics. The pairs of permanent incisors in the dentition of the goat were used to determine age (Wilson and Durkin, 1984).

Figure 1. Geographical location of the sampling of goats in Algeria

Table 1. Number of goats of the different breeds included in the study

Goat breed	Male			Female		
	< 24 months of age	> 24 months of age	Total	< 24 months of age	> 24 months of age	Total
Arabia	65	65	130	98	457	555
Makatia	36	35	71	80	225	305
Kabyle	16	13	29	26	47	73
M'zabite	17	25	42	34	208	242
Saanen	9	16	25	24	69	93
Alpine	15	17	32	34	71	105
Total	158	171	329	296	1077	1373

Body measurements

A series of six parameters were determined for each animal, as recommended by FAO (2013):

- Height at withers (WH, cm), measured as the distance from the ground to the withers;
- Circumference of the chest (CG, cm) was measured using a tailor's tape calibrated in cm, which was taken as the circumference of the body immediately behind the shoulder blades in a vertical plane, perpendicular to the long axis of the body;
- Abdominal circumference (AC, cm) measured using a rigid tape measure, around the body at the most bulging part of the abdomen;
- Body length (BL, cm) was measured using a rigid tape measure, measured as the distance from the point at the top behind the scapular to the base of the tail;
- Spiral circumference (SC, cm) measured using a rigid tape measure, measured from the tip of the sternum, middle of the right arm, middle of the back, one hand brace under the tip of the left hip, middle of the perineum;
- Body weight (BW, kg) was taken using the Salter hanging spring type scale and measured to the nearest 0.5 kg.

During body measurement, two assistants had made animals stand upright and restrained in such a way that their heads, necks and chest were stretched nearly straight.

Statistical analysis

Statistical analysis for body weight and morphometric measurements was carried out with R logiciel (R Core Team, 2013). Data collected were classified according to sex and age. Two age groups: Group 1 (aged less than 24 months) and Group 2 (aged more than 24 months) were used and the significant means were analyzed by one-way analysis of variance (ANOVA). The average means of the morphological traits were compared according to sex using Independent T-test. Pearson's coefficient of correlation was measured between body weight and morphometric measurements.

Prediction of live body weight using body measurements

In our study we tried to estimate the live weight of goats from the local population. Two methods of calculation were used:

- CREVAT formula $P = x.CG^3$ and
- Regression equations.

Formula studied using CREVAT formula

The CREVAT equation based on the chest circumferences (CG) measurement in cattle was used in the present analysis (Marcenac et al., 1980):

$BW = 80.CG^3$, so in goats the calculation is as follows:

$BW = x.CG^3$.

So a constant "x" was determined to define a specific formula for local goats, which is:

$X = BW/CG^3$

For more precision, we compared the live weight of the

goats obtained by the scale with that calculated by the two methods mentioned above.

According to the CREVAT method calculated according to the thoracic perimeter (Marcenac et al., 1980): $P = 80.CG^3$ in large animals such as cattle and horses.

The formula obtained was as follows: $P = x.CG^3$, then $x = P/CG^3$.

Estimating body weight by linear regression equations

The body measurement data we obtained were also used to estimate the live weight of the animals by determining biometric formula obtained from simple and multiple linear regression equations. The biometric formulas were determined using Excel 2010 software using simple and multiple linear regression methods for males and females separately and then for the entire population.

We considered the estimated weight as the dependent variable. The independent variables were: chest circumference, abdominal circumference, spiral circumference, height at withers and body length.

The different equations were compared on the basis of their coefficient of determination (R^2).

Simple linear regression: $Y = a + bX$;

Multiple linear regression: $Y = a + bX_1 + cX_2 + dX_3 + eX_4 + fX_5$,

Where:

Y = Dependent variable (estimated weight);

a = Intercept (value of the dependent variable when the independent value is equal to zero);

b,c,d,e,f = Regression coefficient associated with the independent variable;

X_1, X_2, X_3, X_4, X_5 = Independent variable (chest circumference, abdominal circumference, spiral circumference, height at withers, body length).

Results

Statistical description of live body weight (kg) and body measurements (cm) of goats

The various body measurements and live body weight vary significantly between the different goat breeds (Table 2). Alpine and Arabia goat breeds generally showed the highest values (41.60 kg and 37.67 kg, respectively), while Kabyle showed the lowest (29.52 kg). M'Zabite and Makatia have a weight very close to 35 kg.

The highest measurements of BW, AC, BL and SC were reported in Alpine – 66.99 cm, 97.73 cm, 78.05 cm and 106.29 cm, respectively. The highest value for CG was found in Arabia – 17.72 cm. On the other hand, the Kabyle breed was recorded with the lowest values for all body measurements with exception for AC, which value is the lowest in M'Zabite – 87.55 cm.

Table 2. Mean values (M) of measurements with standard error (SE) and coefficient of variation (CV) by breed

Variables		WH, cm	CG, cm	AC, cm	BL, cm	SC, cm	BW, kg
	M	69.99^{b}	17.24^{ab}	97.73^{a}	78.05^{a}	106.29^{a}	41.60^{a}
Alpine	SE	2.39	0.94	5.83	4.41	6.57	6.59
	CV, %	0.03	0.05	0.06	0.06	0.06	0.14
	M	65.11^{c}	16.82^{b}	88.28^{bc}	69.90^{d}	95.65^{c}	35.69^{c}
Makatia	SE	6.49	2.86	7.49	5.76	6.35	7.23
	CV, %	0.1	0.17	0.08	0.08	0.07	0.2
	M	71.07^{a}	17.72^{a}	88.46^{bc}	71.54^{c}	97.93^{b}	37.67^{b}
Arabia	SE	4.34	2.3	7.71	5.52	5.32	6.32
	CV, %	0.06	0.13	0.09	0.08	0.05	0.16
	M	64.95^{d}	13.52^{d}	89.72^{b}	67.58^{e}	94.01^{d}	29.52^{e}
Kabyle	SE	4.06	1.1	5.89	2.7	4.18	3.81
	CV, %	0.06	0.08	0.07	0.04	0.04	0.12
	M	68.95^{b}	16.39^{b}	87.95^{bc}	75.12^{b}	99.10^{b}	34.71^{d}
Saanen	SE	2.91	1.0	9.27	4.01	6.99	8.34
	CV, %	0.04	0.06	0.11	0.05	0.07	0.2
	M	66.76^{c}	15.45^{c}	87.55^{c}	71.81^{c}	95.48^{cd}	35.62^{c}
M'Zabite	SE	3.84	1.56	9.0	4.6	5.84	7.34
	CV, %	0.06	0.1	0.1	0.06	0.06	0.2

*Means in the same column with different lowercase letters indicate that there is a significant difference ($p<0.05$) between the breeds; WH- Height at withers, CG- Circumference of chest, AC- Abdominal circumference, BL- Body length, SC- Spiral circumference, BW- Body weight.

Correlations between body weight and linear body measurements

A significant positive correlation was observed between animal weights with all measurements performed (GC, AC, SC, WH and BL) ($p<0.001$) (Table 3). The highest relationship was illustrated between BW with CG ($r=0.922$), while the lowest correlation was equally reported between AC and WH ($r=0.483$).

Table 3. Coefficient of correlation between body weight and linear body measurements

	BL	WH	CG	AC	SC	BW
BL	1					
WH	0.677	1				
CG	0.747	0.680	1			
AC	0.566	0.483	0.753	1		
SC	0.793	0.711	0.852	0.759	1	
BW	0.804	0.721	0.922	0.759	0.891	1

*BL- Body length, WH- Height at withers, CG- Circumference of chest, AC- Abdominal circumference, SC- Spiral circumference, BW- Body weight

Predicted live body weights (kg) from body measurements (cm) of goats based on sex and age

The use of simple or multiple linear regression equations allowed us to estimate the weight of goats using one or more parameters. The weight of goats of the studied breeds, assessed according to the sex of the animals (males and females) and age categories (<24 months and >24 months) is presented in Tables 4 and 5.

Table 4. Simple regression analysis of live body weight on different body measurements according to gender and different age categories

Equations	Gender		Intercept	β1	R^2
WH	F	P1	-35.002	0.9812	0.850
		P2	-13.024	0.7324	0.850
	M	P1	-45.2019	1.1469	0.807
		P2	-44.8322	1.1945	0.836
CG	F	P1	-51.632	1.1227	0.950
		P2	-51.632	1.1227	0.967
	M	P1	-49.5547	1.099	0.967
		P2	-70.5425	1.3914	0.962
AC	F	P1	-14.919	0.5845	0.895
		P2	-14.919	0.5845	0.890
	M	P1	-42.6725	0.8952	0.884
		P2	-62.9938	1.1793	0.707
CS	F	P1	-54.655	0.9417	0.850
		P2	-54.655	0.9417	0.860
	M	P1	-46.2743	0.8497	0.930
		P2	-66.929	1.0951	0.874

*WH- Height at withers, CG- Circumference of chest, AC- Abdominal circumference, SC- Spiral circumference; F- Female, M- Male, P1- age < 24 months, P2- age > 24 months, R^2- Coefficient of determination.

Table 5. Multiple regression analysis of live body weight on different body measurements according to gender and different age categories

Equations	Gender		Intercept	β1	β2	β3	β4	β5	R^2
WH+BL	F	P1	-28.6475	0.3576	0.519	-	-	-	0.839
		P2	-40.7436	0.3574	0.747	-	-	-	0.798
	M	P1	-48.9391	0.6792	0.523	-	-	-	0.872
		P2	-62.5158	0.6269	0.808	-	-	-	0.868
WH+BL+CG	F	P1	-39.2888	-0.076	0.273	0.761	-	-	0.941
		P2	-63.5752	0.1391	0.305	0.878	-	-	0.915
	M	P1	-53.6829	0.0625	0.249	0.874	-	-	0.970
		P2	-79.5331	0.191	0.403	0.958	-	-	0.954
WH+BL+CG+AC	F	P1	-42.0297	-0.071	0.285	0.596	0.169	-	0.946
		P2	-67.0181	-0.154	0.306	0.721	0.166	-	0.925
	M	P1	-54.2001	0.0698	0.229	0.810	0.073	-	0.970
		P2	-92.4296	0.2663	0.332	0.807	0.272	-	0.962
WH+BL+CG+AC+SC	F	P1	-42.0754	-0.126	0.208	0.523	0.104	0.215	0.951
		P2	-70.3455	0.1038	0.220	0.625	0.104	0.267	0.952
	M	P1	-53.5429	0.027	0.192	0.736	0.018	0.161	0.972
		P2	-89.7860	0.0497	0.290	0.750	0.139	0.328	0.970

*WH- Height at withers, BL- Body length, CG- Circumference of chest, AC- Abdominal circumference, SC- Spiral circumference; F- Female, M- Male, P1- age ≤ 24 months, P2- age > 24 months, R^2- Coefficient of determination.

In the prediction of body weight, the simple regression analysis found all parameters (WH, BL, CG, AC and CS) to be significant ($p<0.001$) of which R^2 coefficient values varied between 0.707 and 0.967 (Table 4). The CG was reported as the most precise parameter to predict the body weight, of which the R^2 coefficient varied between 0.950 and 0.967.

The multiple regression analysis found all parameters to be significant ($p<0.001$) (WH, BL, CG, AC and CS) of which R^2 values varied between 0.798 and 0.972 (Table 5). The use of the five variables at the same time gives more precision for the

biometric formula of weight estimation compared to the different measurement performed. Indeed, R^2 coefficient values varied between 0.951 and 0.972 in both sexes and in both age categories P1 (age <24 months) and P2 (age >24 months) (Table 5).

The determination of a specific formula of body weight calculation for the goats studied

Based on the CREVAT method and formula of Marcenac et al. (1980) – $P = 80.CG^3$ for calculation of the live body weight of large animals (cattle and horses) we developed the formula for calculation of the live body weight in goats as follows:

$P = x.CG^3$ ($x = P/CG^3$) and $P = 75*CG$.

The results for x-values and the live body weight of the different breed goats – calculated by our formula – P = 75*CG and measured by weighing are presented in Table 6. The total average calculated x-value is x = 75.04±7.99 and the calculated and measured live body weight is 35.72±9.53 and 35.57±9.07, respectively. In all studied goat breeds, the live weight calculated by the formula is equal to or very close to the measured one. The results obtained give us reason to suggest the developed formula to be used for calculating the live weight of different breeds of goats only on the basis of chest circumference measurement.

Table 6. The x-value calculated and body weight corresponding

Variables		x-value	CG, cm	Body weight calculated, kg (P=75*CG)	Body weight measured, kg
Age	≤ 24 months	75.86±8.49	72.96±7.94	30.22±9.65	30.21±8.98
	>24 months	74.70±7.75	79.23±6.53	37.51±9.00	37.39±2.76
Sex	Female	74.75±7.92	77.06±6.79	34.69±8.21	32.50±2.86
	Male	76.75±8.19	79.49±10.75	40.04±14.63	39.72±15.70
Breed	Arabia	77.23±7.27	77.23±7.27	37.67±9.34	37.15±9.56
	Kabyle	74.45±8.99	73.34±5.86	29.52±5.87	30.13±6.83
	Makatia	74.61±7.77	75.98±7.81	35.69±9.08	36.00±9.71
	M'zabite	73.56±6.79	77.95±6.13	35.62±8.47	36.36±8.43
	Alpine	72.62±9.30	81.06 ±10.97	41.6±13.05	42.28±16.80
	Saanen	75.45±8.12	79.51±6 .56	34.71±8.04	34.05±9.12
Average		75.04±7.99	77.41±7.53	35.72±9.53	35.57±9.07

Discussion

Body weight measurement is essential in livestock breeding for any reproductive, feeding, vaccination and drug dosing program (Olawumi and Farinnako, 2017) and to make selection and slaughter decisions by farmers (Musa et al., 2012a). In our study, adult goats (aged over 24 months) were heavier than young goats (aged less than 24 months) (Table 2). This is normal, as the animal grows; its size and shape should increase with age (Semakula et al., 2010; Kabiraj et al., 2011). Therefore, if body weight increased with age, it indicates that the study population was healthy (Sam et al., 2016).

Males were found to be heavier than females because they are heavier at birth than females (Abd-Allah et al., 2019a). This has been reported elsewhere (Adeyinka and Mohammed, 2006a,b; Semakula et al. 2010; Abd-Allah et al., 2019a).

The correlation is one of the most common and most useful statistical tools that describe the degree of relationship between two variables (Zergaw et al., 2017). In this study, positive correlations were recorded between the different traits. Those correlations are related to the growth of the animals (Olawumi and Farinnako, 2017) and according to El-Labban (1999) those correlations could be the result of the pleiotropic effects of the genes and the linkage effects that operate on these traits.

High positive correlations were recorded in this survey between BW and morphometric measurements and the highest correlation was observed with CG (Table 3). Effectively, Bello and Adama (2012) reported that the presence of muscle and bone around the heart region was responsible for the relatively higher and positive relationship between BW and CG compared to other measures. Comparable results were reported by other authors (Adeyinka and Mohammed, 2006a,b; Zergaw et al., 2017).

Body weight is the most commonly used method of measuring body development in animals, but it is not easily measured in the field. This is due to the time and energy required to determine it (Oke and Ogbonnaya, 2011). Prediction of body weight based on body measurements is still the ideal solution. Simple and multiple linear regression equations have been used to predict body weight from different goat body measurements (Seifemichael et al., 2014). In our survey, the simple regression equations have shown significant findings of which CG was the best predictor of body weight compared to other morphometric measures (Table 4). This result is consistent with other studies (Yakubu et al., 2011; Musa et al., 2012b). Concerning multiple regression equations (Table 5), the high and positive association between estimated and measured body weight suggests that anyone or any combination will provide a good estimate of body weight in goats (Olawumi and Farinnako, 2017). The high correlation between predicted and actual live weight measurements justifies

the credibility of using these models to predict the live weight of goats in Algeria (Table 6).

Conclusion

Based on the results obtained it was found: (i) Body weight was positively and highly correlated with all body measurements (Height at withers - WH, Circumference of chest - CG, Abdominal circumference - AC and Spiral circumference - SC). (ii) Prediction equation for live weight is feasible using the CG to estimate body weight with reasonable precision. This therefore reduces the practical usefulness of using other body measures in conjunction with CG. (iii) The formula we developed using only chest circumference (P=75*CG) would be preferable and facilitates the estimation of live weight of goats.

References

Abd-Allah S, Salman F, Shoukry M, Abd-El Rahman H, Mohamed M and Abedo A, 2019a. Study of some morphological characteristics of boer goat raised in Egypt. Advances in Animal and Veterinary Sciences, 7, 888-897. http://dx.doi.org/10.17582/journal.aavs/2019/7.10.888.897.

Abd-Allah S, Abd-El Rahman HH, Shoukry MM, Mohamed MI, Salman FM and Abedo AA, 2019b. Some body measurements as a management tool for Shami goats raised in subtropical areas in Egypt. Bulletin of the National Research Centre, 43, 1-6.

Adeyinka IA and Mohammed ID, 2006a. Accuracy of body weight prediction in Nigerian Red Sokoto Goats raised in North Eastern Nigeria using linear body measurement. Pakistan Journal of Biological Sciences, 9, 2828-2830.

Adeyinka IA and Mohammed ID, 2006b. Relationship of live weight and linear body measurement in two breeds of goat of Northern Nigeria. Journal of Animal and Veterinary Advances, 5, 891-893.

Bello AA and Adama TZ, 2012. Studies on body weight and linear body measurements of castrates and non castrate Savannah Brown goats. Asian Journal of Animal Sciences, 6, 140-146.

Birteeb PT and Ozoje MO, 2012. Prediction of live body weight from linear body measurements of west African long-legged and west African dwarf sheep in northern Ghana. Online Journal of Animal and Feed Research, 2, 427-434.

Cam MA, Olfaz M and Soydan E, 2010. Possibilities of using morphometric characteristics as a tool for body weight prediction in Turkish hair goats (Kilkeci). Asian Journal of Animal and Veterinary Advances, 5, 52-59.

El-labban AFM, 1999. Comparative studies on phenotypic performance of body measurements and carcass characteristics in males of some local strains of chickens. Egyptian Poultry Science Journal, 19, 419-434.

Elmaz O, Dikmen S, Cirit U and Demir H, 2008**.** Prediction of postpubertal reproductive potential according to prepubertal body weight, testicular size, and testosterone concentration using multiple regression analysis in Kıvırcık Ram Lambs. Turkish Journal of Veterinary and Animal Sciences, 32, 335-343.

FAOSTAT, 2018. Statistics of Food and Agriculture Organization of the United Nations.
http://www.fao.org/faostat/fr/#data/QA. Accessed 2 Jan 2018.

Food and Agriculture Organization (FAO), 2013. Phenotypic characterization of animal genetic resources. FAO Guidelines on Animal Production and Health No. 11. Rome, Italy.

Hopker A, MacKay JRD, Pandey N, Hopker S, Saikia R, Pegu B and Sargison N, 2019. Weight estimation in native cross bred Assamese goats. Livestock Research for Rural Development, 31, 10.
http://www.lrrd.org/lrrd31/10/ahopk31162.html

Iqbal M, Javed K and Ahmad N, 2013, Prediction of body weight through body measurements in Beetal goats. Pakistan Journal of Science, 65, 458-461.

Kabiraj SK, Hoque SM, Kh MY and Husain SS, 2011. Testicular biometry and its relationship with body weight and semen output of black Bengal bucks in Bangladesh. Journal of Cell and Animal Biology, 5, 27-32.

Kumar S, Dahiya SP, Malik ZS and Patil CS, 2018. Prediction of body weight from linear body measurements in sheep. Indian Journal of Animal Sciences, 52, 1263-1266.

Madani T, Sahraoui H and Benmakhlouf H, 2015. Goat breeding in Algeria: Breeding systems, performances and mutations. In: National Workshop on "Valorization of local sheep and goat breeds with low numbers", INRA "Institut National de la Recherche Agronomique d'Algérie", Ministry of Agriculture, Rural Development and Fisheries, Algiers, Algeria, 2-3 March 2015 (F). https://drive.google.com/file/d/0Byq7HIXbht6eWGZWdE5lSm1XQzA/view.

Marcenac LN, Aublet H and D'autheville P, 1980. Comparative study of the regions proportions - hippometric compensations. In: Horse Encyclopedia (ed. A. Maloines), Paris, France, pp. 195-212 (F).

Oke UK and Ogbonnaya EO, 2011. Application of physical body traits in the assessment of breed and performance of WAD sheep in a humid tropical environment. Livestock Research for Rural Development, 23, 24.

Olawumi SO and Farinnako EA, 2017. Evaluation of the relationship between body weight and linear measurements in West African Dwarf Goat as influenced by sex and agro-vegetational zone in the Southwestern Region of Nigeria. International Journal of Veterinary Science and Animal Husbandry, 3, 006-012.

Ouchene-Khelifi NA, Ouchene N, Maftah A, Blondeau Da Silva A and Lafri M, 2015. Assessing admixture by multivariate analyses of phenotypic differentiation in the Algerian goat livestock. Tropical Animal Health and Production, 47, 1343-1350. https://doi.org/10.1007/s11250-015-0869-5.

Parés P-M, Mwaanga ES, Caballero M, Sabaté J and Valenzuela S, 2012. Live weight estimation of Gwembe goat (*Capra hircus*) from measurement of thoracic girth. J. Vet. Anat., 5(2), 9-14. https://core.ac.uk/download/pdf/70290083.pdf

R Core Team, 2013. A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org.

Ravimurugan T, Thiruvenkadan AK, Sudhakar K, Panneerselvam S and Elango A, 2013. The estimation of body weight from body measurements in Kilakarsal Sheep of Tamil Nadu India. Iranian Journal of Applied Animal Science, 3, 357-360.

Riva J, Rizzi R, Marelli S and Cavalchini G, 2002. Body Measurements in Bergamasca Sheep, Small Ruminant Research, 221-227.

Sam I, Ekpo J, Ukpanah U, Eyoh G and Warrie M, 2016. Relationship between linear body measurement and live body weight in West African Dwarf Goats in Obio Akpa. Journal of Biology, Agriculture and Healthcare, 6, 118-124.

Seifemichael M, Kefelegn K, Negassi A and Banerjee AK, 2014. Variability in linear body measurements and their application in predicting body weight of Afar goats in Ethiopia. International Journal of Interdisciplinary and Multidisciplinary Studies, 1, 17-25.

Semakula J, Mutetikka D, Kugonza RD and Mpairwe D, 2010. Variability in body morphometric measurements and their application in predicting live body weight of Mubende and Small East African goat breeds in Uganda. Middle East Journal of Scientific Research, 5, 98-105.

Tadesse A and Gebremariam T, 2010. Application of linear body measurements for live body weight estimation highland sheep in Tigray region, North-Ethiopia. Journal of the Drylands, 3, 203-207.

Waheed HM, Moaeen-ud-Din M, Khan MS, Saif-ur-Rehman M and Nawaz-ul-Rehman MS, 2020. Prediction of monthly body weight from body measurements in Beetal goats reared under field and farm conditions. Journal of Animal and Plant Sciences, 30, 25-31.

Wilson RT and Durkin JW, 1984. Age at permanent incisor eruption in indigenous goats and sheep in semi-arid Africa. Livestock Production Science, 11, 451-455.

Yakubu A, Ladokun AO and Adua MM, 2011. Bioprediction of body weight from zoometrical traits of non-descript goats using linear and non-linear models in North Central Nigeria. Livestock Research for Rural Development, 23, Article 130.

Yilmaz O, Cemal I and Karaca O, 2013. Estimation of mature live weight using some body measurements in Karya sheep. Tropical Animal Health and Production, 45, 397-403.

Zergaw N, Dessie T and Kebede K, 2017. Using morphometric traits for live body weight estimation and multivariate analysis in Central Highland and Woyto-Guji Goat Breeds, Ethiopia. African Journal of Agricultural Research, 12, 1326-1331.