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Application of linear body measurements for predicting live weight in Ouled Djellal breed

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ABSTRACT

The objective of this study was to predict the body weight of 66 females and 15 males Ouled Djellal breed aged over 2 years using fourteen simple linear body measurements and CREVAT formula. The total body length (TBDL), body length (BDL), scapular-ischial length (SIL), withers height (WH), heart girth (HG), chest depth (CD), paunch girth (PG), shoulder width (SW), hip-width (HW), trochanter width (TW), ischia width (IW), pelvis length (PL), cannon length (CL) and cannon perimeter (CP) were measured in centimeters, and body weight (BW) was determined in kilogram using a weighing scale. Results of the correlation coefficient showed that heart girth and the withers height were highly correlated with body weight (r = 0.93 and r =0.91 respectively), with variations by sex. Results of the stepwise regression showed that heart girth (HG), withers height (WH), scapular-ischiallength (SIL) and the cannon perimeter (CP) are the best prediction parameters of body weight in animals studied. From the CREVAT formula, the body weight was estimated by the HG (in meters): $BW = 57.9\ HG^3$. According to the different statistical methods used and the formula of CREVAT, we can conclude that body weight in Ouled Djellal breed can be estimated using simple linear body measurement of heart girth.

Key words: Algeria, Body measurements, Live weight, Ouled Djellal

Livestock farming based on local breeds constitutes a very valuable animal industry from the economic, social and environmental points of view. Local breeds have remarkable special characteristics like resistance to prevailing diseases, fertility, maternal ability, longevity, adaptation to the environment and unique attributes of their final products, among others (García 1980). Knowledge of phenotypic characteristics is important to the farmer, but especially for the veterinary. Indeed, the body measurements constitute the basis of the scoring table in a given breed; in addition, some of these measurements are supporting the estimation of body weight, which allows to monitor the growth and the development of the sheep, or to determine suitable medication dosage during health care and required feed amount of the animal (Kunene *et al.* 2009).

In sheep, the objective of body dimensions and measures of muscular development were shown to serve either to supplement body weight as a measure of productivity (Afolayan *et al.* 2002a,b) and condition of the animal as a selection criterion (Lawrence and Fowler 2002, Cam *et al.* 2010) to evaluate carcass yield (Iyeghe *et al.* 1996) or as predictors of some less visible characteristics (Gilbert *et al.* 1993).

It is also used for the selection of future females and males breeders for the purpose of genetic improvement in herds by the use of different methods of biotechnology on Ouled Djellal breed: cases of artificial insemination (Belkhiri *et al.* 2017) and embryonic transfer (Afri-Bouzebda 1985). Knowledge of the weight of ewes is necessary for the determination of PMSG and GNRH doses for a super ovulation program (Afri-Bouzebda *et al.* 2015) and for the health monitoring of postpartum ewes (Lamraoui *et al.* 2016).

The aim of the present paper was to estimate body weight based on a combination of body measurements using multiple regression method (stepwise) and the CREVAT formula in Ouled Djellal breed, to facilitate the determination of body weight in the case where farmers are challenged with the unavailability of weighing scale.

MATERIALS AND METHODS

Sheep samples: A total of 66 ewes and 15 rams with an age range between 2 and 6 years (3.35±0.85 years) of Ouled Djellal breed reared in highlands of Setif were used in the study. The number and tooth form were used to estimate the age of the animals.

Body measurements: The body weight (BW) and fourteen body measurements were measured for each animal before morning feeding to avoid abdominal swelling

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Table 1. Definition of the body measurements calculated for each Ouled Djellal individual

Measurement	Definition
Total body length (TBDL)	Distance from the head of the humerii to the distal end of the pubic bone
Body length (BDL)	Distance from the base of the tail to the base of the neck (first thoracic vertebra)
Scapular-ischial length (SIL)	Distance between the tip of the shoulder and the tip of the ischium
Withers height (WH)	Distance from the highest point of the processusspinalis of the vertebra thoracica to the ground
Heart girth (HG)	Measured as body circumference just behind the forelegs
Chest depth (CD)	Vertical distance from the top of the withers to the xyfoid process of the sternum
Paunch girth (PG)	Circumference of the body just a little behind the hypochondrium, in the most curved part of the body
Shoulder width (SW)	Measurement taken between the two heads of humerii
Hip width (HW)	Maximum distance between the outer edges of the major hip bones on the right and left side
Trochanter width (TW)	Distance between the two trochanters (hip joint)
Ischia width (IW)	Distance between both ischia
Pelvis length (PL)	Distance from point of hip to the tip of the ischiumorileo-ischial distance
Cannon perimeter (CP)	Perimeter of the right foreleg, between the knee and the pastern
Cannon length (CL)	Length of right metacarpus

due to excessive intake of water and feed. The animals were weighed by sheep weighing balance. The body measurements were taken through the sheep measuring scale (tape) and a homemade measuring rod with double bracket (Table 1).

Formula studied: In the present study, the method of CREVAT calculated using the thoracic perimeter (c) was used in cattle (Marcenac and Aublet 1980): $BW = 80.HG^3$, then, in sheep the formula is as follows: $BW = x.HG^3$. So to define a specific formula for local sheep, it a constant "x" was determined which is $x = BW/HG^3$.

Statistical analysis: To determine the correlation between body weight and different body measurements which can be used to estimate or calculate the live weight of Ouled Djellal breed animals; the various parameters studied were calculated and analyzed by several statistical methods, using the STATISTICA 7 software.

Descriptive statistics: To determine the mean and standard deviations of body weight and body measurements studied. ANOVA was used to determine the influence of sex on the parameters studied.

Correlation: Correlation coefficient was used to determine degree of the linear relationship between body weight and other continuous variables. A simple linear correlation was used when there is only one explanatory variable, simple matrix between body weight and body measurements. Correlation was calculated using the formula of Snedecor and Cochran (1981):

$$r_{xy} = \frac{(\sum xy - (\sum x)(\sum y)/n)}{\sqrt{(\sum x^2 - (\sum x)^2/n)(\sum y^2 - (\sum y)^2/n)}}$$

where r, correlation coefficient; x, first character; y, second character; n, total number of observations; Σ, sum of observations.

Multiple linear regression: A multiple linear regression was used when there is more than one predictor variable. This model was used to assess the relative contribution of body weight and different body measurements using the following equation (Snedecor and Cochran 1981):

Table 2. Descriptive statistics of body weight (kg) and body measurements (cm)

Measurement	Mean±SD			CV	P
	Male	Female	Total		
BW (kg)	100.47± 15.58	56.24± 6.28	64.43± 19.32	29.98	<0.001
TBDL (cm)	118.13± 8.82	104± 8.43	106.62± 10.09	9.46	<0.001
BDL (cm)	102.6± 6.79	84.89± 3.85	88.17± 8.25	9.35	<0.001
SIL (cm)	96± 6.00	80.83± 3.83	83.64± 7.30	8.73	<0.001
WH (cm)	93.47± 3.56	79.64± 2.22	82.20± 5.95	7.24	<0.001
HG (cm)	120.67± 6.14	99.02± 4.84	103.02± 9.86	9.57	<0.001
CD (cm)	42.67± 2.13	36.48± 1.98	37.63± 3.13	8.32	<0.001
PG (cm)	129.2± 9.27	108± 6.92	111.93± 11.07	9.89	<0.001
SW (cm)	27.4± 2.29	20.35± 1.28	21.65± 3.14	14.49	<0.001
HW (cm)	27.33± 2.41	21.73± 1.57	22.76± 2.80	12.29	<0.001
TW (cm)	30.13± 2.47	23.53± 1.55	24.75± 3.11	12.57	<0.001
IW (cm)	14.47± 1.88	11.85± 1.06	12.33± 1.60	13.01	<0.001
PL (cm)	33.33± 2.26	28.03± 2.13	29.01± 2.98	10.27	<0.001
CP (cm)	11.47± 0.64	8.91± 0.38	9.38± 1.09	11.62	<0.001
CL (cm)	13.93± 0.88	12.58± 0.86	12.83± 1.01	7.87	<0.001

BW, Body weight; TBDL, body length; BDL, body length; SIL, scapular-ischial length; WH, withers height; HG, heart girth; CD, chest depth; PG, paunch girth; SW, shoulder width; HW hip-width; TW, trochanter width; IW, ischia width; PL, pelvis length; CP, cannon perimeter; and CL, cannon length.

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + \cdots + b_nx_n$$

where Y is the dependent variable (body weight), Xs are independent variables (body measurements), a is the intercept coefficient on the y-axis, and b are coefficients related independent variables to predict the dependent variable.

Stepwise: The stepwise regression method was used to determine which linear body measurement or combination of measurements was a good estimator of the body weight of Ouled Djellal sheep (Draper and Smith 1981). The body weight (BW) as dependent variable and body measurements as independent variables were considered.

RESULTS AND DISCUSSION

Descriptive analysis and comparison: The mean (±SD) and coefficient of variation of each parameter studied in ewes and rams are shown in Table 2.

There are very highly significant differences (P<0.001) in all body measurements between rams and ewes of Ouled Djellal breed.

The influence of sex is significant (P<0.001); rams are heavy (BW), longer (TBD, BDL and SIL), wider (SW) and higher (WH) then ewes with a well-developed heart girth (HG, CD), more developed pelvis (HL, PL, TW and IW), a larger cannon perimeter and relatively long legs than ewes (Table 2).

Correlation between body weight and different body measurements: Results of the simple correlation coefficients of the linear measurements to one another and to the body weight of Ouled Djellal sheep breed are presented in Table 3.

The results showed that the live weight is strongly correlated with body measurements of the Ouled Djellal breed.

In this herd, the highest correlations (P<0.001) were observed between body weight and the heart girth (HG) (r=0.93, P<0.001), the withers height (WH) (r=0.91, P<0.001) and the paunch girth (PG) (r=0.89, P<0.001).

In rams Ouled Djellal, the heart girth (HG: r=0.78, P<0.001) and paunch girth (PG: r=0.77, P<0.001) were highly correlated with body weight. Chest depth (CD:r= 0.71, P<0.001), scapular-ischiallength (SIL: r=0.71, P<0.01) and body length (BL:r=0.68, P<0.01) also show significant positive correlations (P<0.01) with BW of rams however, no significant correlation was observed between the shoulder width (SW) and the hips width (HW) (P>0.05).

In ewes, the paunch girth (PG) is the most correlated measure of BW (r = 0.82, P<0.001), other measurements are strongly correlated with BW, they are respectively: the right chest circumference (HG: r = 0.70, P<0.001) and shoulder width (SW: r = 0.63, P<0.001).

The length of the pelvis (PL) and the total body length (TBL) also show very highly significant positive correlations with the BW (r = 0.45, P<0.001 and r = 0.43, P<0.001). The perimeter of the right cannon of the ewes Ouled Djellal shows a positive correlation (r = 0.36) significant (P<0.01) with the body weight.

Multiple linear regression analysis: Multiple linear regression was used to eliminate the effect of non-effective measurements in the live weight regression model. In this statistical analysis, live weight (BW) is considered a dependent variable and body measurements as independent variables. To determine the regression equation all variables were examined. Regression coefficients and the probability of the estimated variables in predicting the body weight of Ouled Djellal sheep are presented in Table 4.

The obtained results showed that the prediction model equation for body weight is formulated using the body measurements as follows:

BW = –153.98375 + 0.08TBDL + 0.17BDL + 0.35SIL + 0.49WH + 0.45HG + 0.07CD + 0.39PG + 0.01SW – 0.24HW + 0.54TW – 0.37IW + 0.67PL + 1.62 CP – 0.61CL

where, body weight (BW), body length (TBDL), body length (BDL), scapular-ischial length (SIL), withers height (WH), heart girth (HG), chest depth (CD), paunch girth (PG), shoulder width (SW), hip-width (HW), trochanter width (TW), ischia width (IW), pelvis length (PL), cannon perimeter (CP) and cannon length (CL).

In this model, the scapuloischial length (SIL), the heart girth (HG) and the paunch girth (PG) have a significant direct influence (P<0.05) on the BW (Table 4).

Stepwise multiple linear regression: To eliminate the measurements that do not have a significant direct influence on the latter, a Stepwise analysis was used in ewes, rams and in the whole herd. Stepwise multiple regression prediction of body weight from body measurements is presented in Table 5.

The results showed that the heart girth (HG), the withers height (WH), the paunch girth (PG), the scapular-ischial length (SIL) and the cannon perimeter (CP) have a

Table 3. Correlation coefficients showing interrelationships between various measurements of body weight of Ouled Djellal sheep breed

	Sex	TBDL	BDL	SIL	WH	HG	CD	PG	SW	HW	TW	IW	PL	CP	CL
PV	M	0.50	0.68**	0.71**	0.64*	0.78***	0.71**	0.77***	-0.03	0.28	0.19	0.37	0.55*	-0.01	0.10
	F	0.43***	0.32**	0.20	0.39**	0.70***	0.39**	0.82***	0.63***	0.08	0.37**	0.36**	0.45***	0.36**	0.16
	T	0.65***	0.87***	0.84***	0.91***	0.93***	0.82***	0.89***	0.85***	0.75***	0.81***	0.69***	0.76***	0.85***	0.52***

BW, Body weight; TBDL, body length; BDL, body length; SIL, scapular-ischial length; WH, withers height; HG, heart girth; CD, chest depth; PG, paunch girth; SW, shoulder width; HW hip-width; TW, trochanter width; IW, ischia width; PL, pelvis length; CP, cannon perimeter; and CL, cannon length. *Significant correlation at P<0.05, **Significant correlation at P<0.01, ***Significant correlation at P<0.001.

Table 4. The regression coefficient (b), standard error (SE), t-value and probability (P) of the estimated variables in predicting body weight by the multiple linear regression analysis

Variable	b	SE	t	P
TBDL	0.08746	0,09091	0.96	0.3396
BDL	0.17190	0.19344	0.89	0.3774
SIL	0.35434	0.15800	2.24	0.0283
WH	0.49411	0.35827	1.38	0.1725
HG	0.45438	0.21770	2.09	0.0407
CD	0.07193	0.45457	0.16	0.8747
PG	0.39146	0.16146	2.42	0.0181
SW	0.01105	0.49080	0.02	0.9821
HW	–0.24720	0.41857	–0.59	0.5568
TW	0.54308	0.39356	1.38	0.1723
IW	–0.37844	0.60780	–0.62	0.5357
PL	0.67806	0.34556	1.96	0.0540
CP	1.62000	1.39626	1.16	0.2501
CL	–0.61673	0.83209	–0.74	0.4612

Intercept = –153.98375. R^2=0.9336; R^2 Adj= 0.9195.

significant influence on body weight, of which the heart girth (HG) and the withers height (WH) are the best measurements (P<0.001) to determine the body weight of the animals studied (Table 5)

The multiple linear regression and stepwise showed that the right Heart girth (HG) is the only parameter that determines BW in rams. In ewes, however, the paunch girth (PG) is the best criterion for estimating BW, shoulder width (SW), pelvis length (PL), and trochanter width (TW) have a significant direct effect on body weight. The other variables were not included in the model because of their relatively low contribution. Therefore, the last step of the regression model, equation for predicting the body weight obtained is presented on Table 6.

Determination of the body weight according the formula of CREVAT: The formula of CREVAT: BW = x.HG^3 (Marcenac and Aublet 1980) was used to estimate the body weight of the sheep. Modern authors have criticized QUETELET for his mathematical reasoning in an imperfect cylinder, and CREVAT for his empiricism; they sought to develop more precise formulas which take into account,

Table 6. Multiple linear regression of body weight with body measurements

Sex	Regression equation
Flock	BW = –158.73 + 0.39HG*** + 0.81WH*** + 0.50PG*** + 0.43SIL* + 2.37CP*
Ram	BW = –138.04 + 1.97HG***
Ewe	BW = –52.08 + 0.56PG*** + 0.98SW* + 0.52PL* + 0.55TW*

BW, Body weight; TBDL, body length; BDL, body length; SIL, scapular-ischial length; WH, withers height; HG, heart girth; CD, chest depth; PG, paunch girth; SW, shoulder width; HW hip-width; TW, trochanter width; IW, ischia width; PL, pelvis length; CP, cannon perimeter; and CL, cannon length. *P<0.05; **P<0.01 ; ***P<0.001.

among others, changes in the ratio between heart girth and body weight by age and sex.

According to the method of CREVAT, the formula obtained was as follows: BW = x*HG^3 where x = BW/HG^3. HG (in meters).

The body weight of Ouled Djellal sheep is obtained by the following formula: BW=57.9*HG^3.

There are many studies on estimation of body weight from body measurements in different breeds of sheep worldwide (Cam *et al.* 2010, Khaldi *et al.* 2011, Amare *et al.* 2012, Pérez-Cabal *et al.* 2013, Younas *et al.* 2013, Yakubu *et al.* 2005, Yakubu 2010, 2012, 2013). However, the results for this type of study on Algerian sheep appear to be rare (Dekhili and Aggoun 2013).

In this study we presented the different statistical methods used to see the measurements that can be used to estimate weight in the absence of the scale. Result on Table 3 showed that all the linear measurements were highly correlated with body weight of Ouled Djellal sheep (P<0.001). Similar results were reported by other researchers (Topal and Macit 2004, Atta and Elkhidir 2004, Yakubu *et al.* 2005, Afolayan *et al.* 2006, Cam *et al.* 2010, Mmereole and Obinne 2010, Yakubu 2012).

The highest correlations (P<0.001) were observed between body weight and the heart girth (HG) (Dekhili and Aggoun 2013), the withers height (WH) and the paunch

Table 5. Relative contribution (partial and model R^2). Regression coefficient (b), standard error (SE) and probability (P) in predicting body weight by the stepwise procedure analysis

Sex	Step	Variable entered	Partial R^2	Model R^2	b	SE	P
Male	1	HG	0.6064	0.6064	1.97661	0.44170	0.0006
Female	1	PG	0.6669	0.6669	0.56061	0.06868	<0.0001
	2	SW	0.0558	0.7228	0.98664	0.38060	0.0119
	3	PL	0.0216	0.7443	0.52353	0.20300	0.0123
	4	TW	0.0167	0.7610	0.55364	0.26832	0.0433
Flock	1	HG	0.8584	0.8584	0.39600	0.20553	<0.0001
	2	WH	0.0375	0.8959	0.81655	0.26886	<0.0001
	3	PG	0.0161	0.9120	0.50528	0.14359	0.0003
	4	SIL	0.0098	0.9218	0.43513	0.14614	0.0029
	5	CP	0.0043	0.9261	2.37742	1.13852	0.0402

Intercept M= -138.04450. Intercept F= -52.08208. Intercept troupeau = -158.73958

Table 7. Body weight according to the formulas

	Flock	Ram	Ewe
x	57.90±6.27	56.96±6.16	58.12±6.32
HG (m)	1.03	1.20	0.99
BW= x*HG^3 (kg)	63.27	98.43	56.39
BW (kg)	64.43±19.32	100.47±15.58	56.24±6.28

girth (PG) (Djaout *et al.* 2012).The relationship between body measurements and body weight depends on the species, breed, age, size, sex, body condition score of animals (Heinrichs *et al.* 1992, Yanar *et al.* 1995, Afolayan *et al.* 2006) and type of lambing of ewes (Tabbaa 2003).

In rams Ouled Djellal, the heart girth (HG) (Yakubu 2012) and paunch girth (PG) were highly correlated with body weight. Thus, highly significant positive correlations between the HG and BW were reported by Cam *et al.* (2010), Mmereole and Obinne (2010), Yakubu (2012). Chest depth (CD), scapular-ischiallength (SIL) and body length (BL) are positively correlated to BW. However, no significant correlation was observed between the Shoulder width (SW) and the hips width (HW) (P>0.05) unlike to Yakubu (2012) in Uda breed where the HW showed a significant positive correlation (P<0.001).

The paunch girth is practically no longer used because it can cause errors (excessive drinking, pregnant females) despite having a strong positive correlation with BW (Djaout *et al.* 2012). Khan *et al.* (2006) indicate that the body measurement which has a highest correlation with the body weight of the animal can be used as a selection criterion in traditional production systems in rural areas. For this reason, the hearth girth (HG) alone was a good estimator on body weight in Ouled Djellal breed and can be used in both rams and ewes. This is confirmed by the different statistical models studied (Stepwise and the linear regression equation). Heinrichs *et al.* (1992) suggested that some body measurements such as height at withers and the hips width can be the best skeletal parameters because they are not influenced by body condition. Besides, the thoracic perimeter is the most convenient method for use in field conditions; this measurement is fast and requires minimal manipulation (Suhailan *et al.* 2013). Cannon perimeter (CP) of Ouled Djellal ewes showed a significant positive correlation (r = 0.36) (P<0.01) with body weight, while Cam *et al.* (2010) showed no significant relationship (P>0.05) between the CP and the BW in Yankasa females unlike males (P<0.001).

According to Cam *et al.* (2010), Mmereole *et al.* (2010), Musa *et al.* (2012), Yakubu (2012), Suhailan *et al.* (2013), the heart girth (HG) is the most related to the body weight.

The formula of CREVAT obtained is BW = 57.9 * HG^3, it has a constant (x) higher than that calculated in the ewes of local population (x = 50.76) in the region of Setif (Djaout *et al.* 2012).

Several statistical models were used to study the variation and the relationship between body weight and body measurements of ewes and rams of Ouled Djellal breed. It can be concluded that the body weight can be estimated by a simple linear body measurement: the right heart girth (HG), this was confirmed by the formula of CREVAT: BW = 57.9 * HG^3.

Consequently, the withers height (WH), the scapuloischial length (SIL), and the canon perimeter (CP) can be used as a predictor of BW, while in females the shoulders width (SW), the pelvis length (PL) and the trochanter width (TW) are the criteria taken into consideration.

In addition, the multiple statistical procedures that were used in this study showed that simple correlation cannot distinguish the important variables that determine live weight, the final judgment cannot be made on the basis of this method as such it is necessary to use multivariate statistical methods for determining live weight.

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