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Statistical Models based on Morphometric Traits for the Prediction of Body Weight of Algerian Sahrawi Dromedaries

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Abstract: The objective of this work is to study the morphometric profile and determine the mathematical models that will be used for the estimation of live weight of adult dromedaries based on body measurements using multiple regression models. We took thirteen body measurements and live weight of 150 adult dromedaries (27 males and 123 females) selected in three different geographical regions of South-East Algeria. Multiple linear regression models were proposed using some body measurements to predict the live weight of dromedaries. The results show that in the separate male model the R^2 and CCC of Lin increased compared to the general model. The R^2 values were 95% for males against 84.1% in the general model. The CCC of Lin in the general model was 91.4% while it was 97.6% for males in the separate model. However, the female separate model shows that R^2 and CCC of Lin decreased compared to the general model. The R^2 values were 76% for females while 84.1% in the general model. The CCC of Lin in the general model was 91.4% while it was 86% for females in the separate model. It is suggested to use the general model to estimate the body weight of female dromedaries and the separate model for male dromedaries. This study demonstrates that the live weight of the Sahrawi breed can be estimated with a high degree of accuracy using some body measurements and statistical methods, after checking the variance inflation factor to eliminate error rates.

Keywords: Body measurement, Prediction, Sahrawi camel, Statistical models, Weight.

1. Introduction

Camels (*Camelus dromedarius*), since their domestication, are renowned for their production of quality milk, meat and fibre (Cherifi et al., 2013; Volpato and Howard, 2014; YEl Badawi, 2018; Gebremichael et al., 2019; Wilson, 2020a). Camel activity has always contributed to meeting the needs of a pastoral population (Cherifi et al., 2013). This activity very often takes place in the vast expanses of the Saharan rangelands. Indeed, if the desert man was able to survive in an environment where living conditions are extremely difficult, it is thanks to this desert vessel given its particular adaptations (Adamou, 2008; Alary et al., 2021). These are extremely important species as sustainable species with specific attributes (milk composition, immune genes and health) (Burger, 2016; Abrhaley and Leta, 2018; Orazov et al., 2021; Anwar et al., 2022; Gherissi and Gaouar, 2022; Gaouar and Ciani, 2023). The animals are robust and resistant to drought and the ability to cope with certain climatic stresses and shocks (Watson et al., 2016; Robert, 2018). The extent of phenotypic variation is important in the selection and use of different camel populations in breeding programs based on their specific characteristics and body conformation (Bekele et al., 2018; Gherissi et al., 2022; Dich et al., 2023). Body measurement characteristics such as weight, height, length, and width play an important role in assessing the value of camel productivity and economics (Alary et al., 2021; Dich et al., 2022). Several methods are used to analyse data in various breeding contexts to predict the weight of the animal, which is considered an important trait for selection (Çelik and Yilmaz, 2018). For body weight estimation using certain body measurements, the method employed is based on multiple linear regression, as utilized in dog breeds, including Zağar, Zerdava, and Çatalburun dogs raised in Turkey (Özkul et al., 2021), and in other animal species such as camels and sheep (Yilmaz et al., 2013; Meghelli et al., 2020; Haddam et al., 2024b). The objective of this study is to develop mathematical models to predict the weight of dromedaries according to sex.

2. Material and Methods

The study was carried out in three wilayas in southeastern Algeria, the wilayas of Ghardaïa, Ouargla and El-Oued (Figure 1). The animal material of the present study consisted of 150 Sahraoui dromedary breed (27 Males and 123 Females) all adults, in good health and neither in the reproductive period, in gestation or lactating. the distribution of animals is as follows: 16 Males from Ouargla, 2 from Ghardaïa and 9 from El Oued, 68 females from Ouargla, 24 from Ghardaïa and 31 from El Oued.

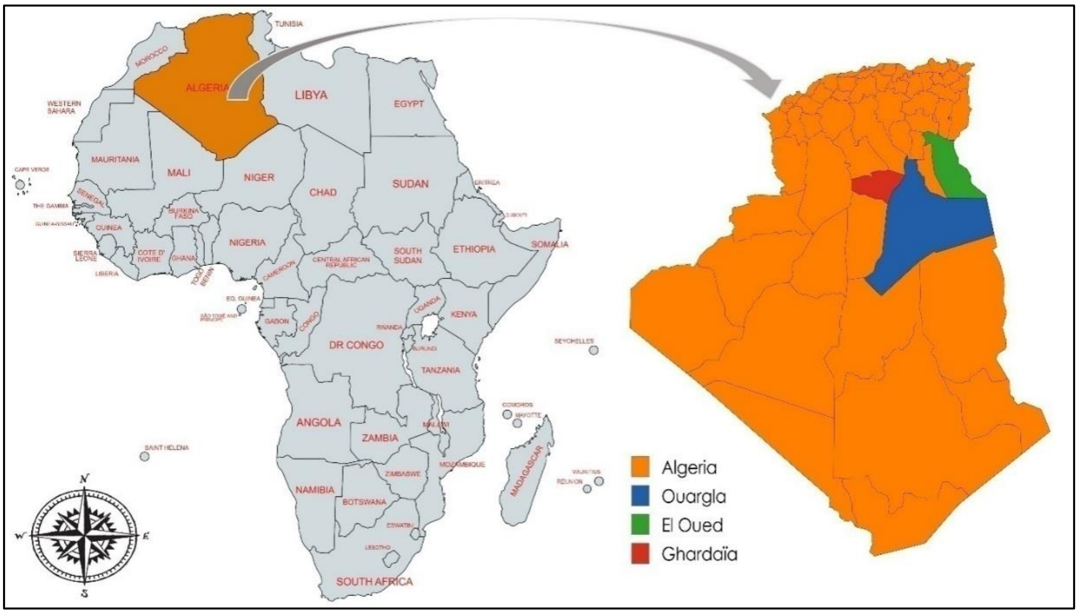

Figure 1: Location of Algeria and sampling areas

Thirteen body measurements were used (Figure 2), HW: height at withers, LHL: length of hind limbs, HH: height at hump, CG: chest girth, BL: body length, TL: tail length, NL: neck length, NG: neck girth, UHL: upper head length, DHL: down head length, HG: head girth, EL: ears length, TG: Thigh girth in centimetre (cm) and LW: live weight in kilogram (kg). The formula of (Mud 1949) was used to estimate live body weight as follow: LW = 53*HW*CG*AG (the three body measurements were used in meter).

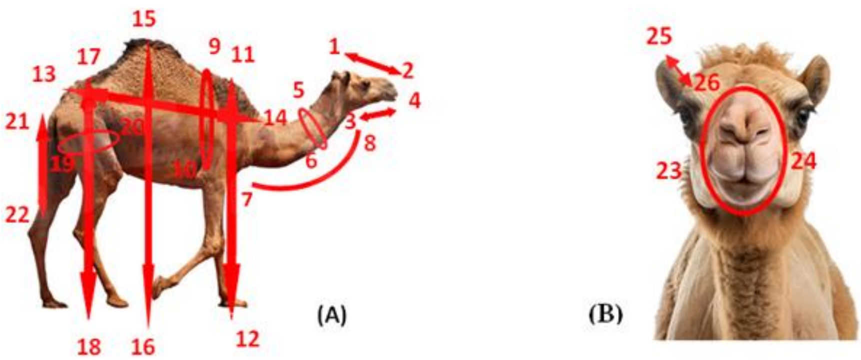

Figure 2: Measured body (A) and head properties (B).

1-2: Upper head length (UHL), 3-4: Down head length (DHL), 5-6: Neck girth (NG) , 7-8: Neck length (NL), 9-10: Chest girth (CG), 11-12: Height at withers (HW), 13-14: Body length (BL), 15-16: Height at hump (HH), 17-18: Length of hind limbs (LHL), 19-20: Thigh girth (TG), 21-22: Tail length (TL), 23-24: Head girth (HG), 25-26: Ears length (EL).

All the analyses in this study have been carried out using R software 4.3.1 version for Windows. First, the normality of the data was checked using Kolmogorov-Smirnov (KS) test. The results of this analysis showed that the data for all the measured characteristics were normally distributed. Afterwards descriptive statistics of the population were made and a t-test was used to evaluate the difference between males and females for all the used variables. Backward stepwise multiple linear regression using several packages in R was used to estimate the live weights of the studied population of Sahraoui dromedary using some body measurements, the estimation's equations for live weights were obtained with multiple linear regression analysis using some body measurements according to sex groups (separated models) and stepwise multiple regression. After that, Dubin-Watson test has been used to detect the presence of autocorrelation in the residuals (prediction errors) from the regression analysis, tolerance and variation inflation factor (VIF) have been checked for each model. Finally, Lin's Concordance Correlation Coefficient has been used to check the accuracy of each predictive model.

3. Results and discussion

Descriptive statistics belonging to the studied body measurements in Sahraoui dromedary breed are reported in Table 1.

Table 1: Descriptive statistics of the studied population of Sahraoui dromedary breed

Variable	N	Mean	Sd	Minimum	Maximum	Se	Cv
HW	150	184.28	12.6	160.00	220.00	1.03	6.84
LHL	150	174.92	12.03	150.00	208.00	0.98	6.88
HH	150	207.79	15.42	175.00	250.00	1.26	7.42
CG	150	185.5	16.64	149.00	236.00	1.36	8.97
BL	150	150.45	9.55	125.00	180.00	0.78	6.35
TL	150	52.95	6.98	40.00	80.00	0.57	13.18
NL	150	99.01	13.04	65.00	152.00	1.06	13.17
NG	150	71.34	7.99	50.00	97.00	0.65	11.20
UHL	150	50.43	5.43	39.00	71.00	0.44	10.77
DHL	150	45.54	5.36	35.00	66.00	0.44	11.77
HG	150	57.3	7.19	34.00	77.00	0.59	12.55
EL	150	10.76	1.02	8.00	13.00	0.08	9.48
TG	150	84.98	10.18	66.00	115.00	0.83	11.98
LW	150	323.98	72.35	202.88	546.35	5.91	22.33

HW: height at withers, LHL: length of hind limbs, HH: height at hump, CG: chest girth, BL: body length, TL: tail length, NL: neck length, NG: neck girth, UHL: upper head length, DHL: down head length, HG: head girth, EL: ears length, TG: Thigh girth, LW: live weight, N: number of samples, Sd: standard deviation, Se: standard error, Cv: coefficient of variation.

The results of descriptive statistics of the studied population (Table 1) reveal that the average height at withers is 184.28 cm, with a range from 160 to 220 cm. The length of hind limbs average is 174.92 cm with a standard deviation of 12.03. It is clear that the hump is higher than the withers with an average of 207.79 cm and with a range from 175 to 250 cm.The average chest girth is 185.5 cm with a standard deviation of 16.64 cm. The average body length is 150.45 cm, with a range of 125 to 180 cm. The average tail length is 52.95 cm, with a standard deviation of 6.98 cm. The average neck length of dromedaries reaches 99.01 cm, with a range of 65 to 152 cm. It is clear that the neck girth is less developed than the thigh girth with an average of 71.34 cm and a standard deviation of 7.99 cm. The average upper head length is 50.43 cm, with a range of 39 to 71 cm. The average down head length is 45.54 cm with a standard deviation of

5.36. The head girth averaged 57.3 cm, with a range of 34 to 77 cm. The ear length averaged 10.76 cm with a standard deviation of 1.02 cm. It is clear that the thigh girth was larger than the head girth with a mean of 84.98 cm and a range of 66 to 115 cm. The live weight averaged 323.98 kg, with a standard deviation of 72.35. The highest coefficient of variation was observed for live weight (22.33 kg), while the lowest was recorded for body length (6.35 cm). Adnane and Zohir (1990) also showed that live weight varies depending on the feeding program, environmental and health conditions. The standard deviation value for ear length (EL, SD= 1.02) shows little dispersion compared to live weight (LW, SD= 72.35), suggesting that ear length is not affected by environmental conditions as live weight.

Results of effect of sex in body measurements in the studied population are presented in Table 2.

Table 2: Impact of sex on body measurements in Sahraoui dromedary breed

Variable	**Males (N = 27)**	**Females (N = 123)**	**Significance**
	Mean±SD	**Mean±SD**	
HW	200.96±14.78	180.62±8.50	***
LHL	191.00±14.73	171.39±7.80	***
HH	230.67±17.41	202.76±9.19	***
CG	202.81±18.04	181.70±13.70	***
BL	156.00±10.63	149.23±8.89	**
TL	61.89±9.52	50.98±4.31	***
NL	109.07±21.46	96.80±9.06	**
NG	81.74±8.15	69.06±5.89	***
UHL	55.19±6.20	49.39±4.67	***
DHL	50.19±5.96	44.52±4.66	***
HG	63.78±8.56	55.88±6.02	***
EL	11.15±1.03	10.67±1.00	*
TG	101.37±9.02	81.38±6.06	***
LW	409.06±83.07	305.30±54.48	***

HW: height at withers, LHL: length of hind limbs, HH: height at hump, CG: chest girth, BL: body length, TL: tail length, NL: neck length, NG: neck girth, UHL: upper head length, DHL: down head length, HG: head girth, EL: ears length, TG: Thigh girth, LW: live weight, N: number of samples, Sd: standard deviation, *: $p<0.05$, **: $p<0.01$, ***: $p<0.001$.

Camel sex had a significant impact on all camel body measurements: HW, LHL, HH, CG, TL, LC, UHL, DHL, HG, TG, LW, ($p<0.001$) as well as BL, NL ($P <0.01$) and EL ($p<0.05$) (Table 2). The large standard deviation value noted in neck length in males (NL= 109.07±21.46) compared to females (NL= 96.80±9.06) could suggest differences in the way these animals use their necks in different ecological or behavioural contexts. In general, males are larger and heavier than females by all measurements. These results are similar to those mentioned by Dioli et al. (1992), Mehari et al. (2007), Amir et al. (2015), Meghilli et al. (2020), Dich et al. (2023), who stated that male camels are generally larger and heavier than females. The higher values of measured parameters by sex could be due to physiological, morphological factors and the activities of different sexes (Meghilli et al. 2020).

Phenotypic correlation coefficients between weight and body characteristics are presented in (Figure 3).

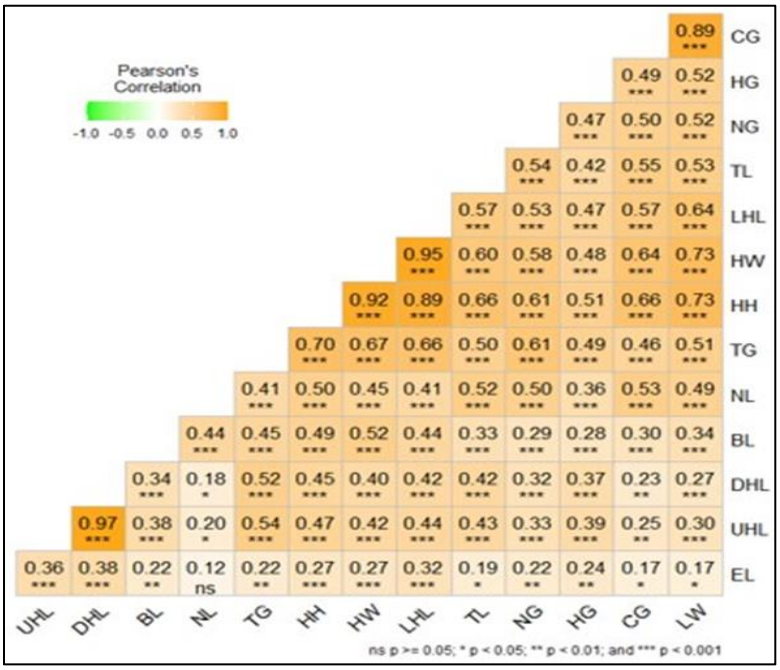

Figure 3: Phenotypic correlation coefficients between live weight and body measurements in the studied population of Sahraoui dromedary breed

In the overall evaluation of Figure 3, which presents the phenotypic correlation coefficients between live weight and body measurements in the studied population of camels of the Sahraoui breed, it can be affirmed that there is no negative correlation among the studied parameters. The highest correlation coefficient was between live weight and CG, HW and HH with R-values of (0.89, 0.73, 0.73) respectively.

Statistical models for body weight estimation in the studied population of Sahraoui dromedary breed using stepwise regression analysis are presented in (Table 3).

Table 3: Weight estimation models of the studied population of Sahraoui dromedary breed according to stepwise regression analysis

Population	Models	$\hat{\beta}_i$			R^2	p-value
		$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$		
All	$\hat{y}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_4$	-397.810	3.891		0.800	***
	$\hat{y}_2 = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_4$	-543.791	1.536	3.152	0.841	***

$\hat{y}_i$: model, x_1= Height at withers (HW), x_4= Chest girth (CG), $\hat{\beta}_0$= Constant, β_i= Regression coefficient, R^2= Adjusted estimation power, p= probability.

Estimation of live weight equations was developed using two stepwise regression models. These regression models and the estimation power (R^2) were presented in Table 3. The first model ($\hat{y}_1$) uses only chest girth (CG) to predict weight with a constant of -397.810, a regression coefficient of 3.891, an R^2 of 0.800 and a p-value (<0.001), while the second ($\hat{y}_2$)includes both height at withers (HW) and chest girth (CG) with a constant of -543.791 and regression coefficients of 1.536 and 3.152 respectively, the R^2 had a value of 0.841 and the p-value (<0.001). The estimation power values (R^2) obtained from the regression models showed that the two developed models can be used to estimate live weight (the $\hat{y}_1$ two-variable model shows a slight improvement compared to the $\hat{y}_1$single-variable model). Both live weight equation models contained chest girth. This situation indicated that chest girth was the most important measurement for estimating live weight (Meghilli et al. 2020).

In order to check the presence of autocorrelation between the two predictive variables of the second model ($\hat{y}_2$) obtained by stepwise regression analysis, Durbin-Watson Statistic was used and the results are presented in the Table 4.

Table 4: Autocorrelation checking of the second model obtained in Sahraoui dromedary population according to stepwise regression analysis

Group	IV	RC±SE	p-value	Tol	VIF	DWS	p-value
	Intercept	-543.791 ± 35.094	***	--	--		
All	HW	1.536 ± 0.243	***	0.633	1.577	2.033	ns
	CG	3.152 ± 0.184	***	0.633	1.577		

IV: independent variable, RC: regression coefficient, SE: standard error, Tol: tolerance, VIF: variance inflation factor, DWS: Durbin-Watson statistics, p: probability, HW: height at withers, CG: chest girth, ns: not significant, ***: p<0.001.

According to the results of (Table 4) we can notice that all of Intercept, HW and CG were highly significant for body weight estimation with a tolerance and a variance inflation factor of 0.633 and 1.577 respectively. Durbin-Watson Statistic showed that there was no autocorrelation in the obtained model despite the fact that the Pearson correlation between HW and CG was very highly significant (Figure 3).

The DWS value was 2.033 and the p-value was (>0.05) according to the results of (Table 4). In order to check the concordance between calculated live weight (Formula) and estimated live weight of the studied population of Sahraoui dromedary breed, Lin's concordance correlation coefficient was calculated and the relation between calculated live weight and estimated live weight is represented by the Figure 4. The results reported in (Figure 4) showed that The Lin's CCC value was 0.914 (91.4%) which is considered as a moderate value according to McBride (2005) (who considers >0.90 is poor, between 0.90 and 0.95 is moderate, between 0.95 and 0.99 is very good and above 0.99 is excellent).

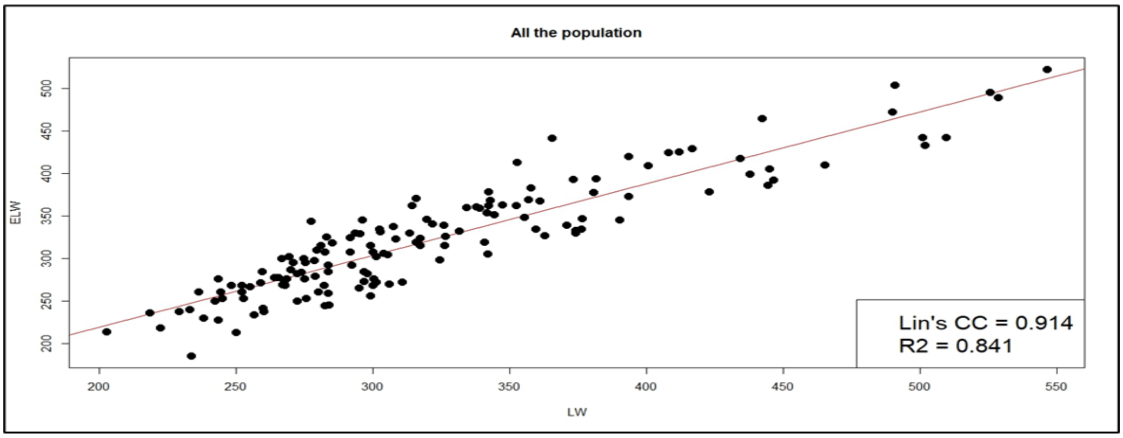

Figure 4: Concordance correlation coefficient of observed vs predicted live weight in all the population of Sahraoui dromedary breed

Phenotypic correlation coefficients between live weight and body measurements were calculated separately for each sex to provide a more accurate approach to estimating body weight from body measurements (Figure 5). In males, a strong correlation was recorded between live weight and CG, NL and TL with R values of (0.94, 0.78, 0.66) respectively ($p<0.001$). On the other hand, in females, a strong correlation was observed between live weight and CG with a value R=0.83 ($p<0.001$). The strong positive correlation between LW and CG is notable in both sexes. The phenotypic correlation coefficients obtained indicate that chest girth (CG) can be used as a reliable predictive indicator to estimate the live weight of camels. These results are similar to those mentioned by Meghilli et al. (2020).

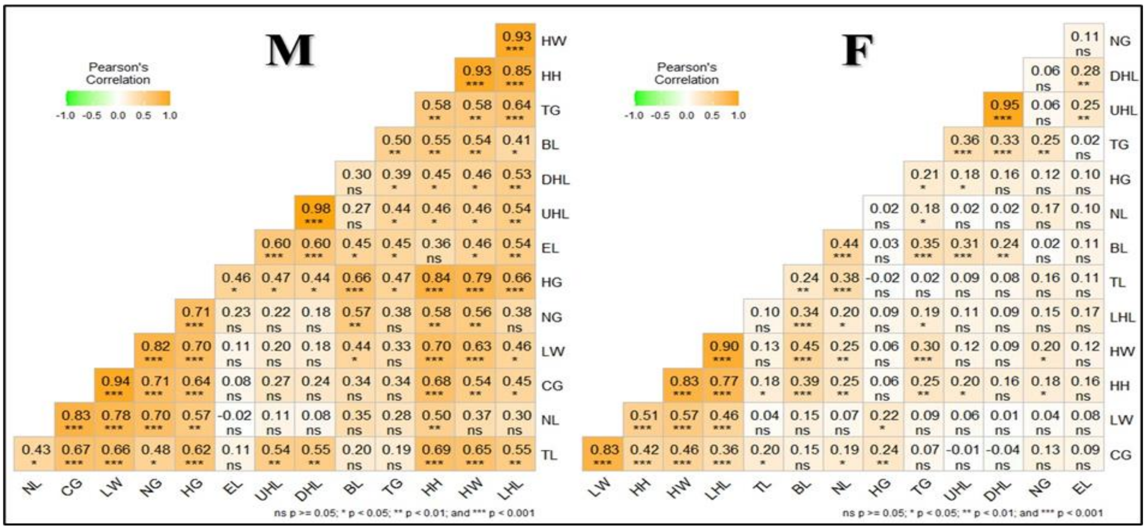

Figure 5: Phenotypic correlation coefficients between live weight and body measurements in males (M) and females (F) Sahraoui dromedary breed

In the separate model, estimation of live weight equations was developed using three stepwise regression models for males and four models for females. These regression models and the power of estimation (R^2) were presented in Table 5.

Table 5: Weight estimation models of males and female's Sahraoui dromedary breed (separate models) according to stepwise regression analysis

Sex	Models	$\hat{\beta}_i$					R^2	*p*-value
		$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$		
M	$\hat{y}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_4$	-466.309	4.316				0.873	***
	$\hat{y}_2 = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_4$	-574.632	0.973	3.885			0.891	***
	$\hat{y}_3 = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \hat{\beta}_3 x_4$	-541.858	4.585	-3.711	3.639		0.950	***
F	$\hat{y}_1 = \hat{\beta}_0 + \hat{\beta}_1 x_4$	-293.083	3.293				0.683	***
	$\hat{y}_2 = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_4$	-485.629	1.499	2.862			0.725	***
	$\hat{y}_3 = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_4 + \hat{\beta}_3 x_6$	-422.199	1.545	2.960	-1.756		0.741	***
	$\hat{y}_4 = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 x_4 + \hat{\beta}_3 x_6 + \hat{\beta}_4 x_7$	-411.022	1.669	2.974	-1.319	-0.602	0.760	***

x_1= Height at withers (HW), x_2: Length of hind limbs (LHL), x_4= Chest girth (CG), x_6: Tail length (TL), x_7: Neck length (NL),$\hat{\beta}_0$= Constant, β_i= Regression coefficient, R^2= Adjusted estimation power, M= Males, F= Females, p= probability.

For males, the first model ($\hat{y}_1$) uses only chest girth (CG) to predict weight with a constant of -466.309, a regression coefficient of 4.316, an R^2 of 0.873 and a p-value (< 0.001), while the second ($\hat{y}_2$) includes both height at withers (HW) and chest girth (CG) with a constant of -574.632 and regression coefficients of 0.973 and 3.885 respectively, an R^2 of 0.891 and a p-value (< 0.001). The last model ($\hat{y}_3$) uses height at withers (HW), length of hind limbs (LHL) and chest girth (CG), with a constant of -541.858 and regression coefficients of 4.585, -3.711 and 3.639 respectively, an R^2 of 0.950 and a p-value (< 0.001). However, for females, the first model ($\hat{y}_1$) uses only chest girth (CG) to estimate live weight with a constant of -293.083, a regression coefficient of 3.293, an R^2 of 0.683 and a p-value (< 0.001), while the second ($\hat{y}_2$) includes both height at withers (HW) and chest girth (CG) with a constant of -485.629 and regression coefficients of 1.499 and 2.862 respectively, an R^2 of 0.725 and a p-value (< 0.001), the third model ($\hat{y}_3$) uses height at withers (HW), chest girth (CG) and tail length (TL) with a constant of -422.199 and regression coefficients of 1.545, 2.960 and -1.756 respectively, an R^2 of 0.741 and a p-value (< 0.001). The last model includes height at withers (HW), chest girth (CG), tail length (TL) and neck length (NL) with a constant of -411.022 and regression coefficients of 1.669, 2.974, -1.319 and -0.602 respectively, an R^2 of 0.760 and a p-value (< 0.001). The analysis of the R^2 values revealed that the highest value was obtained from the third model in males and the fourth model in females. It was indicated that CG with HW and LHL could be used in a regression model for Saharawi males. On the other hand, CG with HW, TL and NL could be used in regression models for females of the same breed. The use of multiple regression models in other mammals, such as the Karya sheep, showed that the highest coefficients of determination (R^2) were obtained from models including body length or body length and chest girth together (R^2=0.79, R^2=0.87), so that live weight in Karya sheep could be estimated with high accuracy (Yilmaz et al., 2013; Haddam et al., 2024b). In dromedaries, live weight models with chest girth measurements had R^2 values of 0.74–0.99; chest girth was the most important measurement that could be used to estimate live weight (Meghelli et al., 2020; Haddam et al., 2024b).

Table 6: Autocorrelation checking of the third model in males and the fourth model in females obtained in Sahraoui dromedary population according to stepwise regression analysis

Sex	IV	RC±SE	p-value	Tol	VIF	DWS	p-value
Males	Intercept	-541.858 ± 53.931	***	--	--	1.51	ns
	HW	4.585 ± 0.756	***	0.110	9.03		
	LHL	-3.711 ± 0.713	***	0.125	7.98		
	CG	3.639 ± 0.249	***	0.683	1.46		
Females	Intercept	-411.022 ± 57.911	***	--	--	2.077	ns
	HW	1.669 ± 0.335	***	0.756	1.321		
	CG	2.974 ± 0.206	***	0.764	1.307		
	TL	-1.319 ± 0.627	*	0.839	1.190		
	NL	-0.602 ± 0.303	*	0.813	1.228		

IV: independent variable, RC: regression coefficient, SE: standard error, Tol: tolerance, VIF: variance inflation factor, DWS: Durbin-Watson statistics, p: probability, HW: height at withers, LHL: Length of hind limbs, CG: chest girth, TL: Tail length, NL: Neck length, ns: not significant, *: p<0.05, ***: p<0.001.

From the results in Table 6, it was found that in males, all the Intercept, HW, LHL, and CG were highly significant in predicting body weight with a tolerance of 0.110; 0.125, and 0.683 respectively, and with a variance inflation factor (VIF) of 9.03; 7.98, and 1.46 respectively. The Durbin-Watson statistic indicated the presence of autocorrelation of the third model in males. The DWS value was 1.51 and the p-value was (> 0.05) according to the results in (Table 6). While in females, only the Intercept, HW, and CG were highly significant in estimating body weight with a tolerance of 0.756 and 0.764 respectively, and with a variance inflation factor (VIF) of 1.321 and 1.307 respectively. However, TL and NL parameters were found to be non-significant (p<0.5) for body weight estimation with tolerance of 0.839 and 0.813 respectively and with variance inflation factor (VIF) of 1.190 and 1.228 respectively. Durbin-Watson statistic showed that there was no autocorrelation of the fourth model in females. The DWS value was 2.077 and p-value was (>0.05) according to the results of (Table 6).

The results presented in (Figure 6) show that R^2 and CCC of Lin increased compared to the general model presented in (Figure 4). The R^2 values were 95% for males compared to 84.1% in the general model. The CCC of Lin in the general model was 91.4% while it was 97.6% for males in the separate model.

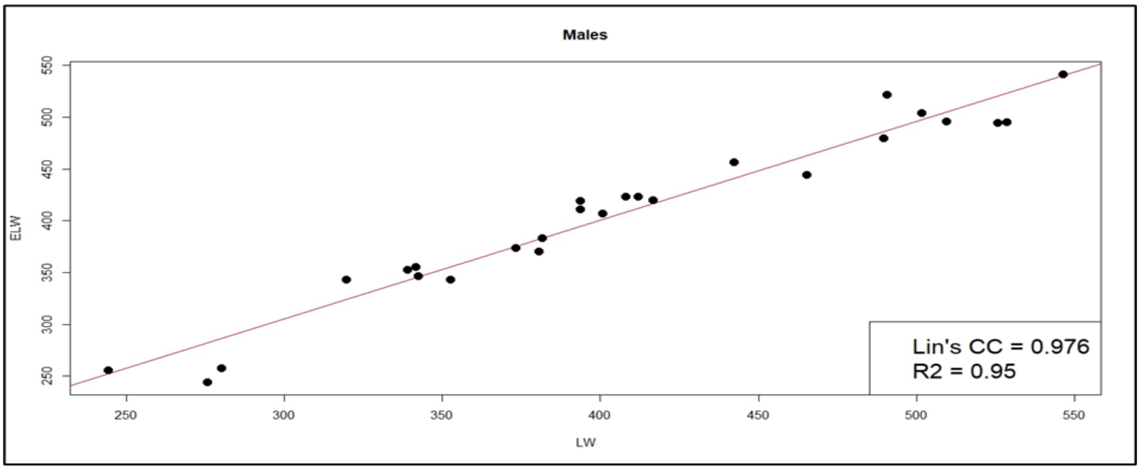

Figure 6: Concordance correlation coefficient of observed and vs predicted live weight in males

However, the results presented in (Figure 7) illustrate that R^2 and CCC of Lin decreased compared to the general model. The R^2 values were 76% for females compared to 84.1% in the general model. The CC of Lin in the general model was 91.4% while it was 86% for females in the separate model. It is suggested to use the general model to estimate the body weight of female camels and the separate model for male camels. Finally, the male separated model demonstrated substantial agreement, with a coefficient of 95%.

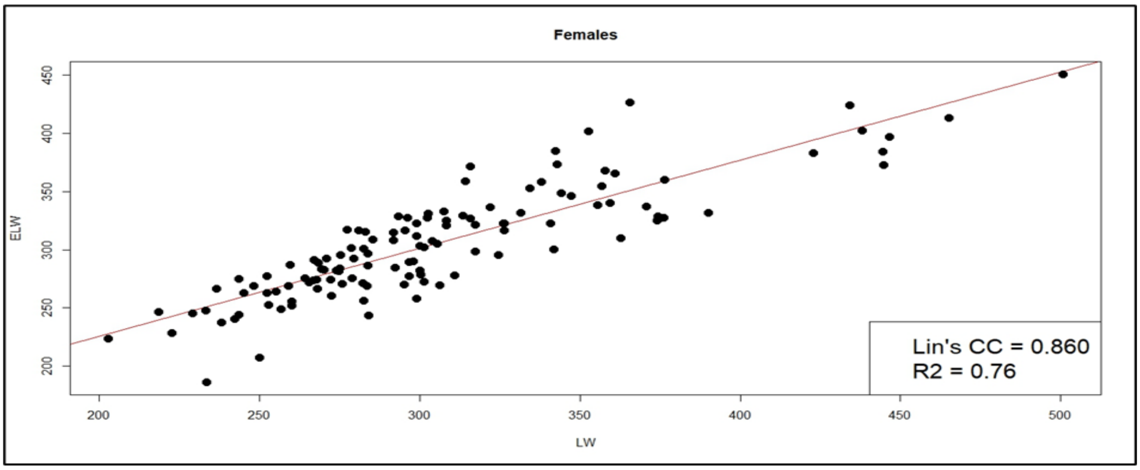

Figure 7: Concordance correlation coefficient of observed and vs predicted live weight in females

The quality assessment of each model was guided by the strength of agreement criteria proposed by Lin (McBride, 2005). These results are similar to those reported by Haddam et al. (2024c) in a study conducted on Sloughi and German shepherd. In female Algerian Sloughi, the R^2 value was 74.7% in the general model versus 65.8% in the separate model, and the CCC of Lin was 85.7% in the general model versus 81.8% in the separate model. In male, the R^2 value was 74.7% in the general model and increased to 74.9% in the separate model, while the CCC of Lin improved from 85.7% to 87.2%. Thus, it is suggested to use the general model to estimate the body weight of female Algerian Sloughi and the separate model for male Algerian

Sloughi. In female German Shepherd, the R^2 being 90.1% and the CCC of Lin being 95.3% versus 96.7% and 98.4%, respectively. Conversely, in males, the R^2 and CCC values of Lin increased compared to the general model, with R^2 being 99.6% and CCC of Lin being 99.8% versus 96.7% and 98.4%, respectively. Similar to the case of the Algerian Sloughi, it is recommended to use the general model to estimate body weight in female German Shepherds and the separate model for males (Haddam et al., 2024c).

4. Conclusion

In this study conducted in Algeria, the models constructed with regression analysis to predict live weight of dromedaries, using specific body measurements, has proven to be very effective. Chest girth has consistently emerged as a reliable predictor in both sexes for estimating live weight of dromedaries. The accuracy of the models varied by sex. The general model, which included chest girth as well as withers height, demonstrated greater accuracy than the separate female model. However, the separate male model, which included chest girth, withers height, and length of hind limbs, demonstrated greater accuracy than the general model.

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