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Research Article

A Comparative Study of the Nonlinear Methods for Estimating Body Weight Based on Body Measurements in Different Sample Sizes in Morkaraman Sheep

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Abstract: The objective of this study is to estimate the body weight of Morkaraman sheep from body measurements with nonlinear models. Five different models (allometric, logistic, saturation growth, exponential and incomplete gamma) are used to estimate best-fitted model for relationship between body length and body weight of Morkaraman sheeps at different sample sizes. Selected 110 sheeps 3-5 years were scored for body weight, body length, height at wither, chest width and rump width. For determining the relationships with body weight between body measurements, correlation analysis was performed. The results of the correlation analysis indicated that the highest relationship according to all sample sizes was between body weight and body length (0.95, 0.90, 0.83, 0.81). Considering all parameters included in the model, the parameter showing the highest correlation with body weight was determined as body length according to all sample sizes. The highest correlation was found in 50 sample sizes (r=0.95). According to the small sample sizes (10-20), Logistic and Saturation growth models can be used to determine the body weight by using body length, on the other hand, the Incomplete gamma model is more successful to estimate body weight when the sample size is nearly 30 and 50.

Keywords: *Body measurements, Morkaraman, Logistic, Saturation growth, Incomplete gamma*

Morkaraman Koyunlarında Farklı Örnek Büyüklüklerinde Vücut Ölçülerine Göre Vücut Ağırlığının Tahmin Edilmesinde Doğrusal Olmayan Yöntemlerin Karşılaştırılması

Öz: Bu çalışmanın amacı, Morkaraman koyunlarının vücut ağırlığının lineer olmayan modellerle vücut ölçülerinden tahmin edilmesidir. Farklı örneklem büyüklüklerinde Morkaraman koyunlarının vücut uzunluğu ve vücut ağırlığı arasındaki ilişki için en uygun modeli tahmin etmek için beş farklı model (allometric, logistic, saturation growth, exponential and incomplete gamma) kullanılmıştır. Üç ile beş yaş arası seçilen 110 koyunun, vücut ağırlığı, vücut uzunluğu, cidago yüksekliği, göğüs genişliği ve sağrı genişliği değerleri ölçülmüştür. Vücut ölçüleri arasında vücut ağırlığı ile ilişkileri belirlemek için korelasyon analizi uygulanmıştır. Korelasyon analizi sonuçları, tüm örneklem büyüklüklerine göre en yüksek ilişkinin vücut uzunluğu ile (0.95, 0.90, 0.83, 0.81) vücut ağırlığı arasında olduğunu göstermiştir. Modelde yer alan tüm parametreler dikkate alındığında, örneklem büyüklüklerine göre vücut ağırlığı ile en yüksek korelasyonu gösteren parametre vücut uzunluğu olarak belirlenmiştir. En yüksek korelasyon 50 örneklem büyüklüğünde bulunmuş olup (r=0.95), küçük örneklem boyutlarına göre (10-20), vücut uzunluğunu kullanarak vücut ağırlığını belirlemek için Lojistik ve Saturation Growth modelleri, örnek büyüklüğü yaklaşık 30-50 arasında olanlarda ise vücut ağırlığını tahmin etmede Incomplete gama modeli daha etkili sonuçlar vermiştir.

Anahtar sözcükler: *Vücut ölçüleri, Morkaraman, Logistic, Saturation growth, Incomplete gamma*

Introduction

The increase in the number and size of cells in certain time intervals in accordance with the type of animal, shaped by the interaction of the genetic structure of living things and the environmental conditions in which they are found, is expressed as growth [1].

Macedo-Barragán [2] concluded that as an alternative to linear models, incomplete gamma and exponential models

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can be used to predict body weight of sheep using some body measurements.

Selection of the appropriate model requires a statistical decision process, since the live weight varies according to the species, environmental conditions and the trait studied. It has been reported in the literature that although a constant rate of weight gain occurs in certain periods for some characteristics of some living things, the weight increases in living things is not constant throughout their lifetime [3-5].

Linear models are often insufficient to model the growth of living things over the lifespan [4-6]. In the case of periods of different growth rates, it is useful or even necessary to use non-linear models, which are slightly more complex than linear models.

Tahtali et al.[7] aimed to model the body weight gains of Romanov lambs and individual growth curves using different equations. Cubic spline model, Logistic model, Gompertz model and Richard models were used as models in the study.

The determination and estimation of non-linear models are more difficult than linear models, and the results are determined iteratively using different methods [8].

In this study, it was tried to determine a model that gave the best fit between body weight and body measurements in different sample sizes. Although these measured variables can be explained by linear models, they can also be explained by nonlinear models. For this purpose, although the variables used in this study are in linear form, non-linear regression models can also be used for this purpose. In this study, it is aimed to determine nonlinear regression models as an alternative to linear regression models.

Material and Methods

Materials

The data used in this study were recorded on 110 Morkaraman sheep maintained in Atatürk University, Food and Livestock Research and Application Center. Body measurements of adult animals aged 3-5 years were recorded using a graduated measuring tape. Whole body measurements were taken with the animal standing, head up and weight on all fours without body movement. Body weight was taken using a suspended digital scale. Sheeps were included in the study as 10, 20, 30 and 50 separately according to sample size.

Methods

Correlation coefficients were used to determine the relationship between parameters. In addition, it is aimed to determine the best model according to the sample size in determining the live weight by using the nonlinear models.

The models were tested for goodness of fit by the (MSE) Mean Square Error and (R^2), adjusted coefficient of determination (R^2_{adj}), Akaike information criterion (AIC), Bayes information criterion (BIC) and mean squared prediction error (MEP). The statements of these evaluators are also presented in detail in Silveira et al.[9].

Results

Considering all parameters included in the model, the parameter showing the highest correlation with body weight was determined as body length according to all sample sizes. As indicated in *Table 1*, the highest correlation was found in 50 sample sizes (r=0.95). This was followed by sample sizes of 30, 20 and 10, respectively. The highest correlations for the BW parameters between BL were found 0.95, 0.90, 0.83 and 0.81, respectively. In addition, the lowest correlation values were between BW and HW (r=0.46), BW and HG (r=0.51) and, BW and RW (r=0.48). Considering all sample sizes, body length was included as an independent variable in nonlinear models.

Table 2 gives the results of nonlinear models, in which five different models for estimating best-fitted model for relationship between body length and body weight of Morkaraman sheeps at different sample sizes.

R^2 and MSE values for models estimated by five different models and sample sizes have been used to determine the best fit models.

Considering the sample sizes; the lowest R^2 and the highest MSE values occurred in the group with sample size 10. According to this group, the highest R^2 value (0.64) was

Table 1. *Correlations between body weight and body measurements with different sample sizes*

Body Weight	Sample Size	BL	HD	HW	CW	HG	RW
BW	10	0.81**	0.57*	0.46	0.73**	0.51	0.48
BW	20	0.83**	0.72*	0.58*	0.75**	0.66*	0.53
BW	30	0.90**	0.78**	0.60*	0.74**	0.76*	0.61*
BW	50	0.95**	0.81*	0.69*	0.74**	0.76*	0.66*

*** P<0.01, * P<0.05;* ***BW:*** *Body weight,* ***BL:*** *Body length,* ***HW:*** *Height at wither,* ***CW:*** *Chest width,* ***RW:*** *Rump width*

Table 2. *Estimation nonlinear models for predicting body weight of Morkaraman lambs from body length with different sample sizes*

n	Model	*Equation*	P	R^2	MSE
10	Allometric	$0.004BL^{2.09}$	0.035	0.59	15.18
	Logistic	$196.85/(1+exp^{(3.446-0.0512BL)})$	0.020	0.64	14.98
	Saturation growth	-19.785BL/(-196.71+BL)	0.016	0.61	14.76
	Exponential	$5.0142exp^{(0.0375BL)}$	0.020	0.60	14.91
	Incomplete gamma	$0.1014BL^{1.214}exp^{(0.021BL)}$	0.028	0.63	14.89
20	Allometric	$0.003BL^{2.11}$	0.016	0.66	14.01
	Logistic	$202.45/(1+exp^{(3.4141-0.0548BL)})$	0.013	0.65	14.01
	Saturation growth	-18.471BL/(-188.16+BL)	0.008	0.71	13.44
	Exponential	$4.7811exp^{(0.0108BL)}$	0.002	0.60	13.75
	Incomplete gamma	$0.1008BL^{1.303}exp^{(0.025BL)}$	0.008	0.68	13.67
30	Allometric	$0.003BL^{2.14}$	0.012	0.74	12.11
	Logistic	$201.48/(1+exp^{(3.358-0.0442BL)})$	0.008	0.79	12.02
	Saturation growth	-20.016BL/(-198.34+BL)	0.010	0.78	12.16
	Exponential	$4.842exp^{(0.0392BL)}$	0.002	0.79	12.08
	Incomplete gamma	$0.1021BL^{1.136}exp^{(0.019BL)}$	0.001	0.82	11.88
50	Allometric	$0.003BL^{2.15}$	0.003	0.88	12.02
	Logistic	$199.61/(1+exp^{(3.303-0.0398BL)})$	0.001	0.89	12.00
	Saturation growth	-20.038BL/(-199.16+BL)	0.001	0.86	12.01
	Exponential	$4.8805exp^{(0.0384BL)}$	0.001	0.88	12.02
	Incomplete gamma	$0.1019BL^{1.149}exp^{(0.020BL)}$	0.001	0.92	11.94

Table 3. *Estimation linear equations for predicting body weight of Morkaraman lambs from body measurements with different sample sizes*

n	Model	*Equation*	P	R^2	MSE
10	Linear	BW = -12.516 + 0.811BL	0.040	0.66	17.16
20	Linear	BW = -11.986 + 0.793BL	0.035	0.69	15.44
30	Linear	BW = -9.542 + 0.707BL	0.012	0.81	13.11
50	Linear	BW = -9.233 + 0.765BL	0.003	0.90	11.08

determined in Logistic and the lowest MSE value (14.76) was determined in Saturation growth models. When sample size was kept as 20, the highest R^2 value (0.71) and the lowest MSE value (13.44) was detected in Saturation growth models.

Considering the different sample sizes, the results of the linear regression model are given in *Table 3*. According to these results, the R^2 value was 0.66 and the MSE value was 17.16 in the model with a sample size of 10, and the R^2 value was 0.69 and the MSE value was 15.44 in the model with a sample size of 20. In addition, the R^2 value was 0.81 and the MSE value was 13.11 in the model with a sample size of 30, and the R^2 value was 0.90 and the MSE value was 11.08 in the model with a sample size of 50. According to these obtained values, it was found that as the sample size increased, the R^2 value increased and the MSE value decreased. According to different sample sizes, these coefficients showed that there is more similarity between the linear and nonlinear methods.

Table 4 shows the results of the evaluators of goodness of fit (R^2_{adj}, AIC, BIC, MEP) for each model. Considering the R^2_{adj} value, the highest value was obtained as Incomplete gamma (0.8464), Logistic (0.7921), Allometric (0.7744) and Exponential (0.7744) with sample size 50. The low MEP values, the lowest values were obtained as Incomplete gamma (10.9096), Exponential (11.0864) and Logistic (11.3212), respectively. The lowest R^2_{adj} value was obtained as Allometric (0.3481), Exponential (0.3600), Saturation growth (0.3721) and Incomplete gamma (0.3969) with sample size 10. Considering the high MEP values, the highest values were obtained as Incomplete gamma (24.8530), Exponential (24.2070) and Allometric (20.6392), respectively. Considering the AIC value, the lowest value was obtained as Incomplete gamma (175.3682), Logistic (187.7116), Allometric (188.9002) and Exponential (189.4751) with sample size 50. The lowest BIC values were obtained as Incomplete gamma (182.4006), Exponential (198.6672) and Logistic (202.1524), respectively.

Table 4. *Results of the quality of fit evaluators for the Morkaraman sheeps with different sample sizes*

n	Model	R^2_{adj}	AIC	BIC	MEP
10	Allometric	0.3481	204.9446	219.7146	20.6392
	Logistic	0.4096	198.4871	213.9151	19.7252
	Saturation growth	0.3721	198.4871	213.7989	15.6051
	Exponential	0.3600	210.0728	226.2827	24.2070
	Incomplete gamma	0.3969	204.9446	220.2445	24.8530
20	Allometric	0.4356	198.2946	215.0813	21.6386
	Logistic	0.4225	210.8582	226.7405	20.2056
	Saturation growth	0.5041	205.5648	222.9836	21.3546
	Exponential	0.3600	204.9446	222.7792	17.3273
	Incomplete gamma	0.4624	208.5478	224.3540	15.1510
30	Allometric	0.5476	206.7871	223.7148	16.7722
	Logistic	0.6241	202.1458	218.5526	14.6922
	Saturation growth	0.6084	199.2580	216.1218	15.4842
	Exponential	0.6241	197.6542	218.8890	14.6692
	Incomplete gamma	0.6724	192.8586	214.4148	12.5628
50	Allometric	0.7744	188.9002	202.3128	12.2018
	Logistic	0.7921	187.7116	202.1524	11.3212
	Saturation growth	0.7396	192.1541	216.7005	13.4086
	Exponential	0.7744	189.4751	198.6672	11.0864
	Incomplete gamma	0.8464	175.3682	182.4006	10.9096

Discussion

Topal and Macit [10] were reported that in their study in 66 Morkaraman sheep, as a result of multiple regression analysis, the R^2 value of body length affecting body weight was 0.282 and MSE value was 31.702, respectively. Ibrahim et al.[11] revealed that CG and its combination with other linear body measurements can effectively define the body weight in Batur sheep. However, the highest R^2 of 0.782 was observed when CG and BL were used as predictors. As a result of the different nonlinear models used to estimate the body weight of Morkaraman sheeps, according to the all sample sizes Incomplete gamma model is the most appropriate model when R^2, MSE, R^2_{adj}, AIC and BIC values were taken into account. Rather et al.[12] were emphasized that the coefficient of determination (R^2) is succesful to estimate body weight from body measurements in Kashmir Merino sheeps. Considering the sample sizes of 30 and 50, the highest R^2 values (0.82-0.92) and the lowest MSE values (11.88-11.94) were found in the Incomplete gamma model, respectively. Demir and Sahinler [13] using nonlinear Brody, Bertalanffy, Logistic, Gompertz and Richards models in their study, selected the model with high coefficient of determination (R^2) and low mean square error (MSE) as the best model to describe growth. In conclusion, Richards and Logistic models were the best predictors of overall growth of lambs in nonlinear models. Among the groups, the lowest MSE and the highest R^2 were obtained in the second group and in the Logistic model. According to this model; R^2 and MSE were found to be 0.999±0.0002 and 0.41±0.060, respectively. Macedo-Barragan et al.[2] reported that according to all non-linear models R^2 value is calculated higher than 0.75 for estimating body weight from body measurements.

The nonlinear regression analysis with R^2 calculated for growth in Awassi lambs showed that the relationship derived from the regression weight in weight at 6 months at weaning according to the exponential function was considered to be the best since the R^2 value was 0.69 [14].

Bilgin et al.[15] reported that Brody is the best model for describing as unfit between body weight and age in sheeps. And also, body measurement in farm animals is used to decide the apparent identity and growth pattern [16,17].

Raungprim et al.[18] used three nonlinear regression models: exponential, polynomial quadratic and power models to analyze the relationship between body parameters and body weight. As a result, it was revealed that the power model gave the best HG and body weight relationship model with the highest R^2 (0.9662, 0.9748 and 0.9702) respectively in swamp buffaloes. Topuz [19] calculated the mean membership degree (MDM) and mean square error (MSE) as MDM=0.896 and MSE=4.871, respectively, in order to decide the adequacy of the model by using the fuzzy logic approach-based posibilistic logistic regression method together with its theoretical background in dairy cattle. According to these values, it was decided that the fit of the model was good.

Considering small sample sizes as 10-20, Logistic and Saturation growth models are more suitable than Allometric, Exponential and Incomplete gamma models for predicting body weight from body length measures. According to the linear model, the highest R^2 and the lowest MSE is obtained from the group of 50 sample size. Considering 30-50 sample sizes group, according the R^2_{adj}, AIC, BIC and MEP values Incomplete model is more appropriate model than the others.

It is concluded that according to the small sample sizes (10-20), Logistic and Saturation growth models can be used to determine the body weight by using body length, on the other hand, Incomplete gamma model is more succesful to estimate body weight when sample size is bigger than 20.

Availabity of Data and Materials

The author declares that data supporting the study findings are also available to the corresponding author.

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Declaration of Conflict of Interest

There was no conflict of interest in regards to author reporting his findings.

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