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Research Article

An Examination of the Relationships Between Live Weight and Body Measurements in Karacabey Merino Sheep Through the Path Analysis Approach

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Abstract

Direct and indirect effects of some of the body measurements on Karacabey Merino Sheep's live weights were estimated using a path analysis in this study. When setting the path model, live weight, back length, body length, shin girth, chest depth, rump width and chest girth measurements of 249 Karacabey Merino sheep of which ages varied between 1 and 4 years were utilized. According to the two-equation causal path model, the body measurement which had the highest direct effect on live weight was chest girth, and it was also shown that chest depth and rump width had indirect effects. It was found that the model expressed a good fit according to the goodness of fit criteria. Consequently, it was revealed that the body measurement which had the greatest contribution to the model set for live weight estimation was chest girth and causal relations between the independent variables variable could be shown with the path analysis.

Keywords: *Path analysis, Path diagram, Karacabey Merino sheep, Live weight*

Karacabey Merinosu Koyunlarinda Canlı Ağırlık İle Vücut Ölçüleri Arasındaki İlişkilerin Path Analizi Yaklaşımı İle İncelenmesi

Özet

Bu çalışmada Karacabey Merinosu koyunlarının canlı ağırlıkları üzerine, bazı vücut ölçülerinin doğrudan ve dolaylı etkileri path analizi kullanılarak tahmin edilmiştir. Path modeli kurulurken, 1-4 yaş arası 249 baş Karacabey Merinosu koyununun canlı ağırlık, sırt uzunluğu, vücut uzunluğu, incik çevresi, göğüs derinliği, sağrı genişliği ve göğüs çevresi ölçümlerinden yararlanılmıştır. İki denklemli nedensel path modeline göre canlı ağırlık üzerinde doğrudan etkisi en yüksek vücut ölçüsünün göğüs çevresi olduğu belirlenmiş, göğüs derinliği ve sağrı genişliğinin dolaylı etkileri de gösterilmiştir. Modelin uyum iyiliği kriterlerine göre iyi uyumu ifade ettiği de tespit edilmiştir. Sonuç olarak; canlı ağırlık tahmini için oluşturulan modele en yüksek katkıyı sağlayan ölçünün göğüs çevresi olduğu, ayrıca path analizi ile bağımlı değişkene ek olarak bağımsız değişkenler arasındaki nedensel ilişkilerin de gösterilebileceği ortaya konmuştur.

Anahtar sözcükler: *Path analizi, Path diyagramı, Karacabey Merinosu koyunları, Canlı ağırlık*

INTRODUCTION

Increasing the yield in sheep breeding just as in other stock breeding is possible through enhancing livestock's genetic structures and environmental conditions and the studies of breeding and selection. Meat yield is one of the primary yields that is not only of financial importance but also meets human's needs [1-3]. For increasing the meat yield in sheep, it is necessary to identify the sheep breed to be selected, the area in which sheep will be bred, and the rangeland and climate conditions optimally [2,4]. Yet, reasons such as tendency towards breeding of low-yield sheep breeds, sheep feeding in low-quality rangelands and early slaughter affect sheep breeding in Turkey in a negative way [5].

Influencing the meat yield, live weight is considered an important criterion in livestock choice in breeding. So much time and labor force is spent for weighing the live weight in rural areas and at small-scale business where measuring equipment is not used frequently [6,7]. Therefore,

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livestock's body measurements are often utilized for live weight estimation [8,9]. On the other hand, the relationship between live weight and morphological measures presents a complex structure. While the degree and direction of the relationship can be determined with correlation analysis in this case, regression analysis can be used when estimating live weight with body measurements. However, effects among variables in the correlation and regression analysis cannot be sufficiently explained as they can be also shaped by a third variable [10]. With developments in the area of computers in recent years, multivariate methods, which have been developed as alternatives to situations where correlation and regression analyses fall insufficient in analyzing relationships among complex variable structures, have become applicable. One of those methods is path analysis. Path analysis is utilized when identifying the causal (direct or indirect) and non-causal (unanalyzed and spurious) effects of one variable on another and breaking variables' correlation coefficients into the components of those variables [6,11]. Path analysis is a subset of structural equation models and presents itself as a methodology complementary to multiple regression model which helps determining the explanatory variable that affects the response variable more [10,12].

The purpose of this study was to identify direct and indirect effects between live weights and several body measurements of Karacabey Merino sheep bred at Karacabey Agricultural Enterprise and to evaluate the model set with different goodness of fit criteria.

MATERIAL and METHODS

The livestock material of the research was 249 Karacabey Merino sheep at the age of 1-4 years bred at Karacabey Agricultural Enterprise. Maintanance and feeding of animals housed in enterprise conditions were carried out on a routine programme of the enterprise. In the study, live weight (the body weight that was taken using a digital scale [kg]), back length (the vertical distance between the base of neck and the waist axis [cm]), body length (the distance between the point of shoulder and the pin bone [cm]), shin girth (the circumference of mid metacarpus [cm]), chest depth (the vertical distance from sternum to withers [cm]), rump width (the distance between the outer edges of Tuber ichii [cm]), chest girth (the circumference of the chest [cm]) and withers height (the distance from the surface of the platform to the withers [cm]) measurements obtained from the sheep after shearing were used.

Descriptive statistics were calculated first for all the variables. Pearson's correlation coefficient was utilized to determine the degree and direction of the relationships among the variables. To identify the variables to be included in the path analysis, preliminary assessments were performed with the multiple regression analysis. Path analysis was conducted and a path diagram was created to interpret direct and indirect relationships among the variables of the model.

The path coefficients were calculated with the help of standardized regression coefficients as follows:

The multiple linear regression model that is constituted by independent variables X_i and the error term e and the dependent variable Y explained by them is expressed as

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots + b_kX_k + e \quad (1)$$

In this model,

b_0: regression constant,

b_i: partial regression coefficients.

The linear regression equation for standardized variables is formed as in Equation 2.

$$Y = P_{YX_1}X_1 + P_{YX_2}X_2 + \ldots + P_{YX_k}X_k + P_{YX_e}X_e \quad (2)$$

Path coefficient (P) is defined as the standardized regression coefficient which shows the direct effect of the independent variables in the path model on the dependent variable, and expressed as the effect which the change of 1 standard deviation in the explanatory variable creates on the dependent variable. In multiple regression analysis, the beta coefficients between the independent variables and the dependent variable are also denoted by P, because they are defined as path coefficients at the same time.

$$P_{YX_k} = b_k \frac{S_{X_k}}{S_Y} \quad (3)$$

Here,

P_{YX_k} : path coefficient,

S_{X_k} : standard deviation of the independent variable ,

S_Y : standard deviation of the dependent variable Y, and

b_k : partial regression coefficient [10].

In the path analysis, one or more dependent variables are analyzed through each independent variable; in other words, more than one multiple regression analyses can be performed at the same time [13]. By this means, models with two or more equations as well as one-equation models can be set. In *Fig. 1a,* equation of the one-equation path model is written as

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 \quad (4)$$

In *Fig. 1b,* equation of the two-equation path model is written as

$$x_3 = a + b_1x_1 + b_2x_2 \quad (5)$$

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 \quad (6)$$

In the path model, direct effect is utilized when identifying the direct effect between two variables and indirect effect

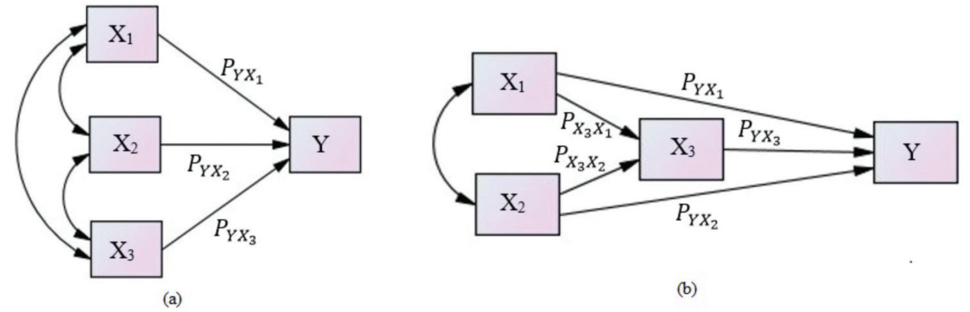
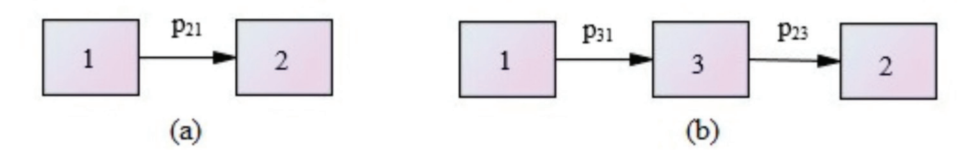


Fig 1. Path models (a) One-equation path model (b) Two-equations path model

Fig 2. Causal relation types in path diagram (a) Direct effect (b) Indirect effect



is the effect of a variable on another variable through one or more variables.

Direct effect is described as the path coefficient between two variables as shown in *Fig. 2a*. Indirect effect can be calculated by multiplying the path coefficients on the path between the variables. So in *Fig. 2b* the indirect effect between Variable 1 and 2 can be calculated by multiplying the path coefficients and [11].

Only the causal (direct and indirect) effects were emphasized for the path model in this study. The fit of model was evaluated in accordance with the goodness of fit criteria suggested by Engel et al.[14].

SPSS 23.0 software package was used to calculate the descriptive statistics and correlation coefficients and for the regression analysis while the path analysis was performed in AMOS 23.0 software. The significance level was accepted to be $P<0.05$.

RESULTS

Descriptive statistics regarding live weight (Y), back length (X_1), body length (X_2), shin girth (X_3), chest depth (X_4), rump width (X_5), chest girth (X_6) and withers height (X_7) measurements of Karacabey Merino sheep are given in *Table 1*.

Correlation coefficients predicted for examining the relationships between live weight (Y) and back length (X_1), body length (X_2), shin girth (X_3), chest depth (X_4), rump width (X_5), chest girth (X_6) and withers height (X_7) and among the body measurements are shown in *Table 2*. Accordingly, correlation coefficients among all the variables were found to be statistically significant ($P<0.001$). It was seen that there was a highly positive relationship between live weight and chest girth, a moderately positive relationship between live weight and back length, body length, rump width and withers height, and a lowly positive relationship between live weight and shin girth.

According to the preliminary assessment performed with the multiple linear regression analysis to establish the theoretical infrastructure of the path model, back length ($t=5.638$, $P<0.001$), body length ($t=4.707$, $P<0.001$), shin girth ($t=3.924$, $P<0.001$), chest depth ($t=4.013$, $P<0.001$), rump width ($t=2.533$, $P=0.012$) and chest girth ($t=10.227$, $P<0.001$) affected live weight on an important level and withers height ($t=0.996$, $P=0.320$) had no important effects on live weight. It was observed that chest girth is a more important measurement for live weight estimation

***Table 1.** Descriptive statistics regarding live weights and body measurements of Karacabey Merino sheep*

Variables	n	Arithmetic Mean	Standard Deviation	Standard Error	Median	Minimum	Maximum
Live weight (Y)	249	51.36	5.99	0.38	52.00	35.00	68.00
Back length (X_1)	249	67.66	3.09	0.20	68.00	55.00	75.00
Body length (X_2)	249	56.19	3.15	0.20	56.00	33.00	68.00
Shin girth (X_3)	249	8.57	0.33	0.02	8.50	7.80	9.70
Chest depth (X_4)	249	31.49	1.84	0.12	32.00	26.00	36.00
Rump width (X_5)	249	19.40	1.49	0.09	19.00	16.00	29.00
Chest girth (X_6)	249	94.33	5.03	0.32	95.00	79.00	106.00
Withers height (X_7)	249	68.41	2.98	0.19	68.00	60.00	91.00

Table 2. *Correlation coefficients among dependent and independent variables*

Variables	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Live weight (Y)	1	0.657***	0.578***	0.378***	0.801***	0.617***	0.846***	0.555***
Back length (X_1)		1	0.437***	0.289***	0.564***	0.412***	0.509***	0.403***
Body length (X_2)			1	0.270***	0.460***	0.387***	0.452***	0.408***
Shin girth (X_3)				1	0.252***	0.200***	0.240***	0.260***
Chest depth (X_4)					1	0.550***	0.793***	0.533***
Rump width (X_5)						1	0.588***	0.466***
Chest girth (X_6)							1	0.501***
Withers height (X_7)								1

**** P<0.001*

Table 3. *Parameter estimations for the path model*

Dependent Variables	Independent Variables	Regression Coefficients			Z	P
		Unstandardized		Standardized		
		Beta	Standard Error	Beta		
Live weight (Y)	Back length (X_1)	0.357	0.062	0.186	5.765	<0.001
	Body length (X_2)	0.285	0.057	0.151	5.02	<0.001
	Shin girth (X_3)	1.997	0.487	0.111	4.099	<0.001
	Chest girth (X_6)	0.907	0.050	0.769	17.966	<0.001
Chest girth (X_6)	Chest depth (X_4)	1.822	0.116	0.665	15.775	<0.001
	Rump width (X_5)	0.779	0.137	0.230	5.676	<0.001

than other independent variables. It was also aimed at investigating the effects of these variables on chest girth for determining whether the effects of all other independent variables on live weight was through chest girth. Accordingly, chest depth (t=11.765, P<0.001) and rump width (t=4.097, P<0.001) measurements had important effects on chest girth, but the effects of back length (t=0.810, P=0.419), body length (t=1.319, P=0.189), shin girth (t=0.241, P=0.809) and withers height (t=0.914, P= 0.362) on chest girth were not important. When examining the Variance Inflation Factor (VIF) and the tolerance values, no multicollinearity problems were found in either of the models. Since withers height was found to be statistically insignificant in both models, it was not included in the path model. Since the effects of chest depth and rump width on chest girth were found to be important, the effects of these variables on live weight were considered being indirect through chest girth.

According to the path diagram in *Fig. 3,* the two-equation causal model was used in live weight (Y) estimation through the body measurements of back length (X_1), body length (X_2), shin girth (X_3), chest depth (X_4), rump width (X_5) and chest girth (X_6). The covariance among the error terms of these variables were also added to the model as a common variance is expected due to the high-level relationship between chest girth and live weight variables.

Parameter estimations and significance of path coefficients for both models are given in *Table 3.* As determined by the standardized regression coefficients, it is seen that the highest contribution to the explanation of live weight in Model 1 was by chest girth and the highest contribution to the explanation of chest girth in Model 2 was by chest depth.

As seen in the path diagram of *Fig. 3,* measurements of back length, body length, shin girth and chest girth had direct effects on live weight while chest depth and rump width affected live weight indirectly through chest girth. Size of the direct and indirect effects abovementioned are given in *Table 4*. Depending on the high correlation between live weight and chest girth, it can be concluded that the highest effect was the direct effect of chest girth on live weight.

Goodness of fit criteria, fit limits, and the goodness of fit values for the model achieved in the study are presented in *Table 5*. Accordingly, it was determined that all the goodness of fit criteria obtained in the model exhibited good fit; in other words, the model fits the data.

DISCUSSION

Path analysis helps reveal the relationships among variables in detail provided that variables have both individual effects and effects along with other variables. There

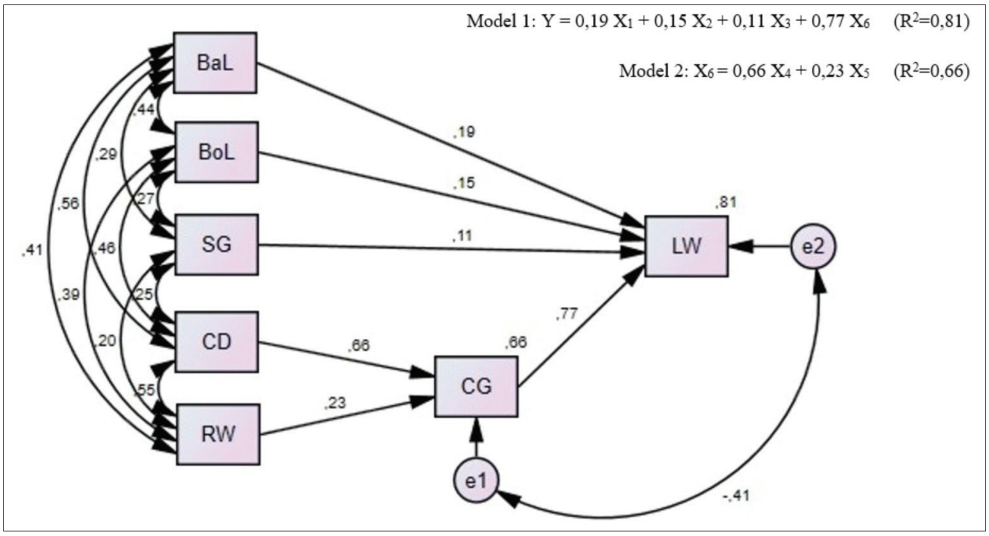


Fig 3. Path diagram of live weight estimation through body measurements

Table 4. *Causal (direct and indirect) effects for the path model*							
Dependent Variables	**Independent Variables**	**Back Length**	**Body Length**	**Shin Girth**	**Chest Depth**	**Rump Width**	**Chest Girth**
Live weight (Y)	Total effect	0.186	0.151	0.111	0.511	0.177	0.769
	Direct effect	0.186	0.151	0.111	0.000	0.000	0.769
	Indirect effect	0.000	0.000	0.000	0.511	0.177	0.000
Chest girth (X_6)	Total effect	-	-	-	0.665	0.230	-
	Direct effect	-	-	-	0.665	0.230	-
	Indirect effect	-	-	-	0.000	0.000	-

Table 5. *Goodness of fit criteria and fit limits*			
Goodness of Fit Criteria	**Good Fit**	**Acceptable Fit**	**Goodness of Fit Values for the Model Achieved**
χ^2	$0 \leq \chi^2 \leq 2df$	$2sd \leq \chi^2 \leq 3df$	4.682
P value	$0.05 < P \leq 1.00$	$0.01 \leq P \leq 0.05$	0.321
χ^2/df	$0 \leq \chi^2/df \leq 2$	$2 \leq \chi^2/df \leq 3$	1.171
RMSEA	0≤RMSEA≤0.05	0.05≤RMSEA≤0.08	0.026
NFI	0.95≤NFI≤1.00	0.90≤NFI≤0.95	0.995
CFI	0.97≤CFI≤1.00	0.95≤CFI≤0.97	0.999
GFI	0.95≤GFI≤1.00	0.90≤GFI≤0.95	0.995
AGFI	0.90≤AGFI≤1.00	0.85≤AGFI≤0.90	0.963

***χ^2:** Chi-square value, **df:** Degrees of freedom, **RMSEA:** Root mean square error of approximation, **NFI:** Normed fit index, **CFI:** Comparative fit index, **GFI:** Goodness of fit index, **AGFI:** Adjusted goodness of fit index*

are many studies using path analysis in sheep and goat breeding [3,15-17], poultry farming [7,18-20] and cattle breeding [21-25] and other livestock breeding [26,27].

In this study, it was seen that chest girth (r=0.846) and chest depth (r=0.801) was highly related to live weight when examining the correlation coefficients that showed the relationships between live weights and body measurements of Karacabey Merino sheep. This finding shows similarity with findings of other studies that examined the relationships between live weight and body measurements [6,8,10,28-30].

In the model obtained with the multiple linear regression analysis that was applied in this study, sheep's live weight was explained by their back length, body length, rump width, chest depth, shin girth and chest girth whereas the body measurement which had the highest effect on live weight was found to be chest girth. It was also reported in other studies with similar purposes [10,29-31] that chest girth has the highest level of effect on live weight.

In the studies which estimated live weight with path analysis and using body measurements, it was observed that the path models that were established were one-equation causal models [6,8,10,30]. However, in this model, a two-equation causal model was established when estimating live weight with path analysis as the indirect effects of chest depth and rump width through chest girth were examined. The goodness of fit criteria for the model established differently from the studies abovementioned were examined and it was determined that the model met all the criteria. The body measurement with the highest direct effect on live weight was found to be chest girth (0.77); and parallel findings were observed in studies performed by Yakubu [8] with Yankasa sheep, Norris et al.[10] with native goat breeds in South Africa, Çankaya [30] with German Fawm x Hair Crossbreed goats, Dekhili and

Aggoun [32] with Ouled-Djellal breed sheep and Yunusa et al.[33] with West African Dwarf sheep. Yakubu and Mohammed [6] reported in their study with Red Sokoto goats and Tyasi et al.[34] indicated in their study with South African Indigenous sheep that body length had the highest direct effect on live weight. Ogah et al.[35] reported in their study with West African Dwarf goats that rump width had the highest direct effect on live weight. It is thought that the differences among the studies are caused by genetic factors such as types and breeds of the livestock and environmental factors such as feeding conditions, climate and area of breeding. In consideration of these differences, it was found that the most important body measurement to be considered when estimating live weight is chest girth.

Whereas multiple linear regression model is rather based on the explanation of dependent variable by independent variables, it is possible with path models to examine causal relationships among independent variables. In this study, it was shown that back length, body length, shin girth and chest girth directly affected live weight and chest depth and rump width not only had direct effects on chest girth but also indirect effects on live weight through chest girth. Beside its advantages, since path analysis allows for establishing different path models with the same dataset, there may be uncertainties about which of the models is superior; therefore, consulting expert opinion in the identification of the optimum model is of importance for the consistency and reliability of estimations. Another issue to be considered in path analysis is that causation and cause-effect relationship are not mentioned and only the concept of effect is used in a path model which is established without a theoretical basis.

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