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RESEARCH ARTICLE

Path Analysis for Determination of Relationships between Some Body Measurements and Live Weight of German Fawn x Hair Crossbred Kids

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Summary

This paper investigated direct, indirect and total effects of some body measurements on live weights of German Farm x Hair crossbred kids using path analysis. For this aim, used data were live weight (LW), chest girth (CG), height at withers (HW), front rump width (FR) and body length (BL) measurements taken from totally 40 German Farm x Hair crossbred kids at weaning period. The results indicated that CG, HW, FR and BL had statistically important effects on LW of the kids. It was also determined that both direct and total effects of CG on LW were higher than the effects of HW, FR and BL, although the indirect effect of BL on LW was the highest. Consequently, with the aim of increasing carcass yield per animal in slaughtering periods, the chest girth measurements should be used to predict the live weight of the German Farm x Hair crossbred kids.

Keywords: *Correlation, Kids, Path coefficient*

Alman Alaca x Kıl Melezi Oğlaklarının Canlı Ağırlıkları İle Bazı Vücut Ölçüleri Arasındaki İlişkilerin Belirlenmesi İçin Path Analizi

Özet

Bu çalışma path analizi kullanımı ile Alman Alaca x Kıl melezi oğlaklarının canlı ağırlıkları üzerine bazı vücut ölçümlerinin doğrudan, dolaylı ve toplam etkilerini incelemiştir. Bu amaçla kullanılan veri, toplam 40 baş Alman Alaca x Kıl melezi oğlaklarından alınan canlı ağırlık (CA), göğüs çevresi (GÇ), cidago yüksekliği (CY), ön sağrı genişliği (ÖS) ve vücut uzunluklarından (VU) oluşmaktadır. Araştırmada, oğlakların CA'sı üzerine GÇ, CY, ÖS ve VU' nun etkileri istatistiki olarak önemli bulunmuştur. Ayrıca, CA üzerine VU'nun dolaylı etkisi en yüksek bulunurken, GÇ'nin hem doğrudan hem de toplam etkisinin CY, ÖS ve VU'na göre daha yüksek olduğu belirlenmiştir. Sonuç olarak, Alman Alaca x Kıl melezi oğlaklarının kesim dönemlerindeki hayvan başına karkas verimini arttırmak amacıyla, canlı ağırlık tahminlerinde göğüs çevresi ölçüleri kullanılmalıdır.

Anahtar sözcükler: *Korelasyon, Oğlak, Path katsayısı*

INTRODUCTION

The main objective of animal breeding practices is to increase the efficiency of the animal. Breeding objectives for improving the productivity of livestock depend upon many factors [1]. Statistical analyses including more than one characteristic may be utilized for different aims related to breeding strategies. Simple correlation analysis is usually preferred by researchers for determining the degree and direction of the relationships between body measurements [2,3]. Since these variables may be interrelated, most of the problems challenging the contemporary researchers are related to whether there is any relationship between two or more variables [4].

Path analysis, developed as a method of decomposing correlations into different pieces for interpretation of effects, lets us look at more than one response variable at a time and allows for variables to be dependent with respect to some variables and independent with respect to others [5]. Path analysis is closely related to multiple regression; you might say that regression is a special case of path analysis [6]. Also,

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path analysis is used to describe the directed dependencies among a set of variables [7].

Application of path analysis in animal breeding practices began to increase with the availability of related computer packages [8-19]. To our knowledge, however, it is not founded the applications of path analysis for estimating direct, indirect and total effects of some body measurements on live weights of the kids. Accordingly, the objective of the present study was determined direct, indirect and total effects of some body measurements on live weights of German Farm x Hair crossbred kids by means of path analysis.

MATERIAL and METHODS

Material

The animal materials of this experiment were totally forty German Fawn x Hair crossbred kids (75% German Fawn + 25% Hair) which were raised at Dairy Goat Unit of Research Farm of Cukurova University. The farm is located in the east Mediterranean region of Turkey, in which subtropical weather conditions prevail with an average temperature of 35°C, 65% relative humidity and 1.1 km/h wind speed during the summer period. It is 40 m in altitude (36 59'N, 35 18'E) and annual precipitation is 450 mm. The data were the measures of live weight (LW) and 4 body measurements (chest girth (CG), height at withers (HW), front rump width (FR) and body length (BL)) of the kids at weaning period. In addition, the rule of thumb in determining the number of samples is that, a minimum of 5 times or optimum of 20 times the number of all the variables should be used. So, 40 individual measurements (25 < n <100) can be sufficient because there are four explanatory variables and a response variable in this study.

Methods

We used the path analysis in order to explore the direct, indirect and total effects of some body measurements on live weights of German Farm x Hair crossbred kids. Path coefficients, standardized versions of linear regression weights, can be used in examining the possible causal linkage between the variables [7]. A path coefficient indicates the direct comparison of values to reflect the relative importance of explanatory variables in order to explain variation in the response variable [20]. The aim of path analysis is to provide estimates of the magnitude and significance of hypothesized causal connections between sets of variables. So, the path analysis is used to determine direct and indirect effects of some body measurements on live weights in animal breeding practices. This is best explained by considering a path diagram. Path diagram is a visual tool used to explain the relationship between response variable and explanatory variables (Fig. 1).

Path analysis is an extension of the ordinary multiple regression model. The growth model for live weight of kids was expressed as power regression model. The general expression of power regression model formed for the measurements (one response and p explanatory variables) is given in Eq. 1 [21].

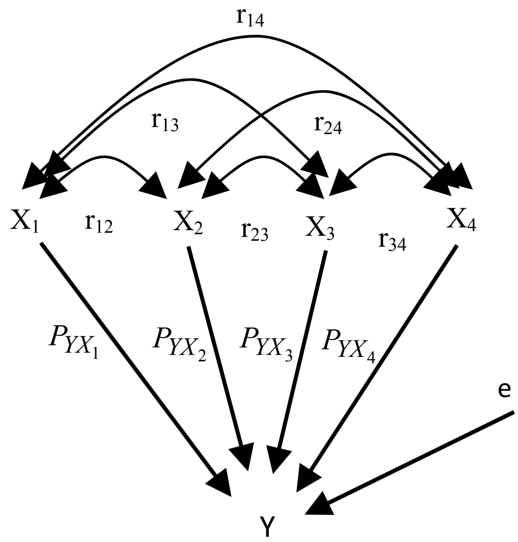

Fig 1. Path diagram for explanatory variables, X_1 to X_4, and response variable Y. P_{YXi}: path coefficient (direct effect), r_{ij}: Correlation coefficient, e: residual effect

Şekil 1. Bağımlı değişken Y ve bağımsız değişkenler X1-X4 için Path diyagramı. P_{YXi}: Path katsayısı (doğrudan etki) , r_{ij}: Korelasyon katsayısı e: Tesadüfi hata

$$y_i = \beta_0 x_{i1}^{\beta_1} x_{i2}^{\beta_2} x_{i3}^{\beta_3} \ldots x_{ip}^{\beta_p} e_i; \quad i = 1,2,\ldots,n$$

or

$$\ln y_i = \ln\beta_0 + \beta_1 \ln x_{i1} + \beta_2 \ln x_{i2} + \ldots + \beta_p \ln x_{ip} + \ln e_i \quad (1)$$

The power model require the ability to work with logarithms. A linear transformation preserves linear relationships between variables. Therefore, the correlation between x and y would be unchanged after a linear transformation [22]. So, we applied logarithmic transformation to linearize and get the following model via Ordinary Least Square (OLS) estimation technique. The prediction standardized power linear regression equation was

$$\ln\hat{y}_i = b_1 \ln x_{i1} + b_2 \ln x_{i2} + \ldots + b_4 \ln x_{i4} \quad (2)$$

where:

$\hat{y}_i$ = the predicted response variable,

b_0 = intercept of the least - squares regression line,

b_i = standardized regression coefficients,

x_{ip} = explanatory variables (CG, HW, FR and BL)

The explanatory variables were screened for multicollinearity problems using variance inflation factors (*VIF*) and tolerance values [20]. Variables with low tolerance tend to have large *VIF* (*VIF*>10) suggest that they have a collinearity [23].

In the presence of multicollinearity, it will be difficult to assess the effect of the explanatory variables on the response variable [21].

In order to calculate the standardized regression coefficients by using unstandardized variables and then multiply them by the ratio between the standard deviation of the respective explanatory variable and the standard deviation of the response variable. So, The path coefficient from an explanatory variable (X_i) to a response variable (Y) can be shown as below [12]:

$$b_i = P_{yx_i} = \hat{b}_i \frac{S_{x_i}}{S_y} \quad (3)$$

where:

$b_i = P_{yx}$ = Path coefficient or standardized regression coefficient, from X_i to Y.

$\hat{b}_i$ = Unstandardized regression coefficient,

S_{x_i} = Standard deviation of X_i

$$S_{xi} = \sqrt{\sum \left(x_{ij} - \bar{x}_i\right)^2 \cdot \frac{1}{n}} = \sqrt{\left(\sum x_{ij}^2 - \frac{\left(\sum x_{ij}\right)^2}{n}\right) \cdot \frac{1}{n}} = \sqrt{s_{xx_i}} \quad (4)$$

S_y = Standard deviation of Y

$$S_y = \sqrt{\sum \left(Y - \bar{Y}\right)^2 \cdot \frac{1}{n}} = \sqrt{\left(\sum Y^2 - \frac{\left(\sum Y\right)^2}{n}\right) \cdot \frac{1}{n}} = \sqrt{s_{yy}} \quad (5)$$

The b_i in (3) are identical to the standardized coefficient estimates obtained from OLS on the standardized variables [24].

Because, the data for all traits were standardized, obtained partial regression coefficients from the above equation are called path coefficients or standardized partial regression coefficients. Path coefficients can be easily calculated with the following solution of matrix system:

$$\begin{bmatrix} P_{YX_1} \\ P_{YX_2} \\ P_{YX_3} \\ P_{YX_4} \end{bmatrix} = \begin{bmatrix} 1 & r_{X_1X_2} & r_{X_1X_3} & r_{X_1X_4} \\ r_{X_2X_1} & 1 & r_{X_2X_3} & r_{X_2X_4} \\ r_{X_3X_1} & r_{X_3X_2} & 1 & r_{X_3X_4} \\ r_{X_4X_1} & r_{X_4X_2} & r_{X_4X_3} & 1 \end{bmatrix}^{-1} x \begin{bmatrix} r_{YX_1} \\ r_{YX_2} \\ r_{YX_3} \\ r_{YX_4} \end{bmatrix} \quad (6)$$

In the Eq. (3), coefficients given by P_{YX_i} were path coefficients (direct effects) between explanatory variable and responsible variable and $r_{X_i X_j} P_{YX_i}$ represented indirect effects of explanatory variable ith on responsible variable via explanatory variable jth, $r_{X_i X_j}$ represented pearson correlation coefficients between ith and jth traits [25].

All the computational work was performed to examine the relationships between responsible variable and explanatory variable by means of SPSS [26]. Then, path analysis was performed using MS-Excel 2003.

RESULTS

Descriptive statistics for both original and transformed data (live weight, chest girth, height at withers, front rump width, body length) in German Fawn x Hair crossbred kids were presented in *Table 1*.

Bivariate correlations displaying the relationship between the body traits and live weight are presented in *Table 2.* All bivariate correlations between live weight with chest girth, height at withers, front rump width and body length were found to be positive and statistically significant (P<0.01).

Table 3 presents the results of regression analysis, in which standardized regression coefficients, standard error, *t*, statistical significant levels, tolerance and VIF values were given to explain the relationship between the body traits and live weight of German Farm x Hair crossbred kids. It was found that all of the selected traits had significant effect on live weight (P<0.05). The traits also explained 92.4% of the

Table 1. *Descriptive statistics for examined traits of the kids*
Tablo 1. *Oğlakların incelenen özellikleri için tanımlayıcı istatistikler*

Traits	n	Mean	SD	Ln Mean	Ln SD
Live Weight	40	18.00	3,58	2.87	0,20
Chest Girth	40	56.35	3,51	4.03	0,06
Height at Withers	40	52.87	3,36	3.97	0,07
Front Rump Width	40	8.94	0,70	2.19	0,08
Body Length	40	47.86	3,61	3.86	0,08

n: *Sample Size,* ***SD:*** *Standard Deviation*

Table 2. *Bivariate correlations for some body traits and live weight of the kids*
Tablo 2. *Oğlakların canlı ağırlıkları ve bazı vücut özellikleri için basit korelasyonlar*

Traits	Live Weight	Chest Girth	Height at Withers	Front Rump Width
Chest Girth	0.899**			
Height at Withers	0.884**	0.743**		
Front Rump Width	0.830**	0.815**	0.688**	
Body Length	0.839**	0.734**	0.815**	0.629**

*** (P<0.01)*

Table 3. *The results of the Standardized Regression Analysis*
Tablo 3. *Standardize edilmiş regresyon analizi sonuçları*

Parameters	CG	HW	FR	BL
Coefficient (b_i)	0.363	0.342	0.189	0.175
Std. Error	0,088	0,084	0,078	0,081
t values	4,108	4,087	2,422	2,175
Significant Level (P)	<0.001	<0.001	0.021	0.036
Tolerance	0.249	0.277	0.320	0.298
VIF values	4.018	3.605	3.128	3.355

$R^2_{adj} = 0.924$

variance in the live weight of German Fawn x Hair crossbred kids. Moreover, because VIF values for the explanatory variables were smaller than 10, the problem of multi-collinearity was not seen *(Table 3)*. Also, F statistics showed that the regression model is statistically significant at the 1% level (F=43.222). Then, goodness of fit chi-square test was performed to check the normality assumption of error terms. It was determined that error terms have a normal distribution ($\chi^2 = 46.54 < \chi^2_{39,0.05} = 54.57$). In additional to this result, White general variance test was applied to determine whether error terms relation with explanatory variables, and it was seen that there was not hetero-scedasticity ($u_i^2 = n.R^2 = 40x0.089 = 3.56 < \chi^2_{4,0.05} = 9.49$). Std error of the estimated model is 0.275 and the value of adjusted R^2 is 0.924. It was seen that the value of adjusted R^2 increased 0.07 when double logarithmic model (power model) was used instead of linear regression model. This increase was investigated by MWD test, and the difference was ensured [27].

Path coefficients of the explanatory variables of German Farm x Hair crossbred kids were presented in *Table 4*. The direct effect of chest girth on live weight is positive and higher than the other traits. Also, its direct effect (0.363) on body weight was lower than total indirect effect (0.536, realized mostly via HW) and significant (P<0.01) as indicated by the *t*-test. Although the correlation coefficient between body length and live weight in the present study was high (r = 0.839), its direct effect (0.175) on body weight was lower than total indirect effect (0.664, realized mostly via HW) and significant (P<0.01) as indicated by the *t*-test.

body length and front rump width (0.629, P<0.01). Also, the relationship between some body traits and live weight is similar to the result of previous studies [13,14,17,28] *(Table 2)*.

It appears that chest girth had the largest effect on live weight, while body length had the least contribution to the model. There was also no multicollinearity problems among the body measurements, since preliminary analysis revealed that the VIF values were smaller than 10 and the tolerance values was greater than 0.1 in all cases *(Table 3)*.

Path analysis permits the partitioning of correlation coefficient into component parts [29]. The first component is the path coefficient (beta weight) that measures the direct effect of the explanatory variable on the response variable. The second component estimates the indirect effect of the predictor variable on the response variable through other explanatory variables [20]. According to the path analysis' results, the chest girth can be used as a forecast index on German Farm x Hair crossbred kids' weight in its selection. These findings are similar to the result of previous studies [14,17,20,28]. Moreover, the body length compared with other should not be preferred to use as a forecast index on German Farm x Hair kids' weight in its selection. This finding is similar to the result of some previous studies [17,20] while the finding is not similar to the result of some previous studies [14,28] *(Table 4)*.

The relationships between live weight and some body measurements might be misleading when path analysis is not taken into consideration. Owing to this, the path analysis is very important for determining factors affecting live weight. The path analysis' result showed that the chest girth can be used as a forecast index for German Farm x Hair crossbred kids' weight, because the direct effect of chest girth on live weight was both positive and higher than height at withers, front rump width and body length. Thus, it can be decided whether a kid can be kept in the herd in terms of its live weight at weaning period and also at the early stages of the fattening period. As a result, it can be said that the chest girth can be used 1) for management decisions and 2) as a selection criteria for meat production of German Farm x Hair crossbred kids'.

Table 4. *Direct and indirect effects of some body traits on live weight of German Farm x Hair crossbred kids*
Tablo 4. *Alman Alaca x Kıl melezi oğlaklarının canlı ağırlıkları üzerine bazı vücut özelliklerinin doğrudan ve dolaylı etkileri*

Trait	Correlation Coefficient with LW	Direct Effect	Indirect Effect				
			CG	HW	FR	BL	Total
CG	0.899**	0.363**		0.254	0.153	0.129	0.536
HW	0.884**	0.342**	0.269		0.130	0.143	0.542
FR	0.830**	0.189*	0.296	0.235		0.110	0.641
BL	0.839**	0.175*	0.266	0.279	0.119		0.664

*** (P<0.01) and * (P<0.05)*

DISCUSSION

The main utility of path analysis in the selection programs is to obtain some useful information for indirect selection. Chest girth, height at withers, front rump width and body length measurements which are frequently recorded variables in small ruminant research are important indicators for live weight of kids. The highest correlation was predicted between chest girth and live weight (0.899, P<0.01), while the lowest correlation was between

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