



Use of Factor Scores in Multiple Regression for Predicting Live Weight in Indigenous Savak Akkaraman Lambs

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ABSTRACT

The objective of this study is to predict live body weight from 12 different morphological traits measured from Savak Akkaraman lambs at three different periods (average 11 days after birth, weaning and at the beginning of grazing) using factor scores in multiple linear regressions to remove multicollinearity problem. Morphological data obtained from 159 lambs were subjected to *Kaiser-Meyer-Olkin (KMO)* and *Bartlett's Sphericity tests* to ascertain the suitability of factor score analysis. A result showed that implementation of factor analysis was appropriate for the studied data set at each period. At each period, factors whose eigenvalues which is the characteristic roots of a square matrix with $p \times p$ were higher than 1 were elected by applying the *Varimax* rotation in explanatory factor analysis. In the first period of average 11 days after birth, 2 factor scores (FS) were used as new latent predictors in order to predict live body weight in multiple linear regression model. The 2FS at the first period, 3 FS at the second period, 4 FS at the third period accounted for 80, 45 and 57 % of the total variability in live weight, respectively. The achieved results revealed that using of body measurements could allow breeders to conduct better breeding programs. Also, it is recommendable that periods in wide variability should be taken into consideration in selection program.

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Authors' Contribution

AT analysed the data statistically and wrote the article. SB conceived and designed the study. SY collected the data.

Key words

Factor scores, Multiple linear regression, Multicollinearity, Savak Akkaraman lambs.

INTRODUCTION

Sheep plays an important position in the enhancement of the rural economy and it is one of the small ruminants that can adapt to harsh climatic conditions in Turkey. In domestic sheep breeding, it is necessary to define the very variable associations between age, body weight and body measurements to select better animals in order to achieve more genetic improvement on reproductive efficiency especially rural conditions for ascertaining feeding amount, medicinal dose and marketing high price of a sheep when weighting device is not available under rural conditions (Eyduran *et al.*, 2010). In sheep breeding, there is a growing interest in describing the relationships between live weight and morphological traits for meat productions in order to improve breeding evolution for long years (Aksoy *et al.*, 2019). The morphological traits, which may be affected by genetic and non-genetic factors, are indirect selection criteria in the improvement of live body weight over generations as a result of high genetic correlations. In addition to, numerous studies have been carried out on forecast of body weight from morphological

characteristics in different sheep breeds (Cankaya *et al.*, 2009; Keskin *et al.*, 2007a, b; Sangun *et al.*, 2009; Eyduran *et al.*, 2009, 2010; Ogah *et al.*, 2009; Yakubu, 2009). However, some authors emphasized the adverse effect of severe multicollinearity, as a result of very high correlations between the handled predictors, on regression parameters; in this case, wrong biological interpretations can be made.

When the estimation of live body weight by means of morphological traits in sheep was considered, reliability of the prediction procedure depends on selecting effective statistical methods. Use of several statistical methods has been adopted such as multiple linear regressions, Pearson correlation, simple regression, nonlinear regression etc. for description of the relationship between body traits. However, these methods can be insufficient in the explanation of complex relationships between predictors and multicollinearity problem may be occurred if the data set is large and complex. In the elimination of the multicollinearity problem occurring owing to very strongly correlations among morphological traits, several earlier reports about joint use of multiple linear regression analysis and factor analysis have been finding recent years (Eyduran *et al.*, 2009; Khan *et al.*, 2014). Using factor scores analysis in multiple regression analysis make available an acceptable opportunity of both obtaining

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uncorrelated-meaningful latent-new independent variables, derived as factor scores from original leashed independent variables, and eliminating multicollinearity problem for ensuring reliability of regression coefficients, as also described previously by many researchers (Eyduran *et al.*, 2009, 2010; Keskin *et al.*, 2007a, b). Eyduran *et al.* (2009) predicted live body weight by means of some morphological traits *i* at weaning period.

On the other hand, there is still lack of information about predicting the live body weight from morphological traits in Savak Akkaraman lambs by means of jointly using factor and multiple regression analyses; therefore the previous report on predicting body weight by morphological traits in the Savak Akkaraman sheep has not yet been found recently. To reveal standard of this breed, the obtainment of more detailed information is still necessary. Hence, the current study was carried out to predict live body weight from more than a few morphological traits at each of three

different periods through factor scores in multiple linear regression models.

MATERIALS AND METHODS

In the present study, the current data consisted of 477 head Savak Akkaraman lambs, which included both genders from different ages ranging from 2 to 8 years. Also the present data was provided from four enterprises between the years 2012 and 2016. Morphological traits at each period were body length (BL), tail length (TL), shin circumference (SC), withers height (WH), chest depth (CD), chest girth (CG), rump width (RW), rump height (RH), head width (HW), head length (HL), ear width (EW) and ear length (EL) as predictors. All the morphological traits for all the lambs were measured at three periods; namely, 11 days age (first period), weaning (second period) and at the beginning of grazing (third period).

Table I.- Pearson's correlation coefficients for after birth period (first period).

	LW	BL	WH	CG	CD	RH	RW	HL	HW	EL	EW	TL
BL	0.828**											
WH	0.798**	0.777**										
CG	0.872**	0.844**	0.833**									
CD	0.797**	0.792**	0.773**	0.863**								
RH	0.826**	0.767**	0.887**	0.848**	0.771**							
RW	0.762**	0.775**	0.654**	0.714**	0.685**	0.630**						
HL	0.625**	0.614**	0.540**	0.538**	0.531**	0.559**	0.621**					
HW	0.607**	0.600**	0.601**	0.610**	0.575**	0.583**	0.461**	0.490**				
EL	0.465**	0.473**	0.570**	0.549**	0.529**	0.546**	0.462**	0.363**	0.296**			
EW	0.556**	0.554**	0.576**	0.632**	0.586**	0.601**	0.482**	0.435**	0.409**	0.727**		
TL	0.617**	0.589**	0.625**	0.682**	0.651**	0.649**	0.441**	0.319**	0.461**	0.392**	0.463**	
SC	0.584**	0.591**	0.578**	0.592**	0.578**	0.556**	0.519**	0.432**	0.468**	0.270**	0.297**	0.440**

** , Correlation is significant at the 0.01 level (2-tailed).

Table II.- Pearson's correlation coefficients for weaning period (second period).

	LW	BL	WH	CG	CD	RH	RW	HL	HW	EL	EW	TL
BL	0.567**											
WH	0.592**	0.690**										
CG	0.637**	0.601**	0.760**									
CD	0.331**	0.265**	0.366**	0.446**								
RH	0.617**	0.646**	0.809**	0.755**	0.376**							
RW	0.412**	0.616**	0.470**	0.421**	0.198*	0.521**						
HL	0.346**	0.459**	0.473**	0.542**	0.179*	0.516**	0.437**					
HW	0.159*	0.134	0.161*	0.209**	0.088	0.156*	0.206**	0.335**				
EL	0.237**	0.458**	0.363**	0.222**	0.138	0.348**	0.419**	0.202*	0.035			
EW	0.100	0.237**	0.222**	0.134	0.057	0.184*	0.200*	0.214**	0.105	0.583**		
TL	0.309**	0.374**	0.380**	0.430**	0.189*	0.520**	0.383**	0.438**	0.074	0.158*	0.047	
SC	0.475**	0.511**	0.411**	0.439**	0.216**	0.381**	0.460**	0.350**	0.093	0.156*	0.059	0.314**

*, Correlation is significant at the 0.05 level (2-tailed). **, Correlation is significant at the 0.01 level (2-tailed).

Table III.- Pearson's correlation coefficients for beginning of grazing period (third period).

	LW	BL	WH	CG	CD	RH	RW	HL	HW	EL	EW	TL
BL	0.244**											
WH	0.670**	0.361**										
CG	0.666**	0.301**	0.674**									
CD	0.465**	0.347**	0.566**	0.683**								
RH	0.659**	0.344**	0.790**	0.690**	0.635**							
RW	0.238**	0.160*	0.293**	0.395**	0.233**	0.314**						
HL	0.484**	0.151	0.339**	0.439**	0.451**	0.438**	0.192*					
HW	0.580**	0.284**	0.493**	0.496**	0.504**	0.532**	0.228**	0.462**				
EL	0.311**	0.012	0.353**	0.252**	0.121	0.333**	0.357**	0.245**	0.149			
EW	0.458**	0.205**	0.407**	0.332**	0.327**	0.409**	0.166*	0.334**	0.281**	0.516**		
TL	0.171*	0.221**	0.370**	0.252**	0.165*	0.165*	0.238**	-0.091	0.174*	0.117	0.083	
SC	0.061	0.011	0.060	0.134	0.005	0.113	0.174*	0.086	0.168*	0.058	0.024	0.008

*, Correlation is significant at the 0.05 level (2-tailed). **, Correlation is significant at the 0.01 level (2-tailed).

Firstly, Kaiser-Meyer-Olkin (KMO) is used for sample adequacy and homogeneity of predictors in explanatory factor analysis. Secondly, Bartlett's test of sphericity is employed to test whether correlation matrix is an identity matrix. Both of tests were performed to determine whether explanatory factor analysis is appropriate for the evaluated data sets. VARIMAX rotation is used to remove multicollinearity problems among raw predictors to interpret easily factor loadings. Factor loading is defined as Pearson correlation coefficient between a morphological trait and a factor score variable.

According to Sharma (1996), the basic matrix form of factor analysis can be presented:

$$Z = \lambda F + \varepsilon \dots\dots (1)$$

Where; ε is a $p \times 1$ vector of error or residual factors, F is an $m \times 1$ vector of factors, λ is a $p \times m$ matrix of factor loadings and Z is a $p \times 1$ vector of variables (Sharma, 1996).

The number of factor was determined in terms of eigenvalues. The factors whose eigenvalues were larger than one were selected. These uncorrelated factor scores welded from explanatory factor analysis were used as new predictors for predicting live weight of the sheep in the multiple linear regressions (Eyduran *et al.*, 2009). The following prediction equations regarding new multiple linear regressions for each period are written:

The first period (app. 11 days):

$$LW = a + b_1FS_1 + b_2FS_2 + e$$

The second period (weaning period):

$$LW = a + b_1FS_1 + b_2FS_2 + b_3FS_3 + e \text{ and}$$

The third period (at the beginning of grazing):

$$LW = a + b_1FS_1 + b_2FS_2 + b_3FS_3 + b_4FS_4 + e$$

Where, a is regression constants (becoming equal to zero),

b_1, b_2, b_3 and b_4 are regression slopes (coefficients) of factor scores (FS) and e is error term. Determination of coefficient (R^2) is used for assessing predictive accuracy of the multiple linear regressions. Variance inflation factor (VIF) was used to capture multicollinearity problem. VIF is advised to be less than 10 (Beyhan *et al.*, 2016).

All the statistical evaluations were done using Minitab (2014) statistical package programs.

Table IV.- Results of Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity.

	KMO test	Bartlett's test
First period	0.93	0.000
Second period	0.86	0.000
Third period	0.83	0.000

RESULTS AND DISCUSSION

Pearson's correlation coefficients between all couple of live body weight and all morphological traits are depicted in Tables I, II and III, respectively. Live body weight (LW) was positive-high correlated with all the body traits for each period ($p < 0.01$). Thus, it was tried to obtain evidence for multicollinearity problem at initial stage. Kaiser-Meyer-Olkin (KMO) criteria of sampling adequacy for after birth, weaning and grazing period were found to be 0.93, 0.86 and 0.83 (Table IV). Another criterion, Bartlett's test of sphericity results revealed that the explanatory factor analysis was suitable for the studied data sets ($p < 0.01$), which was in agreement with those (0.892 KMO and Bartlett test, $p < 0.01$) reported by Eyduran *et al.* (2009) at weaning period. They informed that the studied body traits (*i.e.* body length, body depth, withers height, chest circumference, and width of chest

behind shoulders) had a positive effect on weaning weight. Similarly, the current findings supported the statement of Eyduran *et al.* (2009) at weaning period.

Table V.- Results of factor analysis for first period.

Variable	Factor score coefficients		Rotated factor loadings and communalities		
	F1	F2	F1	F2	Communality
BL	0.173	0.046	0.824	-0.377	0.821
WH	0.103	-0.062	0.787	-0.500	0.869
CG	0.112	-0.056	0.786	-0.018	0.618
CD	0.115	-0.041	0.761	-0.465	0.795
RH	0.095	-0.073	0.754	-0.490	0.810
RW	0.146	0.029	0.746	-0.501	0.808
HL	0.159	0.078	0.723	-0.157	0.548
HW	0.219	0.165	0.721	-0.345	0.639
EL	-0.273	-0.572	0.651	-0.239	0.481
EW	-0.218	-0.503	0.596	-0.392	0.509
TL	0.079	-0.052	0.183	-0.895	0.835
SC	0.296	0.289	0.287	-0.855	0.814
Variance			5.5582	2.9880	8.5462
%Variance			0.463	0.249	0.712

The results of the rotated factor loadings and communalities and factor score coefficients in explanatory factor analysis for each period are shown in Tables V, VI and VII, respectively. Also, Table VIII presents results of multiple linear models built for factor scores and live body weights at three periods. As recommended by

Khan *et al.* (2014) and Eyduran *et al.* (2009), when the pair of regression coefficients and rotated factor loadings have same mathematical signs (++ or --), it can be said that the examined raw predictors, morphological traits, will positively increase live body weight. In this regard, all morphological traits at weaning period affected increasingly weaning weight when considering the signs of factor loadings and regression coefficients in Tables V and VIII. From the Table V, it was understood that CG, WH, BL, CD, RW, HW, RH, HL, EW and EL contributed to formatting the first factor at the first period, whereas TL and SC also made the major contribution to the second factor at the first period. In the study, a bit more than 80% (R^2 and adjusted R^2) of total variability in the first period weight was explicated by both factors. However, corresponding values at the remaining periods were lower.

At the second period, RH (0.846), CG (0.842), WH (0.818), BL (0.737), SC (0.614), TL (0.609), RW (0.573) and CD (0.548) loaded on the first factor (Table VI). In Table VIII, positive regression coefficient of the fs1 at second period was significant ($p < 0.01$). Lambs with larger values in the eight morphological traits would be expected to be heavier at the second period. EL (-0.870) and EW (-0.859) in Table VI significantly contributed to the formation of the second factor. In Table VIII, negative regression coefficient of the fs2 at second period was found significant ($p < 0.05$). This means that lambs that have higher in EL and EW would be expected to be heavier. In Table VIII, regression coefficient of the fs3 at second period was non-significant, meaning that there was no need of implementing HW and HL.

Table VI.- Results of factor analysis for second period.

Variable	Factor score coefficients			Rotated factor loadings and communalities			
	F1	F2	F3	F1	F2	F3	Communality
RH	0.211	0.014	0.057	0.846	-0.201	-0.119	0.771
CG	0.221	0.103	-0.002	0.842	-0.064	-0.177	0.744
WH	0.200	-0.024	0.081	0.818	-0.250	-0.090	0.741
BL	0.152	-0.118	0.066	0.737	-0.379	-0.098	0.696
SC	0.167	0.077	0.023	0.614	-0.041	-0.101	0.389
TL	0.164	0.117	-0.036	0.609	0.018	-0.163	0.398
RW	0.075	-0.126	-0.103	0.573	-0.364	-0.255	0.525
CD	0.199	0.099	0.210	0.548	0.030	0.128	0.318
EL	-0.060	-0.519	0.131	0.224	-0.870	0.048	0.810
EW	-0.162	-0.540	-0.062	-0.012	-0.859	-0.121	0.753
HW	-0.156	0.040	-0.793	0.030	-0.023	-0.903	0.817
HL	0.040	0.027	-0.406	0.533	-0.141	-0.576	0.636
Variance				4.3490	1.9020	1.3461	7.5971
%Variance				0.362	0.159	0.112	0.633

Table VII.- Results of factor analysis for third period.

	Factor score coefficients				Rotated factor loadings and communalities				
	F 1	F 2	F 3	F 4	F1	F2	F3	F4	Communality
CD	0.28	-0.124	0.055	-0.117	0.838	0.07	-0.046	-0.052	0.712
RH	0.199	0.039	0.01	-0.015	0.795	0.308	-0.111	0.079	0.745
CG	0.199	-0.036	-0.047	0.077	0.779	0.21	-0.18	0.175	0.714
HW	0.233	-0.132	0.101	0.13	0.728	0.051	0.02	0.21	0.578
WH	0.149	0.067	-0.179	-0.078	0.723	0.33	-0.338	0.011	0.746
HL	0.203	0.06	0.423	0.044	0.624	0.263	0.433	0.114	0.659
BL	0.176	-0.186	-0.245	-0.161	0.518	-0.107	-0.37	-0.136	0.435
EL	-0.186	0.609	-0.014	0.029	0.054	0.902	-0.067	0.116	0.835
EW	-0.017	0.449	0.106	-0.193	0.336	0.725	0.059	-0.127	0.658
TL	-0.06	-0.014	-0.657	0.001	0.14	0.07	-0.849	0.041	0.748
SC	-0.022	-0.126	0.081	0.795	0.069	-0.064	0.07	0.888	0.802
RW	-0.09	0.181	-0.242	0.391	0.193	0.389	-0.362	0.496	0.566
Variance					3.8294	1.8362	1.3514	1.1812	8.1983
%Variance					0.319	0.153	0.113	0.098	0.683

Table VIII.- MRA results of factors for each period.

	Var.	Coef.	SE Coef.	T-Value	VIF
FP	fs1	0.8086**	0.0352	22.99	1.00
	fs2	-0.3913**	0.0352	-11.12	1.00
S=0.442142 ; R ² =80.70%; R ² _{adj} =80.45%					
SP	fs1	0.6611**	0.0591	11.19	1.00
	fs2	-0.1140*	0.0591	-1.93	1.00
	fs3	-0.0949 ^{NS}	0.0591	-1.61	1.00
S=0.742605 ; R ² =45.90%; R ² _{adj} =44.85%					
TP	fs1	0.6713**	0.0535	12.56	1.00
	fs2	0.3242**	0.0535	6.06	1.00
	fs3	-0.0362 ^{NS}	0.0535	-0.68	1.00
	fs4	0.0543 ^{NS}	0.0535	1.02	1.00
S=0.671891 ; R ² =56.00%; R ² _{adj} =54.86%					

At the third period, it is meaningful to consider only the significantly initial two factors and corresponding morphological traits (CD, RH, CG, HW, WH, HL, and BL strongly contributing to the formation of the first factor, and EL and EW significantly contributing to formatting the second factor). Lambs that have higher values in CD, RH, CG, HW, WH, HL, BL, EL and EW would be expected to be heavier at the last period.

Results of similar studies on factors scores with multiple linear regression models on different species were reported. Khan *et al.* (2014) employed factor scores in MLRA in order to predict body weight from different morphological traits, and reported that factor scores (new derived predictors) were significant contributors (92.0 % R² and Adjusted % 91.9 R²) for the female Harnai sheep and (87.8 % R² and Adjusted % 87.6 R²) for male Harnai sheep. Jahan *et al.* (2013), in Balochi male sheep, reported 91.1% R² of the variability in BW from TL, SL, SC, BL, WH and HG in the Balochi male sheep. Variability of

88.5% on body weight of male sheep was explained by four factors, as for female sheep, variability of 93.8% was explained. Tariq *et al.* (2012) used factor scores in multiple regression analysis with the intention of predict body live weight of Mengali sheep and recorded that 79.1% of the variability in body weight was described by three new-latent variables. Cankaya *et al.* (2009) developed a useful equation for predicting the weaning period for 101 head Karayaka lambs and stated that 73.1% of total variability in weaning weight was clarified by the five uncorrelated variables through same combined approach.

Eyduran *et al.* (2009) mentioned that approximately 80% of total variability in predicting weaning weight of Norduz lambs was accounted for by three latent variables by using factor scores in multiple regression model. Riva *et al.* (2004) revealed the relationships among body measurements using factor scores on adult and young Bergamasca sheep, and informed that the results were changed different husbandry system (transhumance and sedentary system). In Yakubu (2009) obtained two factors that explained 87.53% of the total variability in the body measurements of chickens with Varimax rotation factor analysis. The results obtained from the current study at first period were in conformance with those stated by Tariq *et al.* (2012) and Eyduran *et al.* (2009); however, were lower than those found by some previous researchers (Khan *et al.*, 2014; Jahan *et al.*, 2013; Cankaya *et al.*, 2009).

In agreement with the current study, many authors also reported that use of factor scores analysis in multiple linear regression modeling removed multicollinearity problem (Keskin *et al.*, 2017a, b; Cankaya *et al.*, 2009; Yakubu, 2009; Eyduran *et al.*, 2009, 2010; Jahan *et al.*, 2013; Khan *et al.*, 2014; Beyhan *et al.*, 2016).

The difference of results may be attributed breed,

rearing systems and various non-genetic factors and age of sheep *etc.* In literature, there have been several studies reported for various sheep breeds on the estimation of live weight from several morphological traits by means of factor scores in multiple regression analysis but the present paper was the initial record on body weight prediction of Savak Akkaraman Lambs.

CONCLUSION

The relationship between body measurements and live weight of the Savak Akkaraman lambs were examined reliably using multivariate statistical technique (factor analysis) together with multiple linear regressions to remove multicollinearity problem as a result of very strong correlations between morphological traits. Morphological traits positively affecting the live body weight could be considered as indirect selection criteria for producing heavier lambs. As a result, it is recommendable to jointly use of factor analysis with multiple linear regression for eliminating the multicollinearity problem at especially the first period.

Statement of conflict of interest

The authors declare no conflict of interest.

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