



Full Length Article

Use of Factor Scores in Multiple Regression Analysis for Estimation of Body Weight by Several Body Measurements in Brown Trouts (*Salmo trutta fario*)

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ABSTRACT

This study was conducted to estimate body weight from several biometrical traits viz. total and fork lengths, body height, head length, adipose fin width and adipose fin length of *Salmo trutta fario* trouts. A sample of 140 *Salmo trutta fario* trouts (70 male & 70 female) was used in this investigation. First, only multiple regression analyses were applied to the data on each gender that caused to multicollinearity problem. In order to eliminate multicollinearity problems, multiple regression analysis after factor analysis was used for each fish gender data. Thus the problems were removed by using factor scores in multiple regression analyses. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were used to prove whether factor analysis was appropriate for analysis of both genders. According to these two criteria, the data were fit for application of factor analysis. Three factors with eigenvalues greater than one were selected as independent variables for multiple regression analysis. It was concluded that fish body weight increased when total length, fork length, body height, head length, adipose fin width and length increased. Use of biometrical measurements such as total and fork lengths body height, head length, adipose fin width and length for breeding purposes might provide valuable information on improvement of body weight. © 2010 Friends Science Publishers

Key Words: Factor analysis; Varimax rotation; Multicollinearity; Multiple regression analysis; *Salmo trutta fario* trouts

INTRODUCTION

Knowledge on the relationships among body weight and several body measurements is essential for fish breeding. These biometrical measurements, influenced by genetic and environmental factors, may be used as indirect selection criteria in order to determine the suitability of fish for selection. These relationships may present substantial information on early selection of the fish for breeding.

To determine complex multivariate relationships, estimation of Pearson correlations between biometrical traits and body weight and estimation of body weight from these body measurements using only multiple regression analysis may be insufficient. Interpretation of results obtained from multiple regression analysis may be inaccurate in consequence of multicollinearity problem. However, factor scores for multiple regression models are used to eliminate multicollinearity problem. Multiple regression analysis, after factor analysis, is applied for available data.

Factor analyses are used to reduce a large number of observed variables to a smaller number of factors and to provide an operational definition (regression equation) for an underlying process by observed variables. Factor scores

are nearly uncorrelated. Hence the use of factor scores as the variables in other analyses is possible and may be very helpful (Tabachnick & Fidell, 2001). In small ruminants, few reports on using factor scores for multiple regression analysis were found (Riva *et al.*, 2004; Keskin *et al.*, 2007a & b; Eyduram *et al.*, 2009), whereas there was only a report on combining factor analysis and multiple regression analysis in fishery science (Sangun *et al.*, 2009). However, no reported information on using factor scores in multiple regression analysis for predicting weight of brown trouts (*Salmo trutta fario*) from different biometrical traits was found.

The aim of this study is to estimate body weight from several body measurements (total & fork lengths, body height, head length, adipose fin length & width) in brown trouts (*Salmo trutta fario*). Here factor scores in multiple regression analysis were used to obtain an accurate estimation function from available data.

MATERIALS AND METHODS

Biometrical characteristics i.e., total (TL) and fork lengths (FL), body height (BH), head (HL) and adipose fin

lengths (AFL), adipose fin width (AFW) and body weight (BW) of brown trouts (*Salmo trutta fario*) raised in Erzurum conditions were used in this study. Measurements of the biometrical characteristics belonging to a sample of 140 fish (70 male and 70 female) on four-year-old brown trouts were used. To obtain biometrical measurements, fish were made unconscious using MS222 anesthesia. Total and fork lengths, body height, head length (HL) (cm), adipose fin width and length values of fish were measured by compass and body weight were taken with a weighing balance.

Multiple regression analysis for each gender was used to estimate body weight from body measurements. Factor scores obtained from factor analysis were used for multiple regression analysis in order to eliminate multicollinearity problem. Independent variables (body measurements) were exposed to Factor analysis and factor scores from factors with eigen values greater than one were considered as independent variables in multiple regression analysis. Fish body weights were standardized as a dependent variable. Finally multiple regression analysis was used for standardized body weight and factor scores. Kolmogorov-Smirnov normality test was applied for dependent variable and independent variables. All these variables were normally distributed. Factor analysis was performed using seven body measurements to rank their relative significance and describe possible patterns of interrelationship with regards to body weight.

The factor analysis equation can be written in matrix form:

$$Z = \lambda F + \varepsilon$$

Where Z is a px1 vector of variables, λ is a pxm matrix of factor loadings, F is an mx1 vector of factors and ε is a px1 vector of error or residual factors (Sharma, 1996). Because of differences in the units of variables used in factor analysis, the variables were standardized and a correlation matrix of variables was used to obtain eigenvalues. In order to facilitate interpretation of factor loadings (L_{ik}), VARIMAX rotation was used. Factor coefficients (C_{ik}) were used to obtain factor scores for selected factors. Factors with eigenvalues greater than one were employed in multiple regression analysis (Eyduran *et al.*, 2009).

The suitability of factor analysis was determined by two criteria viz. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy as a measure of homogeneity of variables (Sharma, 1996). A KMO measure of above 0.60 is acceptable for factor analysis and Bartlett's test of sphericity tests whether the correlation matrix is an identity matrix, which would indicate that the factor model is inappropriate.

Score values of selected factors, as independent variables, were used for estimating body weight. The regression equation fitted to "standardized body weight" and "factor score values" is given below:

$$BW = a + b_1FS_1 + b_2FS_2 + b_3FS_3 + e \text{ (for each gender)}$$

Where a, is regression constant (it is the value of intercept & its value is zero); b_1 , b_2 and b_3 are regression coefficients of Factor Scores (FS). FS is factor score and e is the error term. Regression coefficients were tested by a t-statistic. The quality of the regression was measured by the coefficient of determination (R^2) (Draper & Smith, 1998).

Difference between male and female for each biometrical trait was tested by independent samples t test. VIF (Variance inflation factor) are used as an indicator of multicollinearity. VIF for each independent variable should be less than 10. All statistical analyses were performed using MINITAB and SPSS statistical package programs.

RESULTS AND DISCUSSION

Descriptive statistics for each biometrical trait are given as mean and standard error (SE) in Table I. The differences between male and female means for all the traits were significant. The average values of male fish for all characteristics were higher than those of female fish. Pearson correlation coefficients between body weight and TL, FL, BH, HL, AFW were found positive and no significant correlation between body weight and AFL was noted in the male trouts. Correlations coefficients among all the biometrical traits were found positive and statistically significant in the female trouts. The highest correlation was determined between TL and FL in male and female trouts. However, the lowest correlations were found to be between AFL and FL for male trout and between AFW and HL for female trout (Table II).

Results of regression coefficient, their SE values, VIF values, R^2 , adjusted R^2 , mean square error (MSE) obtained from multiple regression analysis for male and female trouts are presented in Table III. Independent variables (TL, FL, BH, HL, AFW & AFL) explained variations in fish body weights (76.4% for male & 63.7% female trouts). The regression of body weight on TL and HL in male and BH, AFW and AFL in female trouts were significant. Because VIF values of TL and FL were larger than 10, there was multicollinearity problem in multiple regression analysis for male and female trouts. Application of multiple regression analysis produced inaccurate interpretations. In order to solve the multicollinearity problem and to perform a reliable regression analysis, factor scores derived from factor analysis, as independent variables, should be used for multiple regression analysis.

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy values for male and female trouts were found around 70% (Sharma, 1996). Results of Bartlett's Test of Sphericity were 315.57 and 377.55 for male and female fish. According to these results, it could be said that available data sets were suitable for factor analysis (Sharma, 1996).

Results of factor analyses for both genders of fish are summarized in Table IV and V. When results of factor analysis were taken into consideration, 3 of 6 factors had eigen values greater than one for both the genders. These

Table I: Descriptive statistics (mean ± SE) for all the biometrical traits

Biometrical Trait	Gender	n	Mean	SE	P
Total length	Male	70	42.802	0.318	**
	Female	70	41.407	0.339	
Fork length	Male	70	39.196	0.285	**
	Female	70	37.760	0.340	
Body height	Male	70	9.766	0.0679	**
	Female	70	9.234	0.111	
Head length	Male	70	9.963	0.114	**
	Female	70	9.201	0.0874	
Adipose fin width	Male	70	3.440	0.0592	**
	Female	70	2.560	0.0381	
Adipose fin length	Male	70	1.786	0.0321	**
	Female	70	1.399	0.0282	
Body weight	Male	70	1.023	0.0244	*
	Female	70	0.948	0.0227	

*: P<0.05; **: P<0.01

Table II: Pearson Correlation coefficient between body weight and other traits for male and female trouts

Sex	Variables	Total Length	Fork Length	Body Height	Head Length	Adipose Fin Width	Adipose Fin Length
Male	Fork length	0.976**					
	Body height	0.597**	0.586**				
	Head length	0.409**	0.415**	0.564**			
	Adipose fin width	0.373**	0.339**	0.448**	0.243*		
	Adipose fin length	0.156	0.149	0.285*	0.219	0.691**	
	Body weight	0.853**	0.821**	0.541**	0.490**	0.404**	0.189
Female	Fork length	0.980**					
	Body height	0.556**	0.569**				
	Head length	0.490**	0.495**	0.729**			
	Adipose fin width	0.290**	0.340**	0.282*	0.258*		
	Adipose fin length	0.341**	0.365**	0.337**	0.279*	0.806**	
	Body weight	0.702**	0.709**	0.637**	0.490**	0.369**	0.290*

Table III: Results of Multiple Regression analysis for male and female trouts

Variables	Gender					
	Male			Female		
	Coefficient	SE Coefficient	VIF	Coefficient	SE Coefficient	VIF
Intercept	-1.7724**	0.2434		-1.1371**	0.2634	
Total length	0.07760**	0.02212	22.2	0.02513	0.02649	27.3
Fork length	-0.02021	0.02426	21.4	0.00979	0.02674	28.0
Body height	-0.02844	0.03182	2.1	0.09531**	0.02438	2.5
Head length	0.04246*	0.01615	1.5	-0.04603	0.02910	2.2
Adipose fin width	0.04957	0.03907	2.4	0.21057**	0.07932	3.1
Adipose fin length	-0.02793	0.06603	2.0	-0.2295*	0.1065	3.0

For male; S=0.1039, R²=0.764, MSE=0.011 Adjusted & R² = 0.742. For female; S = 0.1195, R² = 0.637, MSE=0.014 Adjusted & R² = 0.602

*: P<0.05; **: P<0.01.

three factors were selected as independent variables for multiple regression analyses. The selected factors for male and female trouts explained 88.7 and 92.1% of total variation, respectively in factor analysis. Variance proportions explained by first factor, second factor, and third factor for male trouts were found as 0.362 (2.1746/6), 0.289 (1.7354/6) and 0.235 (1.4121/6), respectively. Variance proportions accounted for by first, second and third factors for female trouts were estimated to 0.327 (1.9595/6), 0.304 (1.8258/6) and 0.290 (1.7379/6), respectively. Factors may be interpreted from the variables that are highly correlated with them. After orthogonal rotation, the value of loading exhibited correlations between variables and corresponding factors. The bold marked loads indicate the highest correlations between variables and

corresponding factors. The higher factor loads represented better variables that were characterized by factors. For both genders, TL and FL were traits having the highest correlation with Factor 1. In factor 2, the highest correlation coefficients between factor 2-AFL along with factor 2-AFW were found in both the genders. Community values for male and female trouts were very large. Factor score values for each fish were calculated by factor scores coefficients.

After factor score values were obtained from three factors, the score values were used as independent variables and body weight was considered as a dependent variable. For each gender, results of multiple regression analyses for these variables are given in Table VI. When probabilities were taken into consideration, the regressions of standardized body weight on factor 1 (P<0.01), factor 2

Table IV: Results of factor analysis for male trout

Variables	Factor Score Coefficients (c_{ik})			Rotated Factor Loadings (l_{ik}) and Communalities			
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	Communality
Total length	0.530	-0.056	-0.175	0.957	0.124	0.215	0.977
Fork length	0.528	-0.073	-0.164	0.954	0.100	0.222	0.969
Adipose fin length	-0.154	0.593	-0.029	-0.010	0.922	0.130	0.868
Adipose fin width	0.038	0.538	-0.146	0.265	0.879	0.114	0.857
Head length	-0.262	-0.130	0.885	0.176	0.088	0.937	0.917
Body height	0.047	0.018	0.415	0.498	0.279	0.639	0.735
Variance				2.1746	1.7354	1.4121	5.3222
% Variance				0.362	0.289	0.235	0.887

Table V: Results of factor analysis for female trout

Variables	Factor Score Coefficients (c_{ik})			Rotated Factor Loadings (l_{ik}) and Communalities			
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	Communality
Total length	0.601	0.085	0.171	0.942	-0.148	-0.284	0.990
Fork length	0.558	0.057	0.172	0.934	-0.190	-0.285	0.989
Adipose fin width	-0.090	-0.057	0.074	0.130	-0.936	-0.115	0.906
Adipose fin length	-0.074	-0.055	0.055	0.167	-0.922	-0.151	0.901
Head length	-0.233	0.069	-0.686	0.218	-0.123	-0.906	0.884
Body height	-0.125	0.054	-0.582	0.329	-0.161	-0.848	0.853
Variance				1.9595	1.8258	1.7379	5.5232
% Variance				0.327	0.304	0.290	0.921

Table VI: Results of multiple regression analysis for male and female trouts

Predictor	Male					Female				
	Coef	SE Coef	T	P	VIF	Coef	SE Coef	T	P	VIF
Factor 1	0.76931	0.06562	11.72	0.000	1.0	0.60482	0.08227	7.35	0.000	1.0
Factor 2	0.16852	0.06562	2.57	0.012	1.0	-0.20552	0.08227	-2.50	0.015	1.0
Factor 3	0.30915	0.06562	4.71	0.000	1.0	-0.38104	0.08227	-4.63	0.000	1.0

For male; $S = 0.5451$, $R^2 = 0.716$ & Adjusted $R^2 = 0.703$. For female; $S = 0.6834$, $R^2 = 0.553$ & Adjusted $R^2 = 0.533$

($P < 0.05$) and Factor 3 ($P < 0.01$) were statistically significant. In male trouts, 71.6% of variation in body weight was explained by all three factors (Table VI). Positively significant effects factor 1, 2, and 3 on body weight were found in male trouts. In female trouts, factor 1 had a positive effect on body weight, whereas, whereas factor 2 and 3 had negative effect. Fish body weight increased with increasing score values of factors with positive effect.

In male gender, body weight led to increase:

- i. With increasing TL and FL in factor 1 (Table IV)
 - ii. With increasing AFL and AFW in factor 2 (Table IV)
 - iii. With increasing HL and BH in factor 3 (Table IV).
- That is, body weight increased with an increase in each of six traits.

In female trouts, body weight led to increase:

- i. With increasing TL and FL in factor 1 (Table V)
- ii. With increasing AFW and AFL in factor 2 (Table V)
- iii. With increasing HL and BH in factor 3 (Table V).

AFW and AFL along with HL and BH variables are negatively correlated with factors 2 and 3 in Table V as well as regression coefficients (-0.20552 & -0.38104) of factors 2 and 3 had negative values in female trouts (Table V & VI). Multiplication of a negative value by another negative value becomes a positive value. For VIF values in Table VI were reduced to 1, multicollinearity problems were eliminated.

There was a reported study on the use of factor scores in multiple regressions in aquaculture.

In a study by Sangun *et al.* (2009) body weights of Lizardfish was estimated by several body measurements (total, standard, fork & head lengths, body depth, body circuit & body height). For this aim, factor analysis scores in multiple regression models were used. They reported that 98.4% of total variation in the body weight was explained by three selected factors, which were greater than one. Findings on eliminating multicollinearity problem were in consistent with those reported by other authors (Riva *et al.*, 2004; Keskin *et al.*, 2007a & b; Eydurán *et al.*, 2009; Sangun *et al.*, 2009).

CONCLUSION

Body weight from several biometrical characteristics in trouts can be estimated by using univariate and multivariate models for selection of trouts with high body weight for fish breeding programs. If confirmed at genetic level, result on biometrical traits for male and female trouts might allow researchers to improve body weight for fish breeding.

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