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Prediction of Hamstring and Quadriceps Muscle Strength Using Multiple Linear Regression

Hamstring ve Kuadriseps Kas Gücünün Çoklu Doğrusal Regresyon Kullanılarak Tahmin Edilmesi

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Abstract
The strength of hamstring and quadriceps muscles plays an important role for athletes and sportspeople in determining their performance. The purpose of this study is to predict the hamstring and quadriceps muscle strength using Multiple Linear Regression (MLR). The dataset used for this study includes the data of 70 athletes consisting of the features gender, sports branch, height, weight and age, as well as the hamstring and quadriceps muscle strength values measured with two types of activities (static training and classic training) used as the target variables. MLR has been used for the development of prediction models using different types of validation options including cross-validation and random percentage data split. The Root Mean Square Error (RMSE) has been utilized as the main error metric for evaluating the performance of the prediction models. The RMSE values of the prediction models range between 14.91 and 32.41 Nm, showing that in addition to machine learning methods, MLR can also be used for predicting the hamstring and quadriceps muscle strength with acceptable error rates.

Keywords: Multiple linear regression, Hamstring, Quadriceps, Prediction

Öz
Hamstring ve Kuadriseps kas gruplarının gücü, atletler ve sporcuların performanslarının değerlendirilmesi için önemli bir rol oynamaktadır. Bu çalışmanın amacı, Hamstring ve Kuadriseps kas gücünün Çoklu Doğrusal Regresyon (Multiple Linear Regression, MLR) kullanılarak tahmin edilmesidir. Bu çalışma için kullanılan veri seti 70 sporcuya ait cinsiyet, spor dalı, boy, ağırlık ve yaş bilgilerinin yanı sıra hedef değişkenleri olarak iki tip fiziksel aktivite (statik antrenman ve klasik antrenman) ile ölçülen hamstring ve kuadriseps kas gücü değerlerinden oluşmaktadır. Tahmin modellerinin oluşturulmasında MLR ile birlikte çapraz doğrulama ve rastgele veri dağılımı olmak üzere farklı doğrulama seçenekleri kullanılmıştır. Tahmin modellerinin değerlendirilmesi amacıyla Ortalama Karesel Hata (Root Mean Square Error, RMSE) değerleri hesaplanmıştır. RMSE değerlerinin 14.91ve 32.41 Nm olarak değişmesi, MLR'nin kabul edilebilir hata oranlarıyla, hamstring ve kuadriseps kas gücünün tahmininde makine öğrenme yöntemlerine alternatif olarak kullanılabilirliğini göstermektedir.

Anahtar kelimeler: *Çoklu doğrusal regresyon, Hamstring, Kuadriseps, Tahmin*

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1. Introduction

Muscular strength is a term that is used to explain the amount of force which can be applied by a muscle against a resistance in a single effort (Akay et. al., 2017). The strength that a muscle can produce during activities can be important in many cases such as athletism, team sports and any type of personal training or physical movement. Especially in sports, the strength of the hamstring and quadriceps muscles has a critical effect on the performance, speed and stamina of sportspeople (Sow et. al., 2017).

The absolute measurement of the strength of hamstring and quadriceps muscles can be made in the laboratories specifically designed for this purpose using advanced isometric devices called isokinetic dynamometers (Sow et. al., 2017). Although this method gives very accurate results, it requires expensive equipment, lots of time and trained staff while measuring the muscle strength. Therefore, the usage of prediction models would be a better choice than the direct measurement.

There have been several studies carried out in literature about the prediction of muscle strength using MLR or machine learning methods, as shown in Table 1.

Table 1. Literature review

Study	Year	Method	Measured Strength	Metric	Value
Abadie et al.	2000	MLR	CPS, SPS, KES	*R*	0.94
Horvat et al.	2003	MLR	Bench Press	*R*	0.91
Harbo et al.	2012	MLR	Knee, Shoulder, Hip, Ankle, Elbow and	*R*	0.79
Muraki et al.	2013	MLR	KES	*R*	0.57
Sow et al.	2017	SVM	Hamstring & Quadriceps Muscles	*RMSE*	15.19
Akay et al.	2017	SVM	Hamstring & Quadriceps Muscles	*RMSE*	15.55

CPS, Chest Press Strength; **KES,** Knee Extension Strength; **MLR,** Multiple Linear Regression; ***RMSE*,** Root Mean Square Error; ***R*,** Multiple Correlation Coefficient; **SVM,** Support Vector Machines; **SPS,** Shoulder Press Strength.

This study proposes to develop new prediction models for determination of hamstring and quadriceps muscle strength with the usage of MLR, with similar or better error rates as in the studies in literature. Eight different prediction models have been built using gender, sports branch, height, weight and age as predictor variables while the measured strength of hamstring and quadriceps muscles during different types of training as the target variables. The *RMSE*'s produced by the prediction models vary between 14.91 Nm and 32.41 Nm.

The rest of the paper is organized as follows. Section 2 describes dataset generation. Section 3 presents results and discussion. Finally, Section 4 concludes the paper.

2. Dataset Generation

In order to create prediction models, the data of 75 college-aged athletes has been used. The muscle strength values which have been used as the target variables are measured with the help of different physical activities including a light run for 5 minutes (classic training, CT), a 5-minute light run followed by 4-minute active stretching (static training, ST), as well as the static training followed by 5 and 15-minute resting periods (ST-5min and ST-15min).

Table 2 shows statistics of the dataset.

Table 2. Statistics of the dataset

Feature	Minimum	Maximum	Mean	Standard Deviation
Gender	0	1	-	-
Sports branch	0	16	5.94	4.67
Height (m)	1.57	2.02	1.71	0.07
Weight (kg)	45	93	62.04	11.27
Age (Year)	19	38	21.78	3.06
M01 (Nm)	50.10	195.90	111.84	36.10
M11 (Nm)	61.20	197.70	111.61	36.44
M21 (Nm)	56.70	202.20	112.59	36.53
M31 (Nm)	46.50	194.60	113.16	36.44
M02 (Nm)	72.20	285.20	154.77	54.80
M12 (Nm)	85.20	278.10	157.01	54.41
M22 (Nm)	85.70	301.20	161.76	56.62
M32 (Nm)	83.40	280.20	157.88	51.95

M01, Hamstring strength (CT)**; M11,** Hamstring strength (ST)**; M21,** Hamstring strength (ST-5min)**; M31,** Hamstring strength (ST-15min)**; M02,** Quadriceps strength (CT)**; M12,** Quadriceps strength (ST)**; M22,** Quadriceps strength (ST-5min)**; M32,** Quadriceps strength (ST-15min)

3. Results and Discussion

In this study, eight different prediction models have been built with respect to the muscle type (hamstring and quadriceps) and the type of physical activity (CT, ST, ST-5min and ST-15min). Five validation options including no validation, 5-fold cross-validation, 10-fold cross-validation, 70-30% random data division and 80-20% random data division have been applied, which yields a total number of 40 evaluations overall.

Comparison of the models has been made by calculating the *RMSE* of each model. Figure 1 and Figure 2 show the visual comparison of the *RMSE*'s of the prediction models.

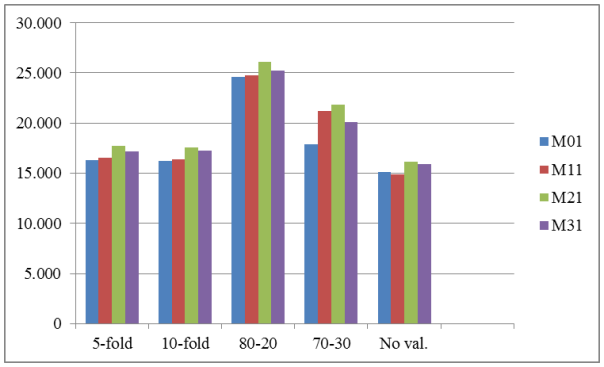

Figure 1. *RMSE* values of hamstring muscle strength prediction models

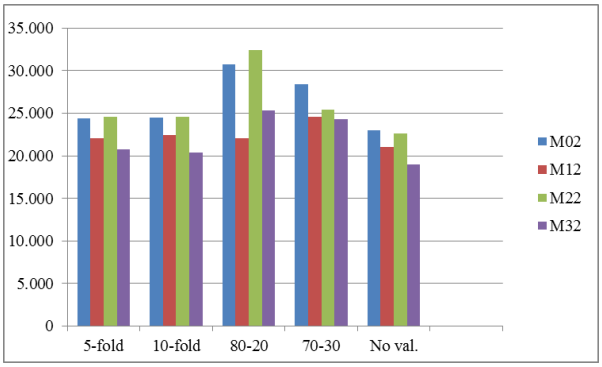

Figure 2. *RMSE* values of quadriceps muscle strength prediction models

- According to the *RMSE* of each prediction model, it has been observed that in general, the models which are used for prediction of hamstring muscle strength yield better results than the ones used for predicting quadriceps muscle strength. The models from M01 to M31 give a mean of *18.95 Nm* as *RMSE* for hamstring muscle strength prediction while the models from M02 to M32 give *24.13 Nm* for quadriceps muscle strength prediction.
- Among the prediction models, model M01 generates the lowest arithmetical mean *RMSE* with *18.03 Nm* while the highest arithmetical mean *RMSE* belongs to the model M02 with *26.19 Nm.*

- When the *RMSE'*s with the validation methods are compared to the ones with the No Validation option, the minimal shrinkage is caused by 10-fold cross-validation most frequently, in 5 out of the 8 models, ranging between 6.89% and 9.74%.
- The best prediction performance among the hamstring muscle strength models is given by model M01 with an average value of *18.03 Nm* while the average *RMSE* value, *21.95 Nm*, for the quadriceps strength is generated by model M32. This comparison shows that the type of training which leads to the best prediction performance is CT for hamstring muscle strength and ST-15min for quadriceps muscle strength.
- Among the models built by using the validation methods, M01 performs the most accurate prediction for hamstring muscle strength with the usage of 10-fold cross-validation and by classic training, with a mean *RMSE* of *16.194 Nm.*
- The highest *RMSE* values, *32.41*, *30.72* and *28.44 Nm* are produced by the models M22 (70-30%), M02 (70-30%) and M02 (80-20%), respectively, all built with the usage of random data division options.

4. Conclusion

This study has been carried out in order to create MLR-based models for prediction of hamstring and quadriceps muscle strength. Eight different models have been built with respect to the type of muscle group (hamstring and quadriceps) as well as the type of physical exercise (static or classic training, with or without rest). The study showed that the hamstring muscle strength prediction models are more accurate than the ones used for the quadriceps muscle strength, and also that the most favorable validation method for this purpose is 10-fold cross-validation while the target variables which yield more accurate predictions are CT and ST-15min for the hamstring and quadriceps muscle groups, respectively. The *RMSE'*s vary between *14.91 Nm* and *32.41 Nm*, which shows that the hamstring and quadriceps muscle strength can be predicted with the usage of MLR with acceptable error rates.

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