

# An Experimental Model on Multiple Regression Analysis in CMJ and SJ Jump Tests on 10 -14 Years Old Players of Tirana Football Club

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**Abstract** In vertical jump performance, the goal of the task is simply to jump as high as possible. In many sports, the height at which an athlete can jump is often of critical importance, as well as the maximal force applied during the vertical jump. In the absence of resistance to air and other external forces, the projection of the center of gravity COG of the whole body is completely determined by the vertical velocity at the moment of takeoff and the acceleration due to gravity. However, this quality does not fully describe the full jump and height achieved. This study aims to use the multiple regression method in both CMJ and SJ vertical jump tests, to understand whether vertical jump performance for Hmax and Fmax respectively parameters, can be predicted based on anthropometric variables such as: age, height, and body mass, as well as biomechanical variables such as: v<sub>max</sub>, F<sub>tot.rel</sub>, EFI and efficiency. Multiple regression method allows to determine the overall fit of the model and the relative contribution of each of predictor to the total variance explained. The equations of regression for this team emerged these parameters as the best predictor of the main variables for each test: for Hmax in CMJ test: v<sub>max</sub> and body mass; and for Fmax in SJ test: body mass and P<sub>max/kg</sub>.

**Keywords** Counter Movement Jump, Squat Jump, Multiple Regression Analysis

## 1. Introduction

Locomotion and neuromuscular function are important factors in understanding and assessing motor performance. The assessment of motor function through jumping movements using force plate measurements are used as an indicator of motor function, [5]. Vertical jump ability is required for success in a number of sports [4]. A study has found that the ability to generate lower body power is a key component for success in many sport activities [7]. There are a variety of strength training methods that are used to develop athletic performance [12], such as sprinting and jumping. Strength training exercises can be classified as general, special or specific, depending on their biomechanical structure and effect on the neuromuscular system, as reported in studies some studies [3; 4]. Applied to the vertical jump, general strength training exercises are those that are aimed at increasing the maximal strength of the muscles involved in jumping [4]. Vertical jump performance is dependent on contractile properties of muscle as well as the augmentation to the concentric work that occurs due to the stretch shorten cycle, as is shown by some studies [5; 8]. A vertical jump that is preceded by a rapid SSC cycle is called a countermovement jump (CMJ), as opposed to a jump that is not immediately preceded by a prestretch, for example a squat jump (SJ) [4]. The usage of arms during a CMJ has been shown to increase takeoff velocity, ground reaction force (GRF) and the height of the

center of gravity (COG) prior to takeoff [11]. Various types of strength-training modalities have been utilized in order to improve lower body power as can be measured by vertical jump [7]. Body weight jumping refers exclusively to non-weighted lower body plyometric exercises, such as squat, countermovement and drop jumps. Body weight jump is also highly practical, because it requires little or no equipment, and can be performed in almost any location and requires limited technical ability [1]. Some studies have shown that both the individual plyometric and weight training programs increased vertical jump performance, but the combination program showed the greatest improvement of vertical jump performance, [2; 5; 10].

The application of the laws of physics to human movement allows a scientific description of this motion. According to the second Newton's law, the ground reaction force  $F_z(t)$  and the body weight are related to the vertical accelerating during vertical jump as follow:

$$\sum F_z = m \frac{dv_z}{dt} = F_z(t) - mg \quad (1)$$

So, the velocity at takeoff phase is given as:

$$v_{t_0} = \frac{1}{m} \int_{t_1}^{t_2} [F_z(t) - mg] dt \quad (2)$$

Based on the energy conservation law, the mechanical energy of the COG in the peak of height can be expressed:

$$E_{K_{t_0}} + E_{P_{t_0}} = E_{K_h} + E_{P_h} \quad (3)$$

Solving the equation the vertical velocity at takeoff is related to the jumping height as follows:

$$H_{jump} = -\left(\frac{v_{take-off}^2}{2g}\right) \quad (4)$$

Some studies have found that jumping ability can be improved in several methods [4; 5], which includes general

and specific exercises.

## 2. Material and Methods

The participating subjects were taken from Tirana football club team, through the application of test measurements performed on a force plate Leonardo Mechanography GRF [9], at the Sports University of Tirana, in Biomechanics laboratory. Subjects participating in were 29 boys aged 10-14, mean ( $12.1 \pm 0.62$ ) years old. Informed consent was obtained from the parents of subjects, in order to consider them as participants of the study. The subjects were tested in two forms: CMJ (counter movement jump) test – test for maximal height, performed with arm swing, and SJ (squat jump) test- test for maximal force, jump without arm swig with arms closed to the waist. The study period includes three phases. The study period includes three phases. The initial phase: before training measurements, middle: after six months and the final phase: nine months after training measurements. The program was based on combined general and specific strength training improving maximal jump height and maximal output strength training which included: plyometric, izokinetic and kinetic chanin exercises. Statistical analyses were performed using SPSS version 20. During the processing of the results, multilpe regression method was used. This method allows to determine the overall fit of the model and the relative contribution of each of predictor to the total variance explained. Statistical significance was set for all statistical procedures at  $p \leq 0.05$ .

## 3. Results

Table 1 gives the descriptive statistics of the anthropometric parameters and generates also the variables obtained during the three measurements of CMJ and SJ test, which are used to find the best predictor in multiple regression analysis.

**Table 1.** Statistical descriptive of anthropometric parameters and variables on three different phases of CMJ and SJ tests

Measurement		Parameter	Mean±SD	Rank	Min. Value	Max. Value	Variance
Anthropometric characteristics		Age (years old)	12.10 ± 0.62	4.00	10.00	14.00	0.38
		Height (m)	1.54 ± 0.94	0.40	1.36	1.76	0.01
		Body mass (kg)	46.55 ± 9.74	38.40	31.90	70.30	94.81
		BMI (kg/m <sup>2</sup> )	19.30 ± 2.37	8.71	15.58	24.29	5.63
CMJ test	Phase I	H1max (m)	0.37 ± 0.05	0.21	0.27	0.48	0.003
		V1max. (m/s)	2.31 ± 0.17	0.73	1.87	2.60	0.03
		E.F.I.1	102.03 ± 14.25	50.00	75.00	125.00	203.03
	Phase II	H2max (m)	0.42 ± 0.57	1.16	0.33	0.49	0.003
		V2max. (m/s)	2.40 ± 0.15	0.50	2.14	2.64	0.02
		E.F.I.2	109.38 ± 10.95	35.00	92.00	127.00	119.96
	Phase III	H3max (m)	0.45 ± 0.05	1.21	0.35	0.56	0.003
		V3max. (m/s)	2.51 ± 0.13	0.56	2.23	2.79	0.02
		E.F.I.3	114.97 ± 10.26	36.00	100.00	136.00	105.25
SJ test	Phase I	F1max (kN)	1.07 ± 0.25	0.97	0.69	1.66	0.06
		P1max./kg	37.66 ± 4.13	14.60	29.04	43.64	17.02
	Phase II	F2max (kN)	1.19 ± 0.27	1.16	0.81	1.97	0.07
		P2max./kg	40.14 ± 4.32	16.46	30.48	46.94	18.64
	Phase III	F3max (kN)	1.40 ± 0.28	1.15	0.97	2.12	0.08
		P3max./kg	41.58 ± 4.55	17.45	31.08	48.53	20.72

### 3.1. Results of Multiple Regression to the First CMJ Test

In the first CMJ test, the multiple regression method is used to understand if the performance of vertical jump test to measure the maximum height (Hmax) can be predicted based on anthropometric variables such as age, body height, body mass and also in the biomechanics variables as maximum velocity (Vmax), the total relative strength (F.tot.rel), Esslinger Fitness Index (EFI) and efficiency of movement.

### 3.2. Adjusting the Overall Model

Multiple regression methods allow determining the overall fit of the model and the relative contribution of each predictor in complete variance to explain. At CMJ test should be known the percentage of variation of test performance on the dependent variable (Hmax) that can be explained by anthropometric and biomechanics parameters as a whole, but also the "relative contribution" of each of the independent variables in explaining variance. By application of the method of multiple regression for the anthropometric and biomechanical data obtained for the first CMJ test, table 2 is generated.

Table 2 gives a summary overview of the model. → R value represents the coefficient of multiple correlations. R can be considered to be a measure of predict quality (Hmax). A value of R = 0.742 in this case shows a good

level of prediction. Value R<sup>2</sup> is also the coefficient of determination, which is part of the variance in the dependent variable that can be explained by the independent variables; values R<sup>2</sup>=0.555 shows that independent variables taken on this model can explain 55% of the variance of the variable independent, so Hmax.

**Table 2.** Summary of the overall model.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.742 <sup>a</sup>	.550	.428	.03944

a. Predictors: (Constant), E.F.I, body height, body mass, age, Fmax.rel, Vmax.

R<sup>2</sup> value adjusted is used to report and accurately interpret the model as a whole, then R<sup>2</sup>=0.428 vale adjusted accurately explains 42.8% of the variance of Hmax in the CMJ test.

In the Anova table, value F Fisher test whether the full regression model fits well with the data. For this parameter, the value of Fischer's, F(6, 22)=4.490 and p=0.004. p <0.050 means that the regression model fits well with the data.

### 3.3. CMJ Test- The Model Coefficient Calculation

The regression coefficients table offers the information needed to predict the dependent variable (Hmax) by independent anthropometric and biomechanics variables as well as to determine the statistical model significance

(based on the value of the column t and sig column. value p). Based on beta coefficients ( $\beta$ ), the general form of Regression equations for predicting Hmax is:

$$H_{max}(\text{predicted}) = y = -0.214 + 0.001(\text{Age}) + 0.055(\text{Body length}) - 0.002(\text{Body mass}) + 0.26(v_{max}) - 0.011(\text{EFI}) \quad (5)$$

This equation gives an analysis of the overall prediction, but provides no information on the best predictors. The coefficient table also tests for statistical significance of each of the independent variables, so it tests if the coefficients are equal to zero in the population. Exploratory study provides information on which independent variables are the most important and best predictors of the regression model.

### 3.4. Finding the Best Models on CMJ Test

Table 3 provides a summary of exploratory models, indicating which variables are included in the model step by step.

**Table 3.** Summary exploratory model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.673 <sup>a</sup>	.452	.432	.03929
2	.735 <sup>b</sup>	.541	.505	.03667

a. Predictors: (Constant), Vmax

b. Predictors: (Constant), Vmax, body mass

According to the model A) → Vmax is the best predictor alone. For this variable, R= 0.673, R<sup>2</sup> = 0.452 and the first step estimates 45.2% of the variance of the independent variable. F and p value reported by Anova are: F (1, 27) = 22,314, p <0.001

According to the model B), Vmax and body mass are the best predictor model. So, body mass is the second best predictor and added after Vmax and which is included in the model. For both variables, R= 0.735, R<sup>2</sup>=0.541 and the second step calculates the 54.1% of the variance of the two respective variables. The corresponding values are: F(2,26)=15,308; p<0.001.

Both models together have significant results, since both of them p<0.001.

### 3.5. Results of Multiple Regression to the Second SJ Test

In the second SJ test, the multiple regression method is used to understand if the performance of the vertical jump test to measure the maximum force (Fmax) can be predicted based on the anthropometric variables such as: age, body height, body mass and also on the biomechanical variables such as: maximum vertical jump height (Hmax), maximum velocity (Vmax), Esslinger Fitness Index (EFI)

and efficiency of movement.

### 3.6. Finding the Best Model on SJ Test

A summary of exploratory models indicating which variables are included in the model step by step is shown in table 4.

**Table 4.** Summary of exploratory model.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.497 <sup>a</sup>	.247	.219	.24565
2	.594 <sup>b</sup>	.353	.303	.23215

a. Predictors: (Constant), Body mass

b. Predictors: (Constant), Body mass; Pmax/kg

According to the model A), → Body mass is the best predictor alone. For this variable, R=0.497, R<sup>2</sup>=0.247 and the first step estimates 24.7% of the variance for the independent variable. F(1, 27)= 8.58 and p=0.006.

According to the model B), Body mass and Pmax/kg are the best predictors model. So Pmax/kg is the second best predictor added after body mass and that was included in the model. For both variables, R=0.594, R<sup>2</sup>=0.353 and the second step calculates 35.3% of the variance of these two variables. F (2, 26) = 7079 and p = 0.00.

Both models together have significant results, since for both models p < 0.050.

## 4. Discussion

### 4.1. The Regression Equation for the Best Predictors on CMJ test

The beta coefficients array ( $\beta$ ) gives the corresponding values for a better predictor model; therefore, based on them regression equation can be constructed. Table 5 noted that  $\beta$  coefficients vary depending on the predictors are included in the model.

**Table 5.** Beta coefficients on CMJ test.

Coefficients <sup>a</sup>						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.220	.142		-1.544	.134
	Vmax	.267	.057	.673	4.724	.000
2	(Constant)	-.193	.133		-1.445	.160
	Vmax	.286	.053	.721	5.354	.000
	Body mass	-.002	.001	-.301	-2.235	.034

a. Dependent Variable: Hmax.

The regression equations for both models involved in exploratory study are as follows:

Equation according to the model A)

$$Y = -0.22 + 0.267(v_{\max}) \quad (6)$$

This is the weight of an equation that includes: Vmax as the best predictors of this model. According to this equation, for any speed increase of 1m/s there is an increase of Hmax with 0.267 m or 26.7 cm.

Equation according to the model B)

$$Y = -0.193 + 0.286(v_{\max}) - 0.002(\text{Body mass}) \quad (7)$$

These are the weights for an equation that includes: Vmax and body mass as the best predictors of this model. According to this model, for any increase in speed of 1m/s there is an increase of Hmax with 0.002 m or 0.2 cm. From the inverse analysis, very small changes of R<sup>2</sup> between the initial step and exploratory study are seen, and this is why models A and B exclude other predictors as not very important in the regression model.

#### 4.2. The Regression Equation for the Best Predictors on SJ Test

Table of beta coefficients ( $\beta$ ) gives the corresponding values for a better predictor model; therefore, based on them, regression equation can be constructed. From Table 6, it is noted that  $\beta$  coefficients vary depending on the predictors are included in the model.

**Table 6.** Beta coefficients on SJ test

Model		Coefficients <sup>a</sup>				t	Sig.
		Unstandardized Coefficients		Standardized Coefficients	Beta		
		B	Std. Error	Beta			
1	(Constant)	.740	.227		3.267	.003	
	Body mass	.014	.005	.497	2.977	.006	
2	(Constant)	-.126	.473		-.268	.791	
	Body mass	.015	.005	.526	3.322	.003	
	Pmax.kg	.020	.010	.326	2.057	.050	

Dependent Variable: Fmax.

The regression equations for both models involved in exploratory study are as follows:

Equation according to the model A)

$$y = 0.74 + 0.014(\text{Body mass}) \quad (8)$$

This is the weight of an equation that includes: body mass as the best predictors of this model. According to this equation, for any increase in body mass of 1kg there is also an increase of the Fmax with 0.014 kN or 14N.

Equation according to the model B)

$$y = -0.126 + 0.015(\text{Body mass}) + 0.02(P_{\max} / \text{kg}) \quad (9)$$

These are the weights for an equation that includes: Body mass P.max/kg as the best predictors of this model.

According to this model, for any increase in body mass of 1kg there is also an increase of Fmax with 0.014N and for every 1 Watt/kg added to Pmax/kg there is an increase of Fmax with 0.02 kN, or 20N.

## 5. Conclusions

Combined general and specific strength training is effective as power training for improving maximal jump height and maximal output in CMJ and SJ tests. The strength exercises develop and improve the psychophysical, coordinative and locomotive condition, enabling the subject to both mentally mobilize and having a higher muscular tonification, by gradually increasing the moving efficiency; and the performance is improved. Multiple regression method applied to CMJ and SJ tests for Tirana football team allows to determine the overall fit of the model and the relative contribution of each of predictor to the total variance explained. In both tests, it was found how much of the variation in the test performance of the depended variable can be explained by anthropometric and biomechanical parameters as well as the relative contribution of each independent variable in explaining the variance. Multiple equations of regression for this team emerged these parameters as the best predictor of the main variables for each test: for Hmax in CMJ test: v<sub>max</sub> and body mass; and for Fmax in SJ test: body mass and Pmax/kg. Clearly, the jumping technique strongly affects the mechanical output muscles, as the motors that generate explosion maximal force and also maximal jump height. Finally, all strength exercises in Tirana Football team players have improved the biomechanical parameters, including the sportive technique.

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