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Developing a new muscle power prediction equation through vertical jump power output in adolescent women

Aziz Güçlüöver, PhD[a],* ID, Mehmet Gülü, RA[b]

Abstract

Explosive power is a performance determinant in many sports activities. Vertical jump tests for assessing power output are widely employed. Accurate and reliable methods are needed to predict human power output using the widely employed vertical jump height.

To determine vertical jump capacity by using force platform in high school-level girls and to develop an equation that predict vertical jump muscle power (MP) (watts) through body composition and vertical jump height.

An experimental group consisting of 87 high school-level young sedentary girls (mean; age; 16.49 ± 1.93, height;161.25 ± 6.21, weight; 55.59 ± 10.27) and a validation (control) group consisting of a similar population of 30 people (mean; age; 16.14 ± 1.31, height; 163.30 ± 6.28, weight; 56.65 ± 9.59), participated in this study. A stepwise linear regression model, including fat free body mass, vertical jump height and fat percentage as independent parameters was applied to develop a new muscle power (MP) estimation equation. Pearson product-moment correlation coefficients were calculated between actual and predicted MP.

The new prediction equation obtained from regression analysis for muscle power (MP) could explain 74.5% (R^2) of the variation. A strong and high correlation was observed between the Pearson product-moment correlation coefficients of the actual and predicted MP (experimental; $r = 0.863$; $P < .000$) and (control; $r = 0.898$; $P < .000$).

The direct measurements of muscle power (MP) require researchers to access costly and complex instruments. This need will be met by the MP estimation equations obtained from a simple vertical jump height and body composition measurement.

Abbreviations: CMJ = countermovement jump, FFM = fat free mass, MP = muscle power, PP = peak power, VJH = vertical jump height, W = watts.

Keywords: adolescent, body composition, force platform, peak power estimation, regression analysis

1. Introduction

Muscle power (MP) is the main component of muscle-skeletal exercise in children and adolescents and is the basis for physical performance and motor skills development.[1] Power can be defined as the ability of the skeletal muscle to produce rapid force (i.e., power equals force multiplied by velocity). The peak power (PP) (watts) is directly related to performance and functionality in many sports.[2,3] Accordingly, test batteries (i.e., a force platform) are designed to measure human performance in a comprehensive and qualified way, including direct peak power testing (PP) (watts).[4,5]

Vertical jump in assessing power output is one of the most common standard measurement methods in which "explosive" athletic performance is assessed. The ability to assess the power of the jump can also be helpful in evaluating the development of the athlete or in determining the training program.[6] The driving effect of lower extremities during a vertical jump was found particularly appropriate for assessing explosive properties of sedentary individuals and elite athletes.[7,8]

Unfortunately, the correct determination of power output requires expensive devices such as power platforms. Most high schools and sports clubs do not have such complex and costly equipment. Therefore, a correct and reliable method is required to predict the output of human vertical jump power. To evaluate any performance variable in a population, either criterion performance levels or normative reference data are required. Normative data are available for vertical jump and muscle power for young adults.[9] In the past and recent times various equations based on a range of variables, including jump height and body mass, were developed to estimate the power generation obtained by indirect methods on adolescent and young adult period participants, and the validity and reliability of the equations were tested by researches.[1,6,10–21] However, there is no equation that can be used to predict vertical jump muscle power in sedentary 15 to 19 years old Turkish high school- level girls. The differences in morphological structures of people in different age group necessitates the development of new equations that can be used

Table 1

Descriptive statistics of participants demographic and physical characteristics.

Variables	Experimental (n=87)		Control (n=30)	
	Mean	SD	Mean	SD
Age (years)	16.491	1.9305	16.147	1.3163
Height (cm)	161.2567	6.2179	163.3062	6.2841
Weight (kg)	55.5988	10.2771	56.6515	9.5965
Fat (%)	23.4245	6.5208	24.6863	6.5519
Fat free mass (kg)	41.2672	5.3113	42.0749	4.5517

to predict the vertical jump power output for estimate to actual leg power more accurately. Considering all of these, the primary aim of this study is to determine the jump capacity of 15 to 19 years old Turkish high school girls students, and the secondary aim is to develop a power equation for predicting vertical jump muscle power, unlike the literature, according to body composition characteristics.

In contrast to the hypothesis that power estimation equations should be applied to each group in general, the hypothesis of this study is that diversification of power estimation equations based on new variables (body composition) literature in determining vertical jump muscle power, will indirectly contribute to muscle power estimation studies although it supports the theory of creating groups-specific equations.[21] In this respect, the development, diversification and implementation of new equations based on different parameters will enable a more accurate and reliable value to be obtained when evaluating the jump power in a population-specific group.

2. Method

2.1. Participants and procedure

The sample group consisted of female high school students aged 15 to 19 years old who are previously completely healthy with no history of illness. The sample size of the study was determined based on the power analysis results.[23] An experimental group consisting of 87 Turkish high school-level young sedentary girls (mean; age; 16.4 ± 1.9, height;161.25 ± 6.21, weight; 55.59 ± 10.27) and a validation (control) group consisting of a similar population of 30 people (mean; age; 16.1 ± 1.3, height; 163.30 ± 6.28, weight; 56.65 ± 9.59), participated in this study. Prior to experimental research, we applied to the Ethics Committee for Clinical Research for the participants. Upon the completion of necessary documents, the approval was obtained with the decision of No. 19/04. Before the measurements were made, written permission was obtained from the subjects, but written permission was obtained from their parents in subjects under 18 years old. A few days before the tests started, several measurements were made to introduce the subjects and the participants were adapted to the tests.

2.2. Determination of body composition

In determining body composition (Tanita BC 418 Body Composition Analyzer, Japan) device was used. The device analyzes fat % and fat-free body weight by sending 50 kHz electrical current to 5 different body regions.

2.3. Determination of muscle power and vertical jump height

The force platform (Force plate AccuPower version 2.0 USA) was used to measure the muscle power of the participants. This device can simultaneously measure the actual muscle power and vertical jump height of the subjects. Before the test, participants were asked to stand upright without moving on the force platform and after this stage they were asked to jump as high as possible through Abalakov vertical jump. Abalakov explosive force measures the elastic component of the muscles and the coordination between the muscles and uses free-moving arms. Abalakov vertical jump test was performed 3 times and the highest value was recorded.

2.4. Statistical analysis

We developed a new MP prediction equation by fitting a stepwise linear regression model, with actual MP. We calculated Pearson product moment correlation coefficients between actual and predicted MP. We compared actual and predicted MP in the independent sample using paired t tests. We set statistical significance at $P < .05$ and performed all statistical analysis with SPSS 21.

3. Results

The demographic and physical characteristics of the participants are given in Table 1. The newly developed prediction equation for estimating Muscle Power (MP) from Fat Free Mass (FFM), Vertical Jump Height (VJH) and Fat % is: $\hat{Y} = -1152,589 + 48,323 X_1 + 43,074 X_2 + 20,296 X_3$ here, $\hat{Y} =$ Muscle Power, $\hat{X}_1$: FFM, $\hat{X}_2$: Vertical jump height, $\hat{X}_3$: Fat %. We present results for our new prediction equation in Table 2.

Table 2

Regression analysis results.

Prediction	Coefficent	Std. Error	t	P	R²	%74,5
Constant	−1152.589	217.180	−5.307	.000*	F-statistic	80.650
FFM	48.323	5.096	9.483	.000*	P value	.000
VJump	43.074	4.176	10.315	.000*		
Fat (%)	20.296	4.109	4.940	.000*		

Table 3

Correlation analysis between the predicted and actual muscle power.

N=87	Prediction MP	Actual MP
Actual MP	1	0.863[**]
		p=0.000
Prediction MP	0.863[**]	1
	p=0.000	

Table 5

Correlation analysis between the predicted and actual muscle power for control group.

N=30	Predicted	Actual
Prediction	1	0.898[**]
		P=.000
Actual	0.898[**]	1
	P=.000	

We present correlation relationship between predicted and actual MP in Table 3. We calculated Pearson product moment correlation coefficients between actual and predicted MP. We observed a strong and highly correlation between our prediction equation and actual MP ($r=0.863$; $P<.000$). We compared actual and predicted MP in the independent sample using paired t tests in Table 4. Predicted and actual Muscle Power (MP) were not significantly different (paired sample t test $P=.999$).

Finally, the validity of the prediction equation obtained on the experimental group of 87 persons tested on the control group of 30 participants and the Pearson correlation analysis was performed between the actual vertical jump muscle power (MP) and the predicted vertical jump muscle power (MP) for the control group. The results of the analysis showed a strong and high correlation between the predicted MP and actual MP values ($r=0.898$; $P<.000$) (Table 5).

4. Discussion

The aim of this study is to determine the jump capacity of Turkish adolescent girls and to develop the power equation for predicting vertical muscle power through body composition and jump height. Many similar studies in the literature in developing the muscle strength prediction equation have benefited from the variables of jump height (cm) and body weight (kg).[1,6,10–18,20,21] From these researchers, the muscle power regression models of researchers such as [6,10,12,15] have been the most valid and reliable accepted equations. In this study, unlike other research dimensions, the muscle power prediction equation was developed with different explanatory variables such as body composition as well as vertical jump height. In this context, the research presents a new muscle strength (MP) prediction equation formulation with body composition and differs from other studies in this regard. Vertical jump prediction equation developed as a result of the research conducted on eighty seven (87) Turkish high school-level girls for the indirect estimation of vertical jump leg power is as: $[Y = -1152,589 + 48,323X_1 + 43,074X_2 + 20,296X_3]$. Pearson product moment correlation coefficients were calculated between the actual muscle power and the predicted muscle power (MP) obtained from the equation. We observed a strong and high correlation between our prediction equation and actual muscle

strength MP ($r=0.863$; $P<.000$). In addition, the validity of the equation developed for 87 subjects was tested on the control group consisting of a similar population of 30 people ($r=0.898$; $P<.000$). These results have shown us that the vertical jump muscle power, which is estimated for adolescent girls, is close to the actual muscle power.

Our research is the first study conducted in Turkey on development power prediction equation on the Turkish female population. Besides, in the literature similar to our sample group, there are a few studies that develop the leg power prediction equation in women of this age group. In the past and recent studies, it is observed that the research on vertical jump height and body weight variables is intensified in developing a regression model for predicting muscle power. One of these researchers,[6] determined the peak power output based on jump height (cm) and body mass (kg) in the study conducted on 108 participants of different genders by applying squat jump and countermovement jump protocols. As a result, they reported that squat jump (SJ) data offered a better prediction equation than the countermovement jump (CMJ) data. Peak Power (W)=$60.7\times$ (jump height cm) +45.3 × (body mass [kg])-2055. ($R^2=0.88$). In another study,[22] developed the regression model [W]=$73.81 \times$ VJH [cm] + 34.666 X body mass [kg] -1617 ($R^2=0.75$) to determine the vertical jump peak power they developed on gymnasts.[10] compared the 3 peak power estimation equations with the actual peak power and found them related to each other (r 0.84–0.99) and (r 0.88–0.99). In addition, they developed the formula from regression analysis: PPest=65.1 X (jump height) + 25.8 (body mass) $- 11413.1$ (R^2 0.92; SEE 120.8). Another researcher,[12] developed the power equation to evaluate muscle power more accurately in the special population. They argued that the developed power prediction equation [Power=($62.5 \times$ jump height (cm)) + (50.3 X body mass (kg) – 218.4.7] could be used in a valid way in male physical education student population[18] developed the power estimation equation using body weight and jump height as independent variables with 3 variables (jump height, body weight, and power): Power=$-666.3 + 14.74$ [Body weight (kg)] +1925.72 [Height (m)]; [$R^2=0.69$, $P<.05$] and found a significant correlation between power generation and jump height on the platform ($r=0.47$). In another study,[21] presented findings that prove the validity of 2 specific prediction equations that measure the vertical jump power on the participants of the male ([61.8jumpheight(cm)] + [37.1body-mass(kg)] – 1941.6) and female ([31verticaljump(CM)] + [45bodymass(kg) – 1.045.4] middle school students and in this research, the author told teachers about the applicability of prediction equations for the indirect determination of jump power for middle school students.

As a result, although the muscle power prediction equations developed by some researchers mentioned above are high in validity and reliability, the regression models are the equations

Table 4

Independent sample t test analysis between the predicted and actual muscle power.

MPower	N	Mean	Std. Dev.	t	P
Actual	87	2074.2414	368.3160	0.001	.999
Prediction	87	2074.2411	317.8152		

developed with jump height and body mass. In this study, a regression model was developed for a different estimation of muscle power than the literature. In this context, the first and new model presented evidence that muscle power can be explained indirectly by variables related to body composition as well as body mass and allowed for further research to develop new equations in different populations. Considering Tanner[24] phase for age groups in terms of morphological and developmental characteristics of the participants, in this type of studies, it is quite difficult to fully control temporal differences that occur mainly during adolescence and besides differences in contraction speed and strength during the jump phase and/or physiological changes. For this reason, differences between age groups can be minimized in order to see real values or methods that will determine the level of development and change levels of the participants during their adolescence will increase the reliability of future studies. In this sense, we foresee that this developed equation may create a practical generalizability limitation on different age and gender populations.

5. Conclusion

Finally, the equation developed in this research is to provide researchers, physical education teachers, and coaches with an easy, practical, and valid method for estimating muscle power through a simple vertical jump at adolescent high school-level girls. While acknowledging the validity of this equation on adolescent girls, we encourage the development of new equations on male populations and elite athletes.

Author contributions

Conceptualization: Aziz Güçlüöver
Data curation: Aziz Güçlüöver
Formal analysis: Aziz Güçlüöver, Mehmet Gülü
Investigation: Mehmet Gülü, Aziz Güçlüöver
Methodology: Aziz Güçlüöver, Mehmet Gülü
Resources: Aziz Güçlüöver, Mehmet Gülü
Validation: Aziz Güçlüöver
Writing – original draft: Aziz Güçlüöver, Mehmet Gülü
Writing – review & editing: Aziz Güçlüöver, Mehmet Gülü

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