

## THE VERTICAL JUMP AND SPRINT PERFORMANCE AS DETERMINANTS OF AGILITY AMONG MALE ADOLESCENTS

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**Abstract.** *The aim of this cross-sectional study was to determine the relationship between the vertical jump (VJ) and sprint performance with agility among male adolescents. The study was conducted on 42 male elementary school students, (age, 13±0.5 years). Among the predictor variables, the Squat Jump (SJ) and Countermovement Jump (CMJ) VJ height were assessed by the Optojump (Microgate, Italy) optical system, and sprint times at 5, 10 and 30 m were assessed using the photocells timing system Witty (Microgate, Italy). Agility as a criterion was assessed with the agility T-test, timed also with photocells. Obtained results showed a significant negative relationship between SJ, CMJ and agility ( $r=-0.52$ ;  $-0.58$ , respectively) and a positive relationship between sprint times at 5, 10 and 30 m and agility ( $r=0.43$ ;  $0.53$ ;  $0.57$ , respectively). A backward stepwise regression analysis showed that the CMJ was the best single predictor of agility ( $R^2=0.34$ ). The results of this study illustrate that enhancing jump and sprint performance will bring better times in agility performance. Finally, the CMJ has best influence on agility among all the predictor variables.*

**Key words:** *Relationship, Squat Jump, Countermovement Jump, Sprint, Agility, Adolescents*

### INTRODUCTION

Success in variety of sports is dependent on numerous motor skills, but in multidirectional sports where players are engaged in rapid changes of direction and short bouts, power, speed and agility are crucial abilities that can affect performance and advantages in game situations (Bompa & Haff, 2009; Delextrat & Cohen, 2009; Garcia-Gil et al., 2018). It has been suggested that agility is one of the determinant factors in upcoming success and optimal performance in younger athletes (Mirkov, Kukulj, Ugarković, Koprivica, & Jarić, 2010; Lloyd et al., 2013). Development spurt in agility performance occurs in adolescence at

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approximately the age of 13-14 in male adolescents, which is proportional with the occurrence of peak height velocity (PHV) (Vänttinen, Blomqvist, Nyman, & Häkkinen, 2011; Lloyd et al., 2013). Therefore, assessment of physical fitness and the identification of performance predictors are important for the selection and screening of young athletes (Norkowski, 2002; Gonçalves, Rama, & Figueiredo, 2012; Ferreira et al., 2019).

Agility is often defined as a complex set of interdependent abilities needed to change whole-body movement direction, velocity or mode as an answer to stimulus (Sheppard & Young, 2006; Bompa & Haff, 2009; Nimphius, Callaghan, Bezodis, & Lockie, 2018). According to some research, underlying factors of this definition appear to be muscle strength and power with the potential of stretch-shortening cycles (SSCs) as a capacity to perform short sprints and fast changes of direction with a great efficacy (Gabbett, Kelly, & Shepard, 2008; Castillo-Rodríguez, Fernández-García, Chinchilla-Minguet, & Carnero, 2012; Spasić, Uljević, Čoh, Dželalija, & Sekulić, 2013). One of the effective training method is plyometric training in order to “learn” and “gain” SSC capabilities in younger athletes (Stojanović & Kostić, 2002; Stojanović, Jovanović, & Stojanović, 2012).

A number of previous studies that have investigated the relationship between jump performance and agility reported significant negative correlations between the Squat Jump (SJ), Countermovement Jump (CMJ) and agility most commonly assessed with the T-test (Pauole, Madole, Garhammer, Lacourse, & Rozenek, 2000; Alemdaroğlu, 2012; Castillo-Rodríguez et al., 2012; Asadi, 2016; Negra et al., 2017). Furthermore, studies that have investigated the relationship between sprint performance and agility also reported significant positive correlations between the T-test and 10 and 20 m sprints (Negra et al., 2017), 30-m sprint (Alemdaroğlu, 2012), also 20 and 40-yard sprints (Peterson, Alvar, & Rhea, 2006). Chaouachi and associates (2009) revealed no significant correlations between 5, 10, and 30 m sprint times and the agility T-test.

From the mentioned previous studies it is evident that the most often used test in the agility assessment was the T-test. It is a standard test of agility with good reliability and validity characteristics (Pauole et al., 2000). It is simple to use (minimal equipment and preparation). The T-test includes speed and four changes in direction. The most accepted field tests used in lower limb power and performance evaluation are the vertical jump (VJ), SJ and CMJ (Stojanović, Čoh, & Bratić, 2016; Petrigna et al., 2019; Aksović, Kocić, Berić, & Bubanj, 2020). Scientific literature on how to train agility for children and adolescents in the best possible manner is limited (Lloyd et al., 2013). Optimization of the agility training programs, a correlation analysis with other physical fitness parameters (muscle strength and power, speed, etc.) is needed (Negra et al., 2017).

The aim of this study is to determine the relationship between VJ and speed performance with agility among male adolescents.

## METHODS

### The sample of participants

A total of 42 seventh grade elementary school male students (age:  $13\pm 0.5$  years; body height  $165.78\pm 8.98$  cm; body mass:  $56.43\pm 10.63$  kg; body mass index:  $20.43\pm 2.72$  kg·m<sup>-2</sup>) participated in this cross-sectional study. The study sample involved only students who voluntarily agreed to participate in the study followed by the testing program. Prior to the study, parental consent was obtained for every participant. This study was conducted in

compliance with the recommendations for clinical research of the World Medical Association Declaration of Helsinki (2013) and the children's privacy was protected by allowing for anonymity. This study was also reviewed and approved by the Ethics Committee of the Faculty of Sport and Physical Education, University of Niš. All of the participants were clinically healthy during the testing protocol.

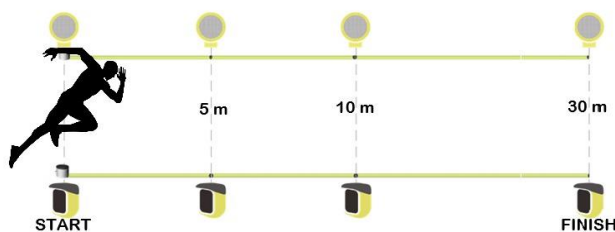
### Procedures

The testing procedures were carried out in two days. On the first day, anthropometric measurements were taken early in the morning and performance measurements (VJs and sprints) were performed in the afternoon. The agility test was performed on the second day in the afternoon.

*Anthropometric measurements.* Body height was measured using a Martin anthropometer GPM 101 (*GPM GmbH Switzerland*) to the nearest 0.1 cm. Body mass was measured with an accuracy of 0.1 kg using the Omron BF511 digital scale (*Omron Healthcare Co, Kyoto, Japan*).

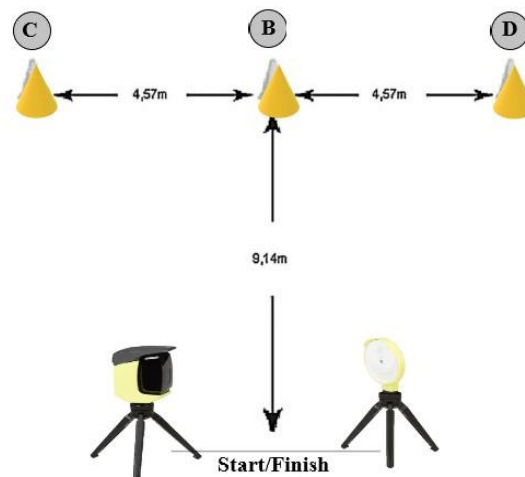
*Vertical jump.* VJ performance was assessed based on the SJ and CMJ using the Optojump (*Microgate, Italy*). The Optojump system is a dual-beam optical device which detects any interruptions in communication between beams and makes it possible to measure flight and contact times during jumps with an accuracy of 0.001 s. VJs were performed following the Bosco protocol (Bosco, Luhtanen, & Komi, 1983). The participants performed a standardized warm-up before testing procedure. Jump height was recorded to the nearest 0.1 cm.

*Sprint.* Sprint performance was assessed by a linear 30-m sprint test with split times at 5 and 10 m. The participants performed two all-out effort 30 m sprints on an indoor wooden (parquet) court. Before the testing procedure, participants performed a standardized warm-up. The recovery period was approximately 2-3 minutes between the sprints. Sprint and split times were measured with four Witty photocell gates (*Microgate, Italy*), positioned at the starting line, 5 m, 10 m, and finish line, with an accuracy of 0.01 s (Fig. 1).



**Fig. 1** Graphical layout of linear 30-m sprint test with split times at 5 and 10 m

*Agility.* Agility was assessed through the T-test following the protocol outlined by Semenick (1990). Time was measured with one Witty photocell gate (*Microgate, Italy*) mounted on a tripod with a height of 0.75 m at the starting line, with an accuracy of 0.01 sec (Fig. 2). The reliability and validity of the T-test were confirmed by Pauole et al. (2000).



**Fig. 2** Graphical layout of the agility T-test

### Statistical analyses

The arithmetic mean (Mean) and standard deviation (SD) values were calculated for each variable. The Kolmogorov-Smirnov test was applied to confirm normality. The relationships between VJ performance, sprint performance and agility were evaluated using Pearson Product Moment Correlation analysis. Cohen (1988) recommended that 0.10 to 0.30 should be interpreted as a weak correlation, 0.30 to 0.50 as a moderate correlation and greater than 0.50 as a strong correlation. A multiple regression analysis with backward stepwise method was used to estimate the best predictor model of agility. Coefficients of determination ( $R^2$ ) were used to interpret the proportion of the variance of the T-test that is predictable from the independent variables. Statistical significance was set at level  $p < 0.05$ .

Statistical procedures and analyses were conducted using the statistical package STATISTICA 10.0 for Windows (StatSoft, Inc., Tulsa).

### RESULTS

The results for the VJ, sprint and agility tests are reported in Table 1.

**Table 1** Descriptive data for all the variables

(n = 42)	Variable	Mean	SD	Min	Max
Vertical	SJ (cm)	22.77	4.73	8.90	30.50
Jumps	CMJ (cm)	24.03	4.61	11.30	32.80
Sprint	5-m sprint (s)	1.30	0.13	1.06	1.59
	10-m sprint (s)	2.17	0.18	1.86	2.53
	30-m sprint (s)	5.53	0.43	4.69	6.51
Agility	T-test (s)	13.32	1.63	10.49	16.42

*Legend: SJ-Squat jump; CMJ-Countermovement jump; SD-Standard deviation.*

The relationship between the performance variables and agility is detailed in a correlation matrix showing the Pearson correlation coefficients (*r*) in Table 2.

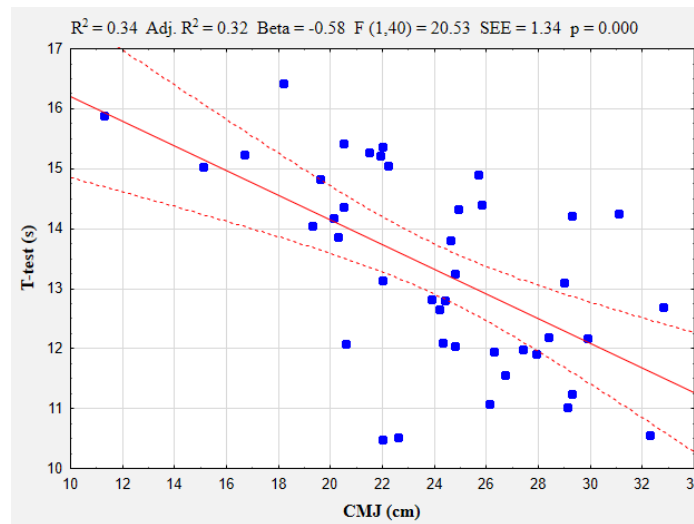
**Table 2** Pearson’s (*r*) correlation matrix of all variables

Variable (n = 42)	SJ (cm)	CMJ (cm)	5-m sprint (s)	10-m sprint (s)	30-m sprint (s)	T-test (s)
SJ (cm)	1.00	0.87*	-0.36*	-0.51*	-0.70*	-0.52*
CMJ (cm)		1.00	-0.29	-0.44*	-0.67*	-0.58*
5-m sprint (s)			1.00	0.92*	0.65*	0.43*
10-m sprint (s)				1.00	0.78*	0.53*
30-m sprint (s)					1.00	0.57*
T-test (s)						1.00

Legend: SJ-Squat jump; CMJ-Countermovement jump; \*-significant at level  $p < 0.05$ .

The agility T-test performance was significantly related to all independent variables (Table 2). Negative strong correlations were found in CMJ and SJ ( $r = -0.58$  and  $-0.52$ , respectively) and a strong positive correlation among sprint times at 30 and 10 m ( $r = 0.57$  and  $0.53$ , respectively). A moderate correlation was found in 5-m sprint time ( $r = 0.43$ ).

A multiple regression analysis with a backward stepwise method showed that CMJ was the best single predictor ( $p = 0.000$ ) of agility (Fig. 2).



**Fig. 3** Linear regression of CMJ as predictor vs. T-test as criteria.

### DISCUSSION

The aim of this study was to determine the relationship between VJ and sprint performance with agility in male adolescents.

The main findings of this study indicate that the agility has a strong correlation with jumping performance and a moderate to strong correlation with straight sprint performance.

Also, a stepwise regression analysis showed that the CMJ was the single significant predictor of the T-test performance in male adolescents.

Agility is a very complex multifactorial motor ability which is affected by interactions of strength, speed, balance, flexibility, and muscular coordination (Sheppard & Young, 2006), but it is not yet clear in what proportion they are associated among adolescents. Results from this study clearly demonstrates the presence of a strong negative relationship between jumping performance and agility, indicating that the greater the lower limbs explosive power, the better the time on the agility T-test. In accordance with the obtained results, Negra et al. (2017) reported the same negative relationship between SJ, CMJ and the agility T-test ( $r=-0.53$ ;  $-0.58$ , respectively) among adolescent athletes of a similar age to the participants of this study. Alemdaroğlu (2012) also reported a very similar significant negative correlation between the CMJ and T-test ( $r=-0.59$ ), but in professional male basketball players. Also, strong correlations were found between jumping performance and the agility test among young basketball players (Asadi, 2016) and students of the Faculty of Physical Education (Castillo-Rodríguez et al., 2012). Pauole et al. (2000) found a moderate significant correlation between the VJ and agility T-test ( $r=-0.49$ ) in college-aged men. However, our results are in contrast with the findings of Peterson, Alvar, & Rhea (2006) who revealed a trivial to small relationship between the VJ and the agility T-test in young male athletes, and Chaouachi et al. (2009) found no significant correlation between the SJ, CMJ and T-test in elite male basketball players.

Furthermore, the results obtained from the correlation matrix showed that sprint performance demonstrates moderate (5-m sprint time) to strong (10 and 30-m sprint times) positive correlations with agility. According to Vescovi and McGuigan (2008), the relationship between speed and agility increases with longer distances and when examining agility with flying sprint times. In accordance with the results of this study, a similar positive relationship was found between the 30-m sprint and T-test ( $r=0.50$ ) in elite male basketball players (Alemdaroğlu, 2012), also the 10 and 20 m sprint and T-test among adolescents (Negra et al., 2017). Peterson and associates (2006) revealed a significant correlation between acceleration (20-yard sprint) and speed (40-yard sprint) with the T-test among young athletes. In contrast, Chaouachi and associates (2009) did not find significant correlations between 5, 10, and 30 m sprint times and the agility T-test and in elite male basketball players.

The obtained relationship between jumping and sprint performance with agility can be explained by the major role of muscle contraction factors involved during acceleration, deceleration and rapid change of directions. Elastic properties of the muscles and their stored energy utilized from SSC are necessary for maximal jumping, sprint and agility performance (Komi & Gollhofer, 1997; Young, Miller, & Talpey, 2015). Also, Hermassi Fadhloun, Chelly, and Bensbaa (2011) outlined that the explosive leg power in the CMJ or SJ is a significant aspect of total time of the agility T-test.

Finally, with a multiple regression analysis using the backward stepwise method all variables were excluded from the regression model except CMJ as the single best predictor for agility performance. CMJ explains 34% of agility variance, same as Negra et al. (2017) reported (CMJ:  $R^2=0.34$ ). Other studies showed that jumping performance explains the agility from ~25% (Jones, Bampouras, & Marrin, 2009; Meylan et al., 2009) up to 46% (Castillo-Rodríguez et al., 2012) of common variance. Spasić et al. (2013) outlined that agility variance explained by power measures infrequently exceeds 50%. A recent study has also proposed a different approach of agility test measurement by removing the confounding

factor of large amounts of linear sprinting (Nimphius et al., 2018). For example, the time taken to run a 10-yard (9.14 m) linear sprint would be subtracted from the time to complete a T-test to calculate the change of direction (COD) deficit which can be a more precise measure of actual agility. The underlying logic behind the COD deficit is that some participants were relying on their better than average acceleration ability (10-m time) to mask their agility performance when assessed using total time (Nimphius et al., 2018). Further studies should investigate the COD deficit in order to gather more precise information about the influence of confounding factors to agility.

### CONCLUSION

From the obtained results from this research, it can be concluded that a significant relationship between jumping and sprint performance with agility exists. Furthermore, lower limb explosive power assessed through the CMJ is best single predictor of agility in male adolescents. The results of this study illustrate the significance of developing lower-body muscular strength and power to enhance jump and sprint performance that will eventually affect overall agility performance in male adolescents.

These findings have practical interest for physical education teachers and coaches which suggests that using a field test such as the T-test for agility and CMJ for jump performance assessment, which is easy to administer, consequently maybe used for physical fitness level assessment, also for training modeling and talent identification among youth non-athletes and athletes. One of the limitations of this study is that the CMJ cannot be used as an accurate predictor of agility because a great portion of variance has been left unexplained.

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## **VERTIKALNI SKOK I SPRINT KAO DETERMINANTE AGILNOSTI ADOLESCENATA MUŠKOG POLA**

*Sa ciljem da se utvrdi povezanost vertikalnih skokova, sprinta i agilnosti dečaka adolescenata, sprovedeno je istraživanje na uzorku od 42 ispitanika muškog pola, učenika sedmog razreda, prosečne starosti  $13 \pm 0.5$  godina. Prediktorske varijable su činile visina vertikalnih skokova koja je procenjena pomoću testova skok iz čučnja (SJ) i skok sa počučnjem (CMJ), primenom Optojump sistema, zatim brzina sprinta na 30 m sa prolaznim vremenom na 5 i 10 m primenom fotočelija. Agilnost kao kriterijumska varijabla je procenjena pomoću Agility T-test. Dobijeni rezultati ukazuju da postoje značajne negativne korelacije između vertikalnih skokova SJ, CMJ i agilnosti ( $r = -0.52$ ;  $r = -0.58$ , tim redosledom), kao i značajne pozitivne korelacije između brzine sprinta na 5, 10 i 30 m i agilnosti ( $r = 0.43$ ;  $0.53$ ;  $0.57$ , tim redosledom). Stepwise regresiona analiza je pokazala da je varijabla CMJ jedini značajni prediktor agilnosti ( $R^2 = 0.34$ ). Zaključuje se da su vertikalni skokovi i sprint značajno povezani sa agilnošću kao veoma kompleksne motoričke sposobnosti, takođe vertikalni skok CMJ ima najveći uticaj razvoj brzine izvođenja testova agilnosti.*

*Ključne reči: povezanost, skok iz čučnja, skok sa počučnjem, sprint, agilnost, adolescenti.*