JUMPING PERFORMANCE IS NOT A STRONG PREDICTOR OF CHANGE OF DIRECTION AND SPRINTING ABILITY IN PREADOLESCENT FEMALE GYMNASTS

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Abstract

This study examined the association between jumping performance, change of direction and sprinting ability in preadolescent gymnasts. Fifty, female 'Gymnastics for All' gymnasts (age: 8.0 ± 0.7 years, training experience: 2.2 ± 0.8 years, height: 129.3± 6.6 cm, body mass: 28.1 ± 5.8 kg) performed one and two-leg counter movement jumps, drop jump, squat jump, standing long jump, 10 and 20 m sprints, and two change of direction tests: 10 m (5 + 5 m with a 180° turn) and 20 m (10 + 10 m with a 180° turn). Significant correlations were found between the examined variables, however multiple regression analyses showed that jumping performance accounted for a small amount of the variance of change of direction (18.4 to 27.1%) and sprinting ability tests (22.6 to 29.3%). Further research is needed to elucidate whether long-term training affects the association between jumping performance and various measures of change of direction and sprinting ability on male and female athletes of different ages and levels of performance.

Keywords: *children, muscle power, acceleration, gymnastics.*

INTRODUCTION

Gymnasts are among the strongest and more powerful athletes in terms of relative strength, as this is expressed per kg of body mass (Jemni, Sands, Friemel, Stone, & Cooke, 2006). Strength and power in gymnasts are developed from a very young age (7-8 years old) (Arkaev & Sutsilin, 2004), with the emphasis placed on rapid force development, i.e. the ability to apply high forces during the limited contact time with the ground or the apparatus (Prassas, Kwon, & Sands, 2006). Strength and power output of the lower limbs is considered as an important contributor to sprinting and change of direction ability tasks (Lloyd et al., 2013; Nimphius, 2014). An indirect measure to assess lower limb muscle power production in children, commonly used in youth sports mostly due to its simplicity, is vertical jump height (Harrison & Gaffney, 2001). Previous research, suggested that lower limb muscle power, is related to sprinting and change of direction ability (Hennessy & Kilty, 2001), both essential components of performance in youth sports (Nimphius, 2014). Recently, Kritikou, Donti, Bogdanis, Donti and Theodorakou, (2017) found that change of direction ability explained a significant part of the variance of the artistry scores in young competitive rhythmic gymnasts.

The physiological, neuromuscular and locomotor determinants of change of direction ability have been largely examined in adults and include speed as well as eccentric and concentric power and whole-body coordination (Hader, Palazzi, & Buchheit, 2015; Nimphius, 2014). Previous studies in adult athletes found strong associations between measures of strength and speed (Wislof, Castagna, Helgerund, Jones, & Hoff, 2004) and strength and change of direction ability (Vescovi & McGuigan, 2008). In contrast, some other studies have shown that measures of power, sprint and change of direction ability are not closely associated (Castillo-Rodríguez, Fernández-García, Chinchilla-Minguet, & Carnero, 2012; Sheppard, Dawes, Jeffreys, Spiteri, & Nimphius, 2014). For example, Vescovi and Mc Guigan, (2008) reported that linear sprinting, agility and vertical jumping are independent locomotor skills in high school female athletes. Although the associations between lower limb muscle power, sprinting and change of direction ability have been examined in adults, giving controversial results, there is limited data in young athletes and especially in preadolescent gymnasts. Thus, the aim of this study was to examine whether jumping performance explains the variance of change of direction and sprinting ability in preadolescent female gymnasts.

METHODS

Participants

Fifty preadolescent Gymnastics for All gymnasts (age: 8.0 ± 0.7 years, training experience: 2.2 ± 0.8 years, height: 129.3± 6.6 cm, body mass: 28.1 ± 5.8 kg) participated in this study. Gymnasts trained 3 days a week, 90 min a day, for at least one year. Each training session involved general and special physical conditioning, as well as technical preparation on the apparatuses. The physical conditioning part aimed to improve strength and power and muscular endurance. It contained, exercises using body weight, strength oriented gymnastic skills and combinations of skills. During this time, they also competed in order to qualify for the gold, silver or bronze team, according to the International Gymnastics Federation Gymnastics for All Rules and Regulations (2009). Participants were recruited on the following eligibility criteria: training experience (1-3 years) and no history of lower limb injuries for the past 6 months. Before participating in the study, the subjects and their parents were fully informed about the training methods to be used, the purpose and risks of this study, confidentiality, anonymity, and the right to terminate participation at will. In addition, written parental consent was obtained for each participant. The procedures were approved by the Institutional Ethics Review Committee and complied with the ethical standards for research involving human participants set by the Declaration of Helsinki.

Testing procedures

The current study required the participants to complete 2 testing sessions at their training facilities, performed 2 days apart. The first testing session included anthropometric measures and familiarization with the physical fitness tests. At the start of the second session, and following a 10 min, standardized, sport-specific warm-up, gymnasts underwent a series of tests in the following order: sprint ability (10 and 20 m), two change of direction ability tests [10 m (5 + 5 m with a 180° turn) and 20 m (10 + 10 m with a 180° turn)] and jumping performance. Jumping tests included one and two-leg counter movement jumps, drop jump (20 cm), squat jump, and standing long jump. Sprint and change of direction ability tests were interspersed with 3 min of interval, and after 5 min of recovery, the gymnasts performed the jump tests. Twenty-four hours prior to each session, the gymnasts were asked to avoid any strenuous activity.

Measures

Anthropometry: Body mass, standing height and sitting height were measured with a calibrated digital scale and a stadiometer (Seca 710, and Seca 208, Hamburg, Germany). Leg length was calculated as follows:

Leg Length = Standing Height (cm) - Sitting height (cm)

The mean value of two consecutive measurements was registered for further analysis. A single researcher, experienced in kinanthropometry, performed all measures in accordance with the International Society for Advancement of Kinanthropometry, guidelines.

Maturity offset: Initially, decimal age was calculated by subtracting date of birth from date of measurement. Maturity offset was calculated according to the prediction equation of Mirwald, Baxter-Jones, Bailey, and Beunen, (2002) for girls:

Maturity offset: -9.376+0.0001882 Leg Length *Sitting Height)) + 0.0022* Age * Leg Length + 0.005841*Age*Sitting Height - 0.002658*age*weight + 0.07693*Weight by Height Ratio*

Jumping performance: Jumping performance was assessed by one and two-leg counter movement jumps, drop jump (20 cm), squat jump, and standing long jump. For all the jumps, the average value of two jumps separated by 10 s of rest was recorded for further analysis. Jump height was assessed using an electronic contact mat (Boscosystem® Chronojump) with the subjects instructed to perform a maximum effort and 'jump as high as possible'. For the one and two-leg counter movement jumps, the drop-jump and the squat jump, subjects were instructed to keep their hands on their hips throughout the jump, to take off with the ankles and knees fully extended and to land in a similarly extended position to ensure the validity of the test. In addition, three criteria were strictly adopted: a) correct body posture b) jumping straight up with no side to side or forward movement, and c) soft landing, including toe to heel rocking and progressive bent of the knees. For the one and the two-leg counter movement jumps, gymnasts were instructed to perform a countermovement until the knees were bent at approximately 90 degrees, and then immediately jump up. ICCs for the right and left leg countermovement jumps were 0.83 ($p<0.01$) and 0.77 ($p<0.01$), respectively. For the two-leg countermovement jump, ICC was 0.89 ($p<0.01$). To execute the drop jump, gymnasts jumped down from a 20cm box onto the mat and then immediately performed a maximal vertical jump. Subjects were required to land in the same point of the take off and rebound as soon as possible with almost straight legs. The ICC for the drop jump was 0.86 ($p<0.01$). For the squat jump subjects were jumping from a semi-squatting position without countermovement. The squat jump technique required the subjects to descend to a position of 90-knee flexion, determined using a hand-held goniometer that positioned the upper thigh parallel with the ground. Gymnasts were instructed to hold this position for 3 seconds, and then jump as high as possible without prior countermovement (Gore, 2000). The ICC for the squat jump was 0.80 ($p<0.01$).

For each trial of the standing long jump, the subjects were instructed to initially stand on a standardized starting point and to bend their knees (the depth of the flexion was self-selected) and bring the arms behind the body. Then, with a powerful drive they extended their legs, moved the arms forward and jumped as far as possible. The distance from the starting point to the landing point at heel contact was used for statistical analysis. All trials were measured to the nearest 0.01 m. The ICC for the standing long jump was 0.74 ($p<0.01$).

Sprint speed (10m and 20m): The starting position was standardized for all subjects. Athletes started in a two-point crouched position with their preferred foot on the starting line and their other foot in line with the heel of the preferred foot. Two cones were placed in 10 and 20 m distance, respectively, in a gymnastics vault corridor. Participants were instructed to run as fast as possible. The total time taken to run the 10 and 20 m sprint was measured using a digital stopwatch. Gymnasts performed 2 trials for each distance interspersed by 1 min rest and the average time was recorded for further analysis. The ICCs for the 10 and 20 m sprint were 0.82 ($p<0.01$) and 0.90 ($p<0.01$) respectively.

Change of direction speed: Change of direction speed (CODs) was tested with two CODs tests: 10 m (5 + 5 m with a 180° turn) and 20 m (10 + 10 m with a 180° turn). Two cones were placed in 5 and 10 m distance, respectively, in a gymnastics vault corridor Participants were instructed to accelerate as quickly as possible along the 5 m distance, pivot 180° on the cone and return as quickly as possible through the starting cones. The same procedure was repeated for the 10 + 10 m. Athletes completed 2 trials interspersed by 1 min rest and the average time was used for further analysis. The total time taken to run the 10 m (5 + 5 m with a 180° turn) and 20 m (10 + 10 m with a 180° turn) was measured using a digital stopwatch. The ICCs for the 5 + 5 m with a 180° turn and for the 10 + 10 m with a 180° turn was 0.78 ($p<0.01$) and 0.75 ($p<0.01$) respectively.

Reactive Strength Index: Reactive Strength Index is the ratio between jump height and time spent in contact with the ground and represents an individual's ability to change quickly from an eccentric to concentric muscle action (Flanagan & Comyns, 2008). RSI was calculated from the equation of Flanagan and Comyns (2008) as follows:

RSI= jump height (millimetres)/ground contact time (milliseconds)

Eccentric Utilisation Ratio: Eccentric Utilisation Ratio is the ratio of countermovement jump (CMJ) to squat jump (SJ) performance, and has been suggested as a useful indicator of power performance in athletes (McGuigan, Doyle, Newton, & Edwards, 2006).

Statistical Analysis

Statistical analyses were carried out using SPSS (IBM SPSS Statistics Version 22.0). Data are presented as means and standard deviations for all variables. The normality of data distribution was checked with the Kolmogorov-Smirnov test. The Pearson's correlation coefficient (*r*) was used to detect linear associations among the selected variables. Multiple regression analyses were used to investigate which jumping performance test contributed most significantly to each change of direction and sprinting ability test. The intra-class correlation coefficient (ICC) was used as a measure of test-retest reliability (Hopkins, Marshall, Batterman, & Hanin, 2009) for all the variables examined in this study and was determined by using a 2-way mixed model analysis of variance. Statistical significance was accepted at $p<0.05$.

RESULTS

Baseline values of jumping performance tests, change of direction and sprinting ability tests are presented in Table 1. Jumping performance was significantly correlated with change of direction and sprinting ability tests (Table 3).

Multiple regression analyses revealed that two leg counter movement jump and drop jump accounted for 18.4% of the variance of 5+5 m CODs and standing long jump, drop jump and age accounted for 27.1% of the variance of 10+10 m CODs. Furthermore, standing long jump and drop jump accounted for 29.3% of the variance of 10 m sprint and age and drop jump accounted for 22.6% of the variance of 20 m sprint (Table 2).

Table 1. Baseline values of the tested variables. Data are means ±standard deviations

Tested variables	
Counter Movement Jump Height (cm)	17.72±3.67
Right Leg Counter Movement Jump Height (cm)	7.76±2.39
Left Leg Counter Movement Jump Height (cm)	7.08±2.35
Drop Jump Height (cm)	14.81±4.03
Drop Jump Flight Time (s)	0.34±0.06
Drop Jump Contact Time (ms)	290±70
Squat Jump Height (cm)	16.94±3.61
Standing Long Jump (cm)	110.76±15.66
Change of direction ability 5+5 (s)	3.78±0.35
Change of direction ability 10+10 (s)	5.90±0.41
Sprinting 20m (s)	4.82±0.50
Sprinting 10m (s)	2.75±0.24
Reactive Strength Index	0.53±0.20
Eccentric Utilisation Ratio	1.05±0.15

Table 2. Results of the multiple regression analyses using age and counter movement jump, standing long jump and drop jump heights as predictors of the performance of change of direction (5+5, 10+10 m) and sprint (10, 20m) abilities

Tested Variables **5+5 m Change of direction**	**Unstandardized coefficient *B***	***SEB***	**Standardized beta coefficient**	**Adjusted R^2**
				0.184*
Constant	4.608	.494**		
Counter movement jump height	-.030	.015	-.310	
Drop jump height	-.019	.014	-.214	
10+10 m Change of direction	**Unstandardized coefficient B**	***SEB***	**Standardized beta coefficient**	Adjusted R^2
				.271*
Constant	8.005	.601**		
Drop jump height	-.029	.014*	-.281*	
Age	-.099	.079	-.169	
Standing long jump	-.008	.004*	-.299*	
10m Sprint	**Unstandardized coefficient *B***	***SEB***	**Standardized beta coefficient**	**Adjusted R^2**
				.293**
Constant	3.528	.218**		
Drop jump height	-.030	.008**	-.480**	
Standing long jump	-.003	.002	-.189	
20m Sprint	**Unstandardized coefficient B**	***SEB***	**Standardized beta coefficient**	**Adjusted R^2**
				.226**
Constant	6.623	.723**		
Drop jump height	-.053	.017*	-.418*	
Age	-.126	.096	-.177	

SEB: standard error of B**;** **: $p < 0.01$, *: $p < 0.05$

Table 3. Correlations between jump performance, change of direction and sprinting ability in preadolescent gymnasts

	Training age	Age	Body mass	Height	CMJ height	R-leg CMJ height	L-leg CMJ height	Drop Jump height	Drop Jump Contact Time	Squat Jump height	Standing Long Jump	COD 5+5m	COD 10+10 m	20m sprint	10m sprint	RSI	EUR	BMI
Training Age																		
Age	.489**																	
Body Mass	-.265	-.050																
Height	-.348*	-.089	.765**															
CMJ height	.606**	.418**	-.427**	-.415**														
R-leg CMJ height	.605**	.382**	-.580**	-.410**	.788**													
L-leg CMJ height	.600**	.519**	-.451**	-.378**	.636**	.775**												
Drop Jump height	.458**	.350*	-.327*	-.371**	.564**	.615**	.531**											
Drop Jump CT	.045	.150	.144	.203	-.137	-.052	.078	-.087										
Squat Jump height	.528**	.415**	-.431**	-.304*	.792**	.802**	.739**	.613**	.005									
Standing Long Jump	.385**	.339*	-.066	-.076	.377**	.273	.350*	.307*	.127	.371**								
CODs 5+5m	-.355*	-.318*	.063	.120	-.431**	-.382**	-.391**	-.389**	.005	-.333*	-.206							
CODs 10+10 m	-.347*	-.369**	.099	.059	-.372**	-.300*	-.252	-.432**	.064	-.321*	-.442**	.489**						
20m Sprint	-.106	-.323*	.006	.061	-.363**	-.278	-.357*	-.480**	.137	-.413**	-.207	.167	.432**					
10m Sprint	-.302*	-.303*	.200	.254	-.360*	-.414**	-.426**	-.538**	.083	-.380**	-.336*	.521**	.622**	.450**				
RSI	.333*	.229	-.300*	-.383**	.458**	.459**	.335*	.763**	-.641**	.430**	.096	-.261	-.333*	-.408**	-.409**			
EUR	0.92	-.057	.036	-.164	.242	-.089	-.232	-.120	-.241	-.387**	-.088	-.111	-.017	.117	.093	.029		
BMI	-.125	-004.	.887*	.390**	-.326*	-.540**	-.399**	-.203	.060	-.405**	-.035	.018	.098	-.026	.121	-.162	.165	
Matutity offset	-.037	.370**	.786**	.724**	-.173	-.248	-.104	-.068	.157	-.152	.038	-.046	-.118	-.271	.116	-.109	-.056	.611**

Note: CMJ height=Counter movement jump height, R-leg CMJ height=Right leg counter movement jump height, L-leg CMJ height= Left-leg counter movement jump height COD=Change of direction ability, Sprint ability, RSI= Reactive strength index, EUR=Eccentric utilization ratio, BMI=Body mass index, Maturity offset
** p < 0.01, * p < 0.050.8±2.9

DISCUSSION

The aim of this study was to examine the association between jumping performance, change of direction and sprinting ability in preadolescent gymnasts. The results of this study showed that Pearson product moment correlation coefficients were statistically significant between the examined variables (Table 3). However, regression analyses showed that jumping performance accounted for a small amount of the variance of change of direction (18.4 to 27.1%) and sprinting ability tests (22.6 to 29.3%) thus being in line with previous research in adolescent female athletes (Vescovi & McGuigan, 2008).

In the present study, drop jump was the variable that showed the highest associations with change of direction and sprinting ability tests (Table 2). The drop jump is a measure of fast (<250 milisecond) stretch shortening cycle performance (Hennessy & Kilty, 2001; Schmidtbleicher, 1992). Fast stretch-shortening actions may promote greater movement speed via elastic energy usage and stretch reflex contributions (Komi & Gollhoffer, 1997). In the present study, the contact time with the ground was 290±70 ms, a time frame near the threshold of fast stretch shortening cycle activities in adults (Schmidtbleicher, 1992). Thus, the jump height those gymnasts could reach after rebound appears to be a good indicator of their performance in locomotion skills, and in particular in the measures of quickness and acceleration used in this study. In line with these results, Pettersen and Mathisen (2012) pointed out that the forceful deceleration of 10 and 20 m sprint and change of direction speed share some of the same neuromuscular characteristics as the landing phase of a drop jump. Indeed, authors have stated that the CMJ may not be the best model to examine the stretch shortening cycle mechanism, and that fast hopping or DJ may provide more insight to the relationship between the muscle-tendon complex during human locomotion (Komi, 1992). Despite a moderate correlation found in this research between drop jump height and counter movement jump height ($r = .564$, $p < 0.01$) it seems that at least to some degree they measure different explosive leg-power qualities (Cronin & Hansen, 2005).

Although it is acknowledged that Reactive Strength Index is a measure that quantifies the strain placed on the muscle-tendon unit during stretch shortening cycle actions (McClymont, 2003), in this study, Reactive Strength Index demonstrated low associations with sprinting and change of direction ability measures. Previous research with 9-15 years old boys, reported no improvement in Reactive Strength Index following 4 weeks of plyometric training in the group of 9-year old boys, and the authors assumed that age and maturational status were more important for the development of the ability to use the stretch shortening cycle than training (Lloyd, Oliver, Hughes, & Williams, 2012). Furthermore, the Eccentric Utilisation Ratio, which is an indicator of stretch shortening cycle performance in adult athletes in various sports (McGuigan, et al., 2006), was not associated with measures of change of direction and sprinting ability. It is known that in a plyometric movement, the goal is to reduce time in the amortization phase, which is defined as the time interval between the eccentric phase and the concentric phase (Voight & Dravovitch, 1991). This depends essentially on the contractile and elastic abilities of the tendomuscular system (Komi, 1992). However, volitional muscular force, motor unit activation, and agonist-antagonist synchronization in children are lower compared with adults (Dotan, et al., 2012). It seems, that for the very young gymnasts of this study, Reactive Strength Index and Eccentric Utilisation Ratio are not representing their ability to use the stretch shortening cycle. It is also reported that neural regulation of leg stiffness and Reactive Strength Index is more effective in adults that in children (Oliver & Smith, 2010) and that both measures of stretch shortening cycle increase with age (Lloyd, Oliver, Hughes, & Williams, 2011). Interestingly, in this study, age was also associated with 10+10 m CODs and 20 m sprint in the present study, despite the small age difference (~1 year) between participants.

The association of standing long jump with 10+10 change of direction speed and 10 m sprinting ability, found in the present study, is not surprising. Previous research has also shown that horizontal jumps may demonstrate higher association than vertical with sprinting ability (Meylan, McMaster, Cronin, Mohammad & Rogers, 2009).

Body mass was not associated with change of direction and sprinting ability, although previous research reported that body mass in strongly related to performance in weight-bearing activities (Bovet, Auguste, & Burdette, 2007). Probably, in normal weight children, other factors like power are more important and/or may counteract the effect of a higher body mass on locomotion. In line with this result, previous research also suggested that body mass and limb length are not related to improvements in stretch shortening cycle actions in 9 to 12 years old children boys (Lloyd, Oliver, Hughes, & Williams, 2012; Veligekas, Tsoukos, & Bogdanis, 2012).

The fact that jumping performance in general, explained a small amount of the variance of change of direction and sprinting ability tests in this study, can be attributed to a number of factors. Previous research findings on the association of lower limb jump performance and change of direction and sprinting ability tests, reported conflicting results. For example, some previous studies in adult athletes found strong associations between measures of strength and speed (Wislof, Castagna, Helgerund, Jones, & Hoff, 2004; Young, McLean, and Ardagna, 1995) and strength and change of direction tests (Vescovi & McGuigan, 2008). In contrast, some other studies have shown that measures of isokinetic power strength, power, and change of direction and sprinting ability tests are not associated (Castillo-Rodríguez, Fernández-García, Chinchilla-Minguet, & Carnero, 2012; Cronin and Hansen, 2005; Sheppard, Dawes, Jeffreys, Spiteri, & Nimphius, 2014) or that the ability of the jumps to predict change of direction ability (Buchheit, Mendez-Villanueva, Delhomel, Brughelli, & Ahmaidi, 2010) or sprint performance is limited (Meylan, McMaster, Cronin, Mohammad, & Rogers, 2009). However, the associations between measures of power and speed, and change of direction speed can only give an insight into performance components, and not a causation (Nimphius, Mc Guigan, & Newton, 2010). Other factors, like the ability to efficiently use the stretch shortening cycle in rapid movements (Markovic & Mikulic, 2010), age, training experience of the participants, and time in the training season (Nimphius, Mc Guigan, & Newton, 2010) may mediate this relationship. For example, Vescovi and Mc Guigan (2008) found that measures of counter movement jump performance explained a small amount of the variance (24-33%), for the sprint times in high school athletes (aged 15.1±1.6 years) however, the amount of variance explained was higher for the college athletes (aged 19.9±0.9 years). It should also be noted that training is considered as a critical factor determining children's muscular performance overtime. Kotzamanidis, (2006) showed that a 10-week, (twice per week), plyometric training program resulted in significantly increased 20- and 30-m sprint velocity, but not 10-m sprint velocity in 11-year-old boys compared with a control group of similar age. Buchheit et al. (2010) also found that a 10-week, 1-hour per week repeated shuttle sprints and explosive strength training produced significant improvement in 30-m sprint, but no significant improvement in 10-m sprint in adolescent male elite soccer players. In line with these results, Kums, Gapeyeva, and Pääsuke (2005) found that elite young rhythmic gymnasts demonstrated a markedly greater ability to use the stretch shortening cycle than controls during drop jump and Piazza, et al. (2014) reported an increase in lower limb muscle power of 6-7% after 6 weeks of resistance training. Thus, further research is needed to elucidate whether long-term training can change the associations between leg muscle power and various measures of change of direction and sprinting abilities, at different time points over a competitive year.

CONCLUSIONS

There is not always a consensus on the association between jump performance, change of direction and sprinting ability parameters', at different ages and performance levels. All the performance scores in this study were statistically correlated, showing that jumping performance is associated with locomotion skills performance in young gymnasts. However, only a small part of the variance in sprinting and change of direction ability are explained by jumping performance. Based on these results, it is suggested that coaches should not rely solely on a single power measurement to predict locomotion performance. Further research, needs to determine the influence of other factors to motor performance and develop assessment batteries including movement coordination, training adaptation, anthropometric and biomechanical elements that should be taken into account.

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