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Associations between Change of Direction, Balance, Speed, and Muscle Power in Prepubescent Soccer Players

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Abstract

Relationships between change of direction (CoD), balance, speed, and power are less extensively studied in youth but provide important information for training. The aim of this study was to determine associations between CoD, balance, speed, and leg power in prepubescent soccer players. Thirty young male soccer players (9.26 ± 0.76 years; Peak-Height-Velocity: -3.42 ± 0.47 years) were assessed for CoD (shuttle run), Y-balance, speed (10-30-m sprint), and muscle power (unilateral, bilateral countermovement jumps [CMJ], unilateral, bilateral standing long jumps [SLJ], and triple hop test). Positive correlations were observed between the shuttle run, and 10-m (r=0.46) and 30-m sprint time (r= 0.47). Negative correlations were found between the shuttle run and SLJ (r=-0.44), bilateral CMJ (r= -0.42), and composite Y-balance (r=−0.49). Linear stepwise regression analysis revealed that 25% of the adjusted variance in the shuttle run test was explained by the Y-balance test (F=9.28; p<0.005). When the 10-m sprint test was added, explained variance amounted to 47% (F=11.87; p<0.001). Medium-sized associations were illustrated between speed, dynamic balance, and CoD in prepubescent soccer players. A greater emphasis on balance and sprint training might be an advantage for youth with less developed neuromuscular capabilities to improve CoD abilities.

Keywords

Field-testing; Shuttle run; Team sports; Agility

Introduction

The ability to quickly change direction is an important prerequisite for success in many sports [1]. In soccer, change-of-direction (CoD) ability is often used as a criterion to evaluate performance in soccer players at different ages. According to Young et al. [2], CoD speed represents the main physical determinant of agility. Excellent CoD skills permit the athlete to create greater space away from their opponents allowing them to perform their tasks with less interference and more time. Within these determinants, several sub-factors exist that are related to either CoD speed (e.g., muscle strength, power, and reactive strength) or perception and decision making (e.g., visual scanning, anticipation, pattern recognition). In fact, evidence from cross-sectional studies indicates significant associations between muscle strength and power [3,4], balance [5], speed [6] and agility. For instance Negrete and Brophy [7] reported a shared variance of 42% between single leg vertical jump and a diamond-shaped agility test in 29 male and 31 female, collegiate participants. Recent investigations suggest that in addition to muscle strength, power, and speed [8], balance is an important influencing factor of CoD ability, specifically in soccer players [9]. In accordance with this finding, Miller et al. [10] postulated that improved balance and postural control during plyometric movements result in enhanced agility performance. This is based on the assumption that agility includes rapid stop-and-go movement patterns which require adequate levels of balance and stability to control and redirect momentum. The importance of balance for agility was documented in a sample of 32 college-age male athletes and 31 college-age female athletes (age 20.02 ± 1.89 years) [5]. However, little is known about potential associations between balance and CoD in a pediatric population, suggesting the necessity to examine the relationships between measures of unilateral, and bilateral leg power, balance and CoD during growth and maturation. With this in mind, the purpose of the present study was to identify possible associations between measures of CoD (4×9.1-m shuttle run test), and components of physical fitness (e.g., balance, muscle strength, power, speed) in prepubescent soccer players. It was hypothesized that balance, muscle strength, power, speed are associated with CoD performance in youth soccer athletes.

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Materials and Methods

Experimental design

Correlations and linear stepwise regression analysis on 30 young male soccer players were conducted to determine associations between CoD (4 × 9.1- m shuttle run test), balance (Y-balance test), speed (10- m, 20- m flying time, 30- m sprint), and muscle power (unilateral, bilateral countermovement jumps [CMJ], unilateral, bilateral standing long jumps [SLJ], and triple hop test).

Participants

Thirty male young soccer players (9.26 ± 0.76 years; 31.83 ± 3.61 kg; 136.70 ± 5.83 cm; body fat: 18.60 ± 4.98 %; predicted years from Peak height velocity (PHV): -3.42 ± 0.47), members of a young team of the national Tunisian league, volunteered to participate in this study. All participants were healthy, without any history of major lower limb injury, and were not taking any medication during their study participation. Participants had at least four years of systematic soccer training experience with a minimum of two training sessions per week (i.e., 90 minutes per session) in addition to their physical education class activities (2 hours per week). Written informed consent was obtained from each of the participants and guardians (for underage players) after receiving a verbal explanation of the potential risks and benefits resulting from this study participation. The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the Ethics Committee of the National Centre of Medicine and Science of Sports of Tunis (CNMSS) before the commencement of the assessments.

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Testing procedures

All procedures were carried out during the second half of the competitive season (May - June). Before the commencement of the study and prior to the initiation of testing, all players completed a one-week familiarization period (two sessions/week) to become acquainted with the general environment, form and technique of each physical fitness test used to evaluate CoD, sprint, muscle power, and balance. During this time, players received standardized instructions on proper movement techniques for physical fitness testing from certified strength and conditioning specialists. During the first session, each subject's height and body mass were collected using a wall-mounted stadiometer and electronic scale, respectively. The body-mass-index (BMI) was calculated as mass per height squared (kg/m^2). The sum of skinfolds was monitored with Harpenden's skinfold calipers (Baty International, West Sussex, England). Body measurements were conducted according to Deurenberg et al. [11] who reported similar prediction errors between adults and adolescents. Deurenberg's prediction equation was used to estimate body fat percentage (BFP). BFP=22.23 + 26.56 × log (biceps, triceps, subscapular, and suprailiac). Thereafter, biological maturity was assessed non-invasively by incorporating measures of chronological age and body height into a regression equation able to predict biological age from PHV [13]. The equation has previously been validated for boys and presents a standard error of estimates reported as 0.542 years [12]. With this equation, all players were categorized as prepubescent. The respective equation is reported below:

Maturity offset=−7.999994 + (0.0036124 × age [yrs] × height [cm])

After the anthropometric measurements were completed, players performed a 10 minute standardized warm-up consisting of jogging followed by a series of dynamic movements (e.g., lunges and skipping). On three non-consecutive test days, players performed two trials each of the CoD test (shuttle run), muscle power test (bilateral and unilateral standing long jump tests, triple hop test, unilateral and bilateral CMJ), speed test (10-m, 30-m sprint, and 20-m flying time), and dynamic balance test (Y-balance test) with approximately 1 minute recovery between trials and the best trial was used for further analysis. The order of these tests were randomized. Within one week, all tests were repeatedly performed and intra-class correlation coefficients (ICC) together with standard error measurement (SEM) were assessed.

Change-of-direction [CoD] performance

CoD was evaluated using the 4 × 9.1-m shuttle run test [13]. Participants stood behind a starting line and started the electronic clock by passing through the first timing gate. At the end of the 9.1-m section, participants were asked to step with 1 foot beyond a marker while reversing the running direction and sprinting back to the start where the same reversal of movement direction was required. After the fourth 9.1-m section, the subject passed through the second timing gate to stop the electronic clock. Test time was taken using the same equipment as in the sprint tests. The shuttle run test was performed two times, separated by at least 2-min of passive recovery. The best performance was recorded and used for further analysis. Since the ability to quickly change direction is an important prerequisite for success in many sports [1], it is often used as a criterion to evaluate performance in soccer players at different ages [14].

Horizontal jump tests

Each participant performed a series of horizontal jumps including a unilateral standing long jump (USLJ) with the dominant leg and the triple hop test for distance. For the USLJ test, the participant began by standing on the designated testing leg with the toe at the starting line and hands on the hips. Each participant was instructed to sink to a self-selected depth as quickly as possible and then jump as far forward as possible and land on two feet. The distance jumped was measured to the nearest 0.01 m with a tape measure [15,16]. The test was repeated twice and the best score was taken for further analysis (cm). Hammami et al. [15] reported that USLJ was the single best predictor of performance in strength and power with post-PHV male soccer players.

The triple-hop for distance test was performed to measure horizontal jump length in a similar way as described by Hammami et al. [15,16]. The players alternated between jumping on the right and the left leg and always started with the dominant leg. From a one leg standing starting position, the player jumped forward and landed on the same leg, jumped forward and landed on the other leg, and jumped for the third time and landed on both legs. If the player lost balance upon landing, the trial was repeated. The distance was measured from the starting line to the place where the rear heel landed after the last hop.The triple hop test is purported to be a good performance indicator forrunning tasks [17].

Vertical jump tests

Players performed the vertical jumps: bilateral jump (CMJ) and single-leg counter movement jump tests (SL-CMJ) [18]. With these two types of jump, participants were instructed to jump as high as possible; verbal encouragement was provided before each trial. Participants were allowed to swing their arms during the jumps as this action was typical of their daily jumping activities and thus was ecologically valid (more realistic). All vertical jump tests were performed using an Ergojump system (Globus Italia, Codogne, Italy), which recorded jump height, with a passive rest of 1 min between each repetitionand 3 min between each test in order to minimize any fatigue effects. Vertical jump and agility performance was significantly correlated with collegiate-aged participants [7].

Sprint acceleration and Speed

Sprint ability was evaluated by a linear 10-m sprint (acceleration), and 30-m sprint (speed) [19]. For each test, two seconds before the assessment, participants were asked to take the start position, with the front foot placed 5 cm before the first timing gate and await the start signal for the next sprint. Time was recorded using photocell gates (Brower Timing Systems, Salt Lake City, UT, USA) placed at the start-finish point and on the 10-m or 30-m lines, respectively, approximately 0.4 m above the ground, and with an accuracy of 0.001 s. Both sprint tests were performed twice, separated by at least 2 min of passive recovery. The best performance was recorded and used for further analysis. In addition, for the 30-m sprint, averages were calculated for 10 m (the first linear 10 m from the start point) and the 20-m flying time (the time for the split between the 10-m and 30-m lines). Acceleration and sprint time have been shown to significantly correlate with agility in adults [20].

Dynamic balance

Dynamic balance was assessed using the Y-Balance test according to a previously described protocol [15,16], which has been shown to

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be reliable in a pediatric population (ICC= 0.92). The Y balance test is extensively used to identify balance deficits and improvements [21]. For this purpose, participants stood on the dominant leg, with the most distal aspect of their big toe on the center of the grid. Thereafter they were asked to reach the maximal distance in the anterior (A), postero-medial (PM), and postero-lateral (PL) directions while maintaining their single limb stance [20]. The maximal reached distance was measured with a measuring tape as the most distal point reached by the free limb. The trial was discarded and repeated if the player failed to maintain unilateral stance, touched down with the reach foot, or finally failed to return the reach foot to the starting position. Balance performance was calculated as the YBT composite score (MADX [%]), obtained by dividing the sum of the maximal reached distances in the three directions by three times the length of the lower limb (LL; measured from the most distal end of the anterior superior iliac spine to the most distal end of the medial malleolus of each limb), then multiplied by 100:

$$\text{MADX}\ \% = \{[(A + PM + PL) / (LL \times 3)] \times 100\}$$

The Y-Balance test has been reported to significantly correlate with proxies of strength (back extensor force) and power (CMJ and LJ) in young soccer players (10-18 years) [15,16]. The inclusion of balance into a plyometric power training program has also been shown to augment particular reactive strength and power (i.e. triple hop test) measures [16].

Statistical analysis

In a first step, data were verified for normal distribution using the Kolmogorov-Smirnov test. Based on these results, data were presented as means and standard deviations (SD). Test-re-test reliability of our variables was computed using Cronbach's model of ICCs and SEMs in accordance with the method introduced by Hopkins [22]. In addition, a paired sample t-test was used to determine significant differences between the scores recorded during the two test trials. The SEM was estimated through the usual formula: $SEM=SDd/\sqrt{2}$ [23]. The relationship between measures of CoD and muscle power, balance, and straight sprint tests was analyzed using Pearson's product–moment correlation coefficient. Associations are reported by their correlation coefficient (r-value), level of significance (p-value), and the amount of variance explained (r^2-value). Values of $r \geq 0.10$ indicate small, $r \geq 0.30$ medium, and $r \geq 0.50$ large size of correlation [24]. Further, multiple linear stepwise multiple regression models were calculated to determine the most robust predictors of CoD. Coefficients of determination ($R^2 \times 100$) were used to interpret the meaningfulness of the relationships [25]. Statistical analyses were performed using SPSS software statistical package (SPSS Inc., Chicago, IL, version. 18.0), and statistical significance was set at $p<0.05$.

Results

Reliability of all measures

Cronbach's alpha intraclass coefficient correlation showed good reliability for all tests. ICC-values ranged from 0.81 to 0.94 and SEM from 0.02 to 5.21. Furthermore, paired t-tests showed no significant differences between the scores recorded during the two test trials for all measured variables (Table 1).

Relationships between measures of CoD and physical fitness

Associations between the shuttle run test and the composite score of the Y-balance test, sprint and jump performances are presented in Table 2. Significant positive correlations were observed between the shuttle run test and 10-m as well as 30-m sprint time (r-range: 0.42 to 0.47; $p<0.01$). In addition, a significant negative correlation was found between the shuttle run test, the standing-long-jump, the CMJ, and the composite score of the Y-balance test (r-range=−0.42 to -0.49; $p<0.02$) (Figure 1).

Multiple regressions

Results pertaining to the multiple regression analysis are shown in Table 3. The multiple regression analysis revealed that the Y-balance, sprint and jump components explained 73% (*F=2.93; p<0.02*) of the variance of CoD performance. Furthermore, the single best predictor of CoD (shuttle run test) was the Y-balance test with an explained variance of 25% (*F=9.28; p<0.005*). With the inclusion of 10-m sprint time in the regression equation, 47% of explained variance in CoD performance was reached (*F=11.87; p<0.001*).

Table 1: Performance characteristics, descriptive statistics and reliability measures for anthropometrics and physical fitness tests. ICC=intra-class correlation coefficient; SD: Standard deviation; SEM=standard error of measurements (N=30).

Independent variables	Mean ± SD	ICC	CI 95%	SEM
Age (Yrs)	9.26 ± 0.76	-	-	-
Height (cm)	136.70 ± 5.83	-	-	-
Sitting Height (cm)	66.60 ± 2.53	-	-	-
Body Mass (Kg)	31.83 ± 3.61	-	-	-
Predicted Years from PHV	-3.42 ± 047	-	-	-
Body Fat (%)	18.60 ± 4.98	-	-	-
Standing Long Jump (cm)	182.67 ±13.20	0.88	0.74 - 0.94	1.72
Unilateral Standing Long Jump (cm)	111.03 ± 21.21	0.90	0.80 - 0.95	2.18
Triple Hop Test (cm)	404.93 ± 66.00	0.94	0.88 - 0.97	5.21
CMJ	22.58 ± 3.87	0.91	0.80 - 0.96	0.40
Unilateral CMJ	12.74 ± 3.28	0.84	0.67 - 0.93	0.06
Composite Score Y-Balance Test (%)	142.31 ±14.82	-	-	-
10-m Sprint (s)	2.09 ± 0.11	0.89	0.77 - 0.95	0.03
30-m Sprint (s)	5.04 ± 0.18	0.92	0.84 - 0.96	0.02
20-m Sprint (s)	2.95 ± 0.17	0.92	0.83 - 0.96	0.02
Straight Line 15-m Dribbling Test (s)	4.92 ± 0.21	0.81	0.60 - 0.91	0.03
4 × 9.1-m Shuttle Run Test (s)	9.67 ± 0.94	0.93	0.85 - 0.97	0.08

Table 2: Relationship between agility performance and various measures of physical fitness.

	Variable	r	p-value
4 × 9.1-m Shuttle Run Test (s)	Standing Long Jump	-0.446	**0.013**
	Unilateral Standing Long Jump	0.141	0.457
	Triple Hop Test	-0.206	.276
	CMJ	-0.424	**.020**
	Unilateral CMJ	-0.082	0.666
	Composite Score Y-Balance Test	-0.499	**0.005**
	10-m Sprint	0.463	**0.010**
	30-m Sprint	0.476	**0.008**
	20-m Sprint	0.199	0.291
	Straight Line 15-m Dribbling Test	-0.021	0.913

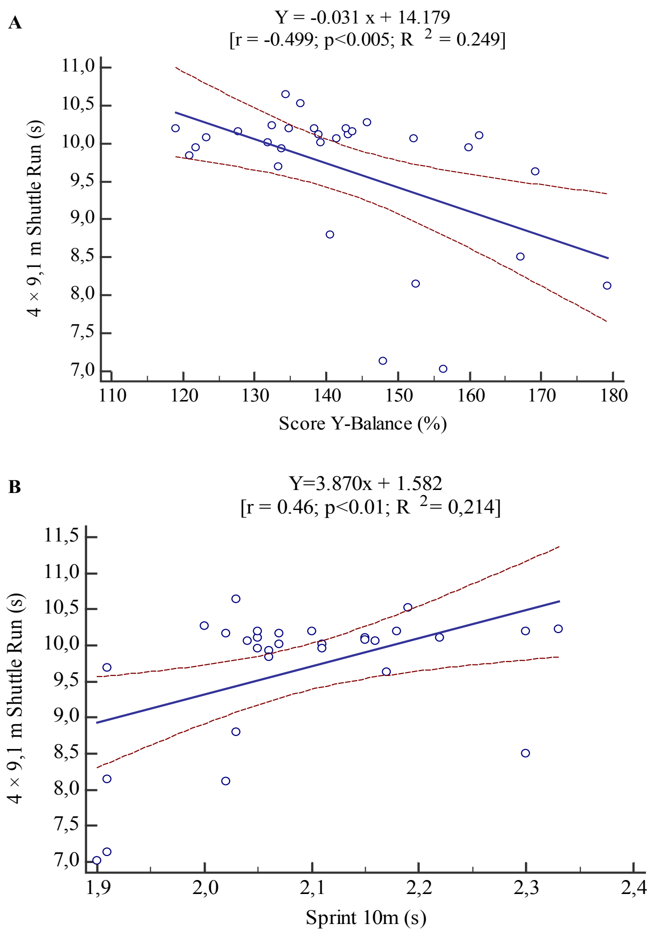

Figure 1: Relationship between: A) 4 × 9.1-m Shuttle Run Test and Y-Balance Test performance; B) 4 × 9.1-m Shuttle Run Test and 10-m sprint time.

Table 3: Results of stepwise multiple regression analysis of predictors that influenced agility performance (4 × 9.1-m Shuttle Run Test).

	Model	Unstandardized Coefficients		Coefficients Beta	Sig.	R^2
		B	Std. Error			
4 × 9.1-m Shuttle Run Test	(Constant)	6.05	2.75		0.037	
	Y-Balance Test	-0.03	0.01	-0.50	0.001	0.25
	10-m Sprint Time	3.91	1.17	0.47	0.002	0.47

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Discussion

The present study is the first to examine potential associations between CoD performance and unilateral/bilateral muscle power, sprint, and balance performance in prepubescent soccer players. Medium to large correlations were found between measures of CoD and variables of balance, muscle power (standing long jump, CMJ), and sprint performance (10 and 30-m sprint time). This suggests that

either the tests assess similar physical attributes or performance in one test is able to predict performance in another. The Y-Balance test was considered the single best predictor for CoD with an explained variance of 25%. If the predictor 10-m sprint time was added to the equation, explained variance of CoD increased to 47%. Thus, our results confirm previous studies conducted in adult populations and different team sports.

The observed strong correlations between CoD and measures of acceleration and sprint in soccer players are similar to findings reported by Little and Williams [26] in professional soccer players. These authors observed that the zigzag test for agility highly correlated with the 10-m acceleration test ($r=0.34$; $p<r= 0.005$), and the flying 20-m test ($r= 0.45$; $p<0.0005$). In contrast to our findings and the

results of Little and Williams, and Vescovi and McGuigan [27], revealed low-to-weak correlations between agility performance (Illinois and pro-agility) and in-line sprint performances (9.1,18.3, 27.4, and 36.6 m). Our study revealed moderate correlations between the shuttle run test and

Speed performances (10 and 30-m). CoD capability [27] and acceleration are important factors that Influence soccer performance [28].

Another finding of the present study was a moderate relationship between CoD performance and CMJ and standing-long-jump performance. This is not surprising, since it confirms the already established relation between vertical jump height and short-duration sprint time [29], and is in agreement with those biomechanical analyses, which report that short-distance sprints, jumping and CoD are highly dependent on the subject´s ability to generate powerful movements of the knee extensors, hip extensors, and plantar flexors muscles [14,30]. Both agility performance and jumping drills are explosive anaerobic power movements and the high-phosphate (i.e. ATP-CP) capacity can increase with maturation due to the physiological changes or through the specificity of the training stimuli [31]. In contrast to our results, Sporis et al. [9] found that zigzag agility was moderately correlated with both 20- m sprint times ($r=0.603$, $p<0.05$) and 30 - m sprint times ($r=0.560$, $p<0.05$). Sheppard and Young [4] suggested that CoD test complexity (i.e., distance covered and number of change in directions) was related to variability in acceleration and deceleration which may have affected the magnitude in association between jumping performance and CoD ability results.

Dynamic measures of balance correlated with CoD ability (shuttle run) and the multiple regressions show additional findings regarding the hierarchy of the influence of different predictors on CoD performance. With these pre-PHV soccer players, the only variable able to predict the ability to change direction (shuttle run) was the Y-balance score with an explained variance of 25%. Since this pre-PHV group had not yet reached the phase of accelerated growth, the vestibular systems would have a more consistent morphology (i.e. height, mass, limb and trunk lengths) over time with which to optimize their strategies to maintain static balance. Evidently, the optimal motor control for CoD in prepubescent soccer players includes advanced dynamic balance capabilities. Sekulic et al. [5] reported that balance measures were significantly correlated to the agility performance in men but not in women. Balance is rarely studied in relation to CoD ability, although authors have noted the necessity for an improvement in balance to improve agility performance [25,32] or recognized balance control as a facet of agility [18]. Balance influence on CoD should be found in the ability to accurately coordinate the timing and action of skeletal muscles (i.e., coordination), which is essential for both balance and CoD [33]. In the present study, CoD ability was performed under less stable conditions with high speed dynamic contractions performed within a more limited base of support (shuttle run) or with the center of gravity being moved outside the base of support, which would be positively affected by higher balance scores.

Mirkov et al. [32] reported that the most prominent advantage of soccer players over control participants during the tested ages (11-14 years) appeared to be movement agility. Hence, this advantage could be related to their ability to achieve and maintain balance more efficiently. Indeed, the ability to make frequent CoD is related to the ability to maintain appropriate postural adjustments and therefore, an appropriate ability to maintain balance. This hypothesis can be easily verified by analyzing the motion pattern requirements and mechanical demands of the shuttle run test. Specifically, for the successful execution of this test, the ability to perform rapid accelerations and decelerations while moving forward and quickly changing movement from side to side are crucial. Given that these actions cause frequent perturbations of the center of gravity, which require efficient neuromuscular control adaptations, one's ability to efficiently maintain static and dynamic balance may positively affect high-speed athletic maneuvers [14].

Furthermore, the line-sprint component (i.e. 10 - m sprinting) contributed to the predictive model. Similarly, with Jones et al. [14], the flying 5-m sprint accounted for 58% of the CoD variance. It is proposed that the inconsistency of the relationships found between acceleration ability and CoD performance, are due to the different mechanical requirements of the execution of the various tasks. In 'linear' acceleration, the participants are facing the direction of movement, which is not the case for the 're-acceleration' part of the shuttle run or any other turning task, when the subject initially is facing the original forward direction they were travelling in and then has to turn the head and then shoulders and hips before the first step to accelerate into the new direction. This would lead to a technically different execution of the first step, potentially affecting the final acceleration. Future research should also investigate the combined effect technical and physical factors, as well as the decision-making abilities on CoD. Sheppard and Young, [4] and Young and Farrow [34] in their reviews of agility presented a deterministic model of agility and suggested that the technical component of CoD could be dependent on foot placement, adjustment of strides to accelerate and decelerate and body lean and posture. Further research into the technical determinants of CoD could also help rationalize how the reported physical factors link to CoD.

A limitation of the present study was that the tests did not include actual sport situations where the athlete must control the ball and deal with the mental and physical distractions of opposing athletes. Further studies using more relevant technical agility tests to soccer

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performance and functional representative of model constructs according to maturity status (Pre-PHV, PHV and Post-PHV) are warranted.

Conclusions

The results of this study illustrate the importance of developing high levels of lower-body speed, balance and power to enhance CoD performance in pre-pubescent soccer players. Ultimately, it is also likely that effective training procedures to improve balance, speed, and CoD will include specific training drills. Furthermore, a greater emphasis on prior balance and sprint training should be placed on younger athletes with less developed neuromuscular capabilities [15,16] in order to improve CoD performance. Enhanced CoD ability should prove beneficial to young soccer players as they must coordinate the dribbling, passing and kicking of a ball (power) while sprinting and being jostled by opponents.

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