



## RESEARCH ARTICLE

## The Influence of Linear Sprint and Jump Performance on Change-of-Direction Performance in Male and Female State-Representative Youth Basketball Players

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### Abstract

**Background:** Good change-of-direction sprint performance is considered important for basketball players. Regarding the components of a change-of-direction task, a correlation between the linear sprint and concentric power output can be assumed. Previous studies have shown heterogeneous correlation coefficients between different change-of-direction (COD) tests and linear and jump performance.

**Methods:** Therefore, 47 trained youth basketball players (13.2 ± 3.6 years; 34 males and 13 females) were recruited. Linear sprint (10 and 20 meters), squat jump, and COD sprint tests (the zig-zag test and triangle test) were conducted. One-tailed Pearson correlation analysis was used to assess the relationship of sprint and jump performance with COD tests, and two-tailed analysis was used to assess the relationship between the different COD tests.

**Results:** This study showed that both linear sprint variables and concentric power output explained the variance in the different COD tests in a homogeneous manner ( $r^2 = 0.14$  to 0.42). The correlation coefficients did not statistically differ between the male and female players, and the different COD tests correlated moderately with one another ( $r^2 = 0.42 - 0.46$ ). For both analyses, the intercorrelation results did not differ significantly between sexes and analyzed correlation coefficients.

**Conclusion:** It is recommended that the squat jump, 10- to 20 meter linear sprint, zig-zag and triangle tests are included in batteries of tests conducted in youth basketball players.

COD tests with the same structure may have similar physiological requirements; however, these tests have task-specific characteristics. Therefore, coaches and sport scientists must review and select different tests with logical validity based on sport-specific requirements.

### Keywords

Athletic performance, Sports, Exercise test

### Introduction

In team sports, players must perform several high-intensity activities during a game [1,2]. These actions are important for scoring and even determining the outcome of a game [3]. Many authors have suggested that power, agility and good sprint performance are important characteristics for basketball players [4,5]. Basketball players have to perform different movements every two seconds [6]. Often, athletes run straight ahead and cut – they brake, change directions, and accelerate again – with a directional change of less than 90 degrees [7]. Therefore, COD tests are of great interest for training purposes. The zig-zag test (ZZT) is commonly used in team sports, such as basketball [8]. However, different authors have recommended different COD tests [3,9,10]. For example, COD tests such as the triangle test (TriT) are commonly used in team sport assessments [11]. Different COD tests last for different

durations, cover different distances, and require different degrees of directional changes and are therefore influenced by different variables [11,12]. Standardizing all COD tests does not seem possible due to the many available variations. The length and approximate total time of the TriT (10 meters [m], 2.9 to 3.5 s) [11] and ZYT (approximately 20 m, 5 to 6 s) [13] demonstrate the different requirements of these tests [11].

CODs consist of an acceleration phase, which is similar to the acceleration phase in a sprint. This phase is typically followed by a deceleration/braking phase caused by eccentric muscle work [14] and a directional change (turn) that involves the manipulation of the base of support relative to the center of mass to apply an external force and reacceleration in a new direction [14,15]. Logically, a correlation between CODs and linear sprints as well as concentric power output can be assumed. However, a variety of correlation coefficients between different CODs and 10 m - 20 m linear sprints (LS) ( $r^2 = 0.22 - 0.56$ ) and jump performance ( $r^2 = 0.06 - 0.22$ ) have been reported in the literature [9,13,16-18]. This variety in correlation coefficients is also true for the correlation of the ZYT with the squat jump (SJ) ( $r^2 = 0.01 - 0.26 - 0.79$ ) [19,20], 10 m LS ( $r^2 = 0.05 - 0.17$ ) and 20 m LS ( $r^2 = 0.03 - 0.21$ ) [8,19]. Little and Williams [21] showed that 20 m LS performance has a higher impact on ZYT performance ( $r^2 = 0.21$ ) than 10 m LS performance ( $r^2 = 0.12$ ). Kadlubowski, et al. [11] showed a moderate correlation between TriT left turn (TriTL) and SJ performance ( $r^2 = -0.19$ ) and a strong correlation between TriT right turn (TriTR) and SJ performance ( $r^2 = -0.28$ ). The authors found a strong correlation between TriTL and 10 m LS performance ( $r^2 = 0.39$ ) and TriTR and 10 m LS performance ( $r^2 = 0.26$ ).

To the authors' knowledge, no studies have 1) analyzed the influence of LS and jump performance on COD performance without decision-making processes (as indicated by the TriT and ZYT) in youth basketball players or 2) compared the correlations between the different COD tests. It was hypothesized that COD test performance is influenced moderately by both SJ and LS performance. The 20 m LS performance explains more of the ZYT variance than 10 m LS performance and vice versa for the TriT (depending on the total distance of the respective tests).

## Methods

To answer the research question the tests were carried out on two testing days. On testing day 1, the SJ and LS were conducted with a 15-min break between the tests. On testing day two, the participants were randomly assigned to one of two groups, which performed the TriT and ZYT in a different order and included a 15-min break between the tests. All participants were used to perform all the tests because they usually perform them semiannually.

## Participants

Thirty-four male ( $13.1 \pm 0.4$  years old;  $175.3 \pm 8.8$  cm;  $60.8 \pm 11.4$  kg) and thirteen female ( $13.6 \pm 0.5$  years old;  $170.2 \pm 6.6$  cm;  $57 \pm 4.1$  kg) youth basketball players were recruited from different under 13-year-old (U13) and under 14-year-old (U14) elite youth training centers. The youth basketball teams played in the highest junior divisions in Germany and were part of a state selection team. The basketball players performed 3 to 4 basketball sessions per week (approximately 1.5 training sessions/day) and competed on the weekend. All participants had played basketball since their early childhood and therefore were very highly trained relative to other individuals of the same age. The participants did not participate in fatiguing training sessions for a minimum of 3 days before testing. None of the players reported any injuries at the time of testing.

All participants and their parents were informed about the experimental risks involved with the research. All participants and their parents provided written informed consent to participate in the present study. Furthermore, approval for this study was obtained from the institutional review board (German University of Health & Sport, No. 01/2019.92002800). The study was performed with human participants in accordance with the Helsinki Declaration.

## Design and procedures

The warm-up for the testing day consisted of non-specific running at low-to-medium intensity for approximately 5 minutes (min). Then, coordination exercises, such as running with lifted knees, heeling, and side stepping, were performed for approximately 5 min. Afterwards, the athletes completed a 5-min dynamic stretching program (standing scales, hand walks, lunge steps with twisting and lateral lunges with rotation). Subsequently, 3 acceleration runs covering approximately 30 m were performed with short walking breaks. Overall, the total warm-up time on each test day was 20 min.

The subjects performed three attempts per COD test, with a 2-min break between each test. A description of the test setups can be found in the following previous studies: ZYT [8] and TriT [12]. The total distance of the ZYT was 20 m, with 3 changes in direction, and the total distance of the TriT was 10 m, with 2 changes in direction. In contrast to the ZYT, which involves turning in both directions, the TriT was carried out for each of the two directions separately since the test only allows one turning direction. If the pylons or hurdle bars were knocked down or touched during COD testing, a follow-up attempt was completed. The tests were separated by a 15-min break. LS performance was measured for distances of 10 and 20 m. Every athlete had three attempts. Between each completed sprint, the athletes received a 2-min break [22]. The time was measured for all tests with a double-timing gate system (wk7 time watch, Ditzingen, Germany). The starting

point was marked with a small cap 0.75 m away from the starting gate to avoid early triggering, e.g., by a hand movement or a bent body position. The subjects chose independently when the measurement began according to the activation of the barriers. Thus, the reaction time was excluded from the measurement.

Jumping performance was measured using a contact mat (Refitronic, Schmitt, Germany) that operates as a switch. This system send information to the computer regarding whether the mat was loaded. From this information, the flight time and the jump height were determined for all jumps. The jump height was calculated from the flight time ( $gt^2/8$ ;  $g$  = the gravitational acceleration [ $9.81 \text{ m}\cdot\text{s}^{-2}$ ] and  $t$  = flight time). The squat jump was initiated at a knee angle of  $90^\circ$  without countermovement, and the hands were positioned on the hip. The participants performed 6 trials, and the best result was used for analysis. Between every jump, the athletes received a 1-min break.

### Statistical analyses

The data were analyzed using SPSS 26.0. (IBM, Ehningen, DE, Germany). The significance level for all statistical tests was set at  $< 0.05$ . The descriptive statistics for all measures are presented as the mean  $\pm$  standard deviation (SD). For the soccer players ( $n = 47$ ), the Kolmogorov-Smirnoff test for normality confirmed that group's data were normally distributed. Reliability analyses were performed using the Intraclass Correla-

tion Coefficient (ICC) and 95% confidence interval insert (95% CI). Furthermore, a bivariate one-tailed Pearson correlation analysis was used to assess the relationship between linear sprint and concentric power performance and performance for the different COD tests. To determine significant differences in the correlation coefficients between subgroups (male vs. female), the data were  $z'$ -transformed according to the Fisher method. The difference between the two transformed values after standardization was assessed for significance

$$(z = \frac{z'_1 - z'_2}{\sqrt{\frac{1}{n_1 - 3} + \frac{1}{n_2 - 3}}}).$$

A bivariate two-tailed Pearson correlation analysis was used to assess the relationship between the different COD tests. Additionally, the intercorrelation was assessed by correlation analysis with different COD tests. The correlation coefficients are displayed as the coefficients of determination ( $r^2$ ). Benjamini and Hochberg's method was used to control the study-wise false discovery rate to be 0.05 [23]. The best time for each test was used for the statistical analysis. ICCs  $> 0.7$  were classified as acceptable [24].

### Results

The Kolmogorov-Smirnoff test results showed that all parameters were normally distributed. COD performance for all the different tests, the ICC and the 95% CIs

**Table 1:** Reliability of the performance variables.

Fitness Test	males	females	pooled	
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	ICC (95% CI)
TriTR	3.63 $\pm$ 0.17 s	3.65 $\pm$ 0.13 s	3.64 $\pm$ 0.16 s	0.72 (0.5 - 0.85)
TriTL	3.62 $\pm$ 0.18 s	3.61 $\pm$ 0.11 s	3.62 $\pm$ 0.16 s	0.81 (0.65 - 0.89)
ZZT	5.35 $\pm$ 0.23 s	5.41 $\pm$ 0.17 s	5.36 $\pm$ 0.22 s	0.76 (0.57 - 0.87)
SJ	26.5 $\pm$ 3.6 cm	24.9 $\pm$ 2.2 cm	26.1 $\pm$ 3.3 cm	0.96 (0.91 - 0.99)
10 m LS	1.98 $\pm$ 0.09 s	2.01 $\pm$ 0.09 s	1.99 $\pm$ 0.10 s	0.93 (0.87 - 0.96)
20 m LS	3.39 $\pm$ 0.15 s	3.46 $\pm$ 0.15 s	3.41 $\pm$ 0.15 s	0.95 (0.91 - 0.97)

Mean test scores  $\pm$  SDs and reliability data for all players; ICC = Intraclass Correlation Coefficient; CI = Confidence Interval; TriTR = Triangle test right turn; TriTL = Triangle test left turn; ZZT = Zig-zag test; SJ = Squat jump; 10 m LS = 10 meter linear sprint; 20 m LS = 20 meter linear sprint; s = seconds; cm = centimeters.

**Table 2:** One-tailed determination coefficients for linear sprint and concentric power performance and performance for the change-of-direction tests.

Fitness Tests		10 m LS	20 mLS	SJ
TriTL	$r^2$	0.14*#	0.26*#	0.26*#
	95% CI	0.01 - 0.35	0.07 - 0.48	0.7 - 0.26
TriTR	$r^2$	0.26*#	0.27*#	0.17*#
	95% CI	0.07 - 0.48	0.08 - 0.49	0.14 - 0.62
ZZT	$r^2$	0.29*#	0.42*#	0.41*#
	95% CI	0.09 - 0.51	0.20 - 0.62	0.39 - 0.76

TriTR = Triangle test right turn; TriTL = Triangle test left turn; ZZT = Zig-zag test; SJ = Squat jump; 10 m LS = 10 meter linear sprint; 20 m LS = 20 meter linear sprint; \* = level of significance ( $p < 0.05$ ); #  $p <$  false discovery rate of 0.05 for this study; 95% CI = 95% confidence interval of the coefficient of determination

for the performance tests are displayed in (Table 1). The ICCs of the tests were greater than 0.76, indicating very strong to nearly perfect correlations and therefore good reliability according to a previous study [24].

The one-tailed Pearson correlation coefficients between LS and SJ performance and COD performance are shown in (Table 2). The correlation coefficients between the male and female subgroups did not differ significantly ( $p < 0.05$ ). Therefore, all correlation coefficients presented correspond to the entire group. The highest correlation coefficients were observed between 10 m and 20 m LS performance ( $r^2 = 0.83$ ) and between ZTT and TriTL performance ( $r^2 = 0.46$ ). Moreover, the least significant coefficients were observed between TriTR and 10 m LS performance ( $r^2 = 0.14$ ) and between TriTR and SJ performance ( $r^2 = -0.17$ ). After adjusting for the study-wise false discovery rate for the values, all coefficients remained significant.

The two-tailed Pearson correlation coefficients between the COD tests show the following results: there is a strong correlation between ZTT and TriTL performance ( $r^2 = 0.46$ ), as well as between ZTT and TriTR performance ( $r^2 = 0.42$ ). The analysis also showed a strong correlation between TriTR and TriTL performance ( $r^2 = 0.44$ ). The intercorrelation coefficients were not significantly different between sexes. For the pooled group the intercorrelation was calculated with  $z = 0.35$  ( $p = 0.36$ ).

## Discussion

The data of this study showed that 1) both linear sprint variables and concentric power output explain the variance in performance for different COD tests in a homogeneous manner ( $r^2 = 0.14 - 0.42$ ), 2) the correlation coefficients do not differ statistically between male and female players and 3) TriTR, TriTL and ZTT correlate moderately with one another ( $r^2 = 0.42 - 0.46$ ); for both analyses, the intercorrelation results showed no significant differences.

Interestingly, the correlation coefficients did not differ significantly for the influence of 10 m and 20 m LS and SJ performance on performance for different COD tests. Notably, there were no significant differences in the coefficients between the male and female players. SJ and 20 m LS performance correlated slightly more strongly with COD performance than 10 m LS performance ( $r^2 = 0.26 - 0.41$  vs.  $r^2 = 0.17 - 0.42$  vs.  $r^2 = 0.14 - 0.29$ , respectively) for all COD tests, but the 95% CI did not indicate significant differences between coefficients. In general, this finding is not in line with those of other studies that showed a higher correlation of 10 m LS performance than SJ performance with COD performance ( $r^2 = 0.19 - 0.56$ ) [9,16-18,25]. Additionally, Little and Williams [21] showed that the 20 m LS performance has a larger impact on ZTT performance ( $r^2 = 0.21$ ) than 10 m LS performance ( $r^2 = 0.12$ ) does, which could not be

confirmed in this study. In addition, it should be noted that SJ and sprint performance are correlated in a moderate to strong manner in different studies [26,27], so it is possible that intercorrelations influence the calculated coefficients. The absence of significant differences in the coefficients between sprint performance and concentric power and for the COD tests may indicate that the two CODs are not heterogeneous enough to reveal differences. In general, the authors suggest that the strongest correlations between two variables are assumed to indicate the highest possible agreement in terms of neuronal, metabolic and/or morphological demands [28]. Nevertheless, the results of this study indicate a moderate-to-strong influence of speed-strength variables on performance in the 10- to 20 m distance COD tests with 2- to 3 directional changes, independent of the direction of rotation.

The analysis of the correlations between the 3 COD tests in terms of performance showed strong coefficients ( $r^2 = 0.42 - 0.46$ ), with no significant differences between coefficients. This seems to be in line with the findings of Kadlubowski [11], who also showed a strong correlation between the TriTR and TriTL ( $r^2 = 0.26$ ). However, slightly more variance was found in the current study, likely due to study population being more heterogeneous and including younger athletes ( $13.1 \pm 0.6$  vs.  $18.5 \pm 4.5$  years old). All tests in this study had a minimal difference in the distance, number and degree of COD. The similar neuronal, metabolic and/or morphological demands are supported by high coefficients, with nonsignificant differences between coefficients. Nevertheless, 42 – 46% of variance was shown in this study, indicating there are still task-specific characteristics, even though there were small differences in the test structure (i.e., degree/direction of rotation, running speed) [29]. Therefore, the results are far from the level, to assume a generalizability of the COD tests in team sports [11].

A limitation of this study is that a different number of male ( $n = 34$ ) and female ( $n = 13$ ) subjects were included in this study, which may provide an explanation for the heterogeneous correlation coefficients. However, the data set is valuable because only a few studies have investigated and compared young female and male basketball players. It should also be noted, that levels of reliability corresponding to ICCs of 0.72 to 0.81 can be considered acceptable [24]. An ICC of 1.0 is expected when measuring the same skill. Therefore, an explained variance of 52% - 66% indicates a certain variability of the COD test and means that the results must be viewed with a certain degree of caution.

The results of this investigation, in general, show that COD performance is influenced by linear sprint performance and concentric power output. However, it is recommended that the SJ, LS, and COD tests are included in the batteries of tests performed by youth basketball

players. COD tests with the same structure may have similar physiological requirements. Therefore, the tests assessed in this study do not seem to measure a 'general' ability to change direction but rather task-specific performance. Therefore, coaches and sport scientists must review and select different tests with logical validity based on sport-specific requirements. In general, plyometric and strength training is recommended to increase COD performance and should be supplemented by training for the corresponding target exercise.

## References

- Bloomfield J, Polman R, O'Donoghue P (2007) Physical demands of different positions in FA premier league soccer. *J Sports Sci Med* 6: 63-70.
- Duthie G, Pyne D, Hooper S (2005) Time motion analysis of 2001 and 2002 super 12 rugby. *J Sports Sci* 23: 523-530.
- Brughelli M, Cronin J, Levin G, Chaouachi A (2008) Understanding change of direction ability in sport. *Sports Med* 38: 1045-1063.
- Hoffman J, Fry AC, Howard R, Maresh CM, Kraemer WJ (1991) Strength, speed and endurance changes during the course of a Division I basketball season. *J Strength Cond Res* 5: 144-149.
- Latin RW, Berg K, Baechle T (1994) Physical and performance characteristics of NCAA division I male basketball players. *J Strength Cond Res* 8: 214-218.
- Klusemann M, Pyne D, Hopkins W, Drinkwater E (2013) Activity profiles and demands of seasonal and tournament basketball competition. *Int J Sports Physiol Perform* 8: 623-629.
- Goodman C (2008) Improving agility techniques. *NSCA's Performance Training J* 7: 10-12.
- Sekulic D, Spasic M, Mirkov D, Cavar M, Sattler T (2013) Gender-specific influences of balance, speed, and power on agility performance. *J Strength Cond Res* 27: 802-811.
- Draper JA, Lancaster MG (1985) The 505 test: A test for agility in the horizontal plane. *Aust J Sci Med Sport* 17: 15-18.
- Emmonds S, Nicholson G, Beggs C, Jones B, Bissas A (2017) Importance of physical qualities for speed and change of direction ability in elite female soccer players. *J Strength Cond Res* 33: 1-27.
- Kadlubowski B, Keiner M, Hartmann H, Wirth K, Frick U (2019) The relationship between change of direction tests in elite youth soccer players. *Sports* 7: 1-8.
- Keiner M, Sander A, Wirth K, Schmidtbleicher D (2013) Long-term strength trainings effects on change-of-direction sprint performance. *J Strength Cond Res* 28:223-231.
- Nimphius S, Callaghan SJ, Bezodis NE, Lockie RG (2017) Change of direction and agility tests: challenging our current measures of performance. *Strength Cond J* 40: 1-13.
- Jones PA, Thomas C, Dos Santos T, McMahon JJ, Graham-Smith P (2017) The role of eccentric strength in 180° turns in female soccer players. *Sports* 5: 42-53.
- Spiteri T, Cochrane JL, Hart NH, Haff GG, Nimphius S (2013) Effect of strength on plant foot kinetics and kinematics during a change of direction task. *Eur J Sport Sci* 13: 646-652.
- Gabbett TJ, Kelly JN, Sheppard JM (2008) Speed, change of direction speed, and reactive agility of rugby league players. *J Strength Cond Res* 22: 174-181.
- Lockie RG, Schultz AB, Callaghan SJ, Jeffries MD, Berry SP (2013) Reliability and validity of a new test of change-of-direction speed for field-based sports: the change-of-direction and acceleration test. *J Sports Sci Med* 12: 88-96.
- Young WB, Miller IR., Talpey SW (2015) Physical qualities predict change-of-direction speed but not defensive agility in Australian rules football. *J Strength Cond Res* 29: 206-212.
- Braz TV, Nogueira WJ, Cruz W, Businari GB, Ornelas F., Brigatto F, Lopes RL (2017) Relation between different variables of vertical jumps and sprints in brazilian professional soccer players. *J Exerc Physiol* 20: 33-46.
- Schultz FA, Cavazzoni P, Carnevale RV, Abad CC, Kobal R, et al. (2015) Speed and power predictors of change of direction ability in elite snow athletes. *J Hum Sport Exerc* 10: 847-856.
- Little T, Williams AG (2005) Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res* 19: 76-78.
- Silverman S, Thomas J, Nelson J (2001) Research methods in physical activity. Human Kinetics, Champaign.
- Benjamini Y, Hochberg Y (2017) Controlling the false discovery rate. A practical and powerful approach to multiple testing. *J R Stat Soc* 57: 189-300.
- Shrout PE, Fleiss JL (1979) Intraclass correlations: uses in assessing rater reliability. *Psychol Bull* 86: 420-428.
- Kadlubowski B, Keiner M, Stefer T, Kapsecker A, Hartmann H, et al. (2020) Influence of linear-sprint performance, concentric power and maximum strength on change of direction performance in elite youth soccer players. *Ger J Exerc Sport Res* 51: 116-121.
- Ingbrigtsen J, Brochmann M, Castagna C, Bradley PS, Ade J, et al. (2014) Relationships between field performance tests in high-level soccer players. *J Strength Cond Res* 28: 942-949.
- Köklü Y, Alemdaroglu U, Özkan A, Koz M, Ersöz G (2015) The relationship between sprint ability, agility and vertical jump performance in young soccer players. *Sci Sports* 30: 1-5.
- Vescovi JD, McGuigan MR (2008) Relationship between sprinting, agility, and jump ability in female athletes. *J Sports Sci* 26: 97-107.
- Falch HN, Raedergard HG, van den Tillaar R (2020) Effect of approach distance and change of direction angles upon step and joint kinematics, peak muscle activation, and change of direction performance. *Front Sports Act Living* 2: 1-10.