applied sciences

MDPI

Article

Relationship between the Reliability of Tennis-Specific Change of Direction (77COD) Test and Squat Jump–Countermovement Jump in Adolescent Tennis Players

Selman Kaya [1,*], Aysu Önal [2] and Gökhan Deliceoğlu [3]

[1] Department of Coaching Education, Faculty of Sports Sciences, University of Yalova, Yalova 77000, Turkey
[2] Department of Training and Movement Sciences, Institute of Health Sciences, University of Gazi, Ankara 06500, Turkey; aysu.onal@gazi.edu.tr
[3] Department of Coaching Education, Faculty of Sports Sciences, University of Gazi, Ankara 06500, Turkey; gokhandeliceoglu@gazi.edu.tr
* Correspondence: selman.kaya@yalova.edu.tr; Tel.: +90-536-611-4177

Abstract: The aim of this study was to investigate the reliability of the tennis-specific change of direction (77COD) test with vertical jump tests (Squat Jump and Countermovement Jump) in adolescent tennis players. A total of 58 athletes (31 girls, 27 boys) actively playing tennis, with an average age of 10.57 $\pm$ 2.54 years, participated in the study. Tests and retests were completed within 2 weeks. Bland–Altman (B&A) plots were established and Pearson's correlation analysis was conducted on the 77COD, CMJ, and SJ tests. Simple linear regression analysis (enter method) was used to determine the significant predictors of the 77COD variable from the SJ-CMJ variables. The SJ and CMJ were found to be highly negatively correlated with the 77COD test ($-0.72 \leq r \leq -0.74$). The test–retest reliability of the 77COD test was found to be very high, with an intraclass correlation coefficient (ICC) of 0.95. Our findings showed that the 77COD test is suitable for determining COD ability in adolescent tennis players. In addition, vertical jump heights are an informative and practical performance indicator for 77COD. In conclusion, the 77COD test is a COD test that can be used in coaching practices without the need for complex testing materials.

Keywords: tennis; reliability; change of direction

check for updates

Citation: Kaya, S.; Önal, A.; Deliceoğlu, G. Relationship between the Reliability of Tennis-Specific Change of Direction (77COD) Test and Squat Jump–Countermovement Jump in Adolescent Tennis Players. *Appl. Sci.* **2024**, *14*, 9266. https://doi.org/10.3390/app14209266

Academic Editor: Mark King

Received: 16 August 2024
Revised: 18 September 2024
Accepted: 9 October 2024
Published: 11 October 2024

1. Introduction

Tennis is an intermittent sport that involves short–intense and medium–low-intensity long-term physiological capacities, as well as sudden biomechanical activities like acceleration, deceleration, change of direction (COD), and striking [1]. A player runs a total of ~8–12 m per point [2]. In a competitive match, players perform more than 1.000 CODs [3]. Players perform ~4 CODs per rally, but in a long rally, more than 15 CODs are applied [4]. Most of the time, lateral direction changes are more common than forward movements in rallies [5]. Additionally, although data show that COD movements in tennis are within ~4 m [4], 80% of all tennis shots are played at a distance of less than 2.5 m [6]. Therefore, COD abilities should be monitored to improve players' performance [7].

In tennis, since many physical components like speed, agility, COD, and jumping that are necessary for success are power-based [8–10], upper and lower body strength and power are important performance determinants [11]. Additionally, due to the importance of CODs in many sports, conditioners and coaches aim to use the most appropriate tests to accurately measure the physical quality of CODs [12,13]. When the literature is examined, many agility tests have been developed and used to assess COD ability [14–16]. The most common of these tests are the pro-agility shuttle [17–21], the three-cone drill or L-run test [17,19,22], the T-test agility [23–25], and the Illinois agility test [21,25–27]. Although most COD tests are largely correlated with athletes' ability to accelerate and decelerate [28], several studies have shown a weak and inconsistent relationship between CODs and straight-line sprinting [16,29–32].

Previous studies have reported a significant relationship between COD and jump tests [21,32–38]. These results suggest that athletes' jump performances could be one of the factors affecting athletic skills like COD. However, the relationship between vertical jumps and COD in tennis players remains uncertain.

Considering the specific demands of the sport is essential when selecting the most appropriate COD test to accurately represent an athlete's strengths and weaknesses. The quest for the optimal COD test in tennis players to determine performance most accurately has long been investigated and remains an intriguing topic for sports scientists. Since leg neuromuscular qualities are important determinants of COD performance [39], there is a need for a reliable tennis-specific test to assess COD ability associated with vertical jump tests. Furthermore, we could not find a tennis-specific reliable COD test correlating with vertical jump tests for adolescent tennis players.

Based on this information, the objectives of this study were as follows: (1) to examine the reliability of the 77COD test in adolescent tennis players; (2) to determine the relationship between vertical jump (Squat Jump–Countermovement Jump) height and the 77COD test.

2. Materials and Methods

2.1. Study Design

This research examined the test–retest reliability of the 77COD test with vertical jump tests using a correlation design. Tests and retests were completed within 2 weeks. Participants visited the facility twice. After body composition measurements were taken, participants participated in the tests. A 10-day rest was given between the tests. All tests were conducted at the same training facility (indoor hard court) and at the same time of the day (10:00 a.m.–15:00 p.m.).

2.2. Subjects

Athletes aged between 9 and 15 years who had been actively playing tennis for at least 3 ± 4 years participated in the present study (girl n = 31, boy n = 27, age = 10.57 ± 2.54 years, body mass = 40.27 ± 13.83 kg, height = 146.60 ± 14.22 cm, body mass index = 18.36 ± 2.62 kg/m^2). Tennis players who had undergone physical therapy (rehabilitation) in the past 12 months were excluded. A total of 58 athletes participated in this study, and all completed the study. Participants' height (measured using a stadiometer with ±1 mm accuracy) and body weight (measured using a digital weighing scale with ±0.1 kg accuracy) were recorded. Athletes were instructed to avoid intense training for 24 h before each test day. They were also prohibited from consuming any stimulatory foods from 24 h prior to the test and were advised not to eat 2–3 h before each evaluation session. Before participating in the study, athletes and their families were informed about the research, and all signed an informed consent form. This study was approved by the Ethics Committee on Human Research of Gazi University (ID: 2023-1468). The research adhered to the Helsinki Declaration (October 2013, Brazil) throughout the study.

2.3. CMJ and SJ Test

Athletes ran two laps around the tennis court to warm up and performed tennis-specific warm-up exercises for 10 min (e.g., shoulder rotations, overhead triceps, standing trunk rotations, side lunge, butt kicks). All exercises were performed in 2 sets and 8 repetitions. CMJ and SJ were performed on a mat system with ±0.1 cm accuracy (Optojump, Microgate, Bolzano, Italy). A 30 s passive recovery period was applied between each jump for both the SJ and CMJ. Eight CMJs (3 trials maximal + 5 familiarization submaximal) followed by eight SJs (3 trials maximal + 5 familiarization submaximal) were performed with maximum effort. Participants stood still with their hands akimbo until verbally commanded to complete the CMJ. Participants were instructed to minimize the transition between descending and ascending stages and to jump as fast and high as possible. Participants were free to choose the depth of the movement. They were also instructed not to make any movements during the flight. After the CMJ, a 5 min passive rest was taken. Participants then stood on the force platform again for the SJ. While standing on the force plate, subjects were asked to bend their legs. After having maintained this crouch position for about 2 s, they were asked to apply force as fast as possible and to jump to maximum height. The jumps were performed without countermovement. The best score of each test was used for analysis.

2.4. 77COD Test

The 77COD test consists of three movement patterns commonly used by tennis players during matches: forward, backward, and lateral shuffle. The 77COD test spans a total length of 12 m and consists of seven stations. The first station involves a forward sprint, the second a backward sprint, the third a lateral shuffle, the fourth a forward sprint, the fifth a backward sprint, the sixth a lateral shuffle, and the seventh a forward sprint. Participants stood 50 cm behind the starting gate and began the test upon hearing the verbal command from the starting official. The athletes completed the test by performing a forward sprint to the first cone, a backward sprint to the second cone, a lateral shuffle to the third cone, a forward sprint to the fourth cone, a backward sprint to the fifth cone, a lateral shuffle to the sixth cone, and a forward sprint to the seventh cone. Participants completed a 2 m sprint between vertical and horizontal stations, and a 1 m sprint between the backward stations. They were instructed to touch the cones (cone height = 1 m) at each station. Photocell gates were placed at the start and finish points. A Fusion Smart Speed photocell system (Fusion Sport, Coopers Plains, QLD, Australia) was used to measure the time taken for direction changes. Each participant performed two submaximal trials before the test. After the familiarization phase, the test was conducted with two maximal-effort trials. The average time of the two trials was recorded. A 3 min passive recovery period was given to athletes between tests (Figure 1).

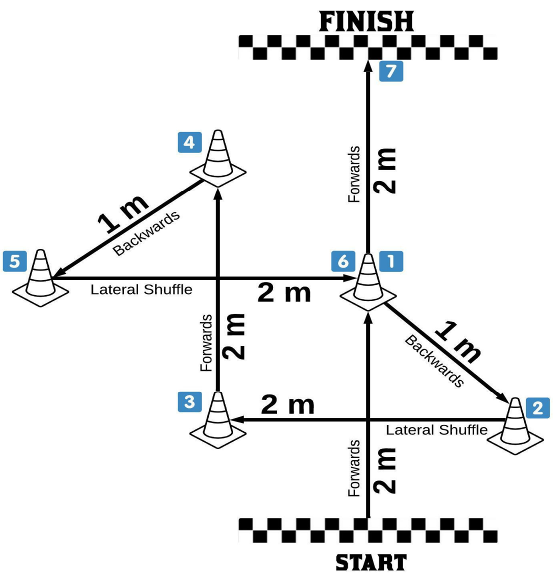


Figure 1. 77COD test.

2.5. Data Analyses

Data were transferred to SPSS (IBM: Version 27, Armonk, NY, USA) for normality assessment and analysis. The normality distribution was evaluated using the Shapiro–Wilk test ($p > 0.05$). Pearson's correlation analysis was conducted on the 77COD, CMJ, and SJ tests. Simple linear regression analysis (enter method) was used to determine the significant predictors of the 77COD variable from the SJ-CMJ variables. The adjusted R-squared value

(R^2; coefficient of determination) was used to indicate how much of the total variation in the 77COD variable could be explained by the SJ-CMJ variables.

A Bland–Altman (B&A) graph was created to evaluate the agreement between the test and retest performances [40]. A scattering graph was drawn representing the average values [(Test1 + Test2)/2] on the X axis and the score differences of the two tests (Test1–Test2) on the Y axis. The mean differences between two tests were considered as estimated deviation (Test1–Test2 mean). The 95% limits of agreement, which reflect random error, are expressed as mean $\pm$ 1.96 $\times$ SD. The upper limit of agreement is mean + 1.96 $\times$ SD, and the lower limit of agreement is mean—1.96 $\times$ SD. A sample T-test was used to compare the test–retest means of the 77COD, SJ, and CMJ tests. Cronbach's alpha (α) reliability coefficients and 95% coefficients of variation (CV) were calculated for all tests. Minimum reliability was accepted as CV < 10% [41]. The mean differences were analyzed at a 95% confidence interval. ICC values less than 0.50 indicate poor reliability, values of 0.50–0.75 indicate moderate reliability, 0.75–0.90 indicate good reliability, and greater than 0.90 indicate excellent reliability [42]. An alpha value of <0.05 was used to assess statistical significance.

3. Results

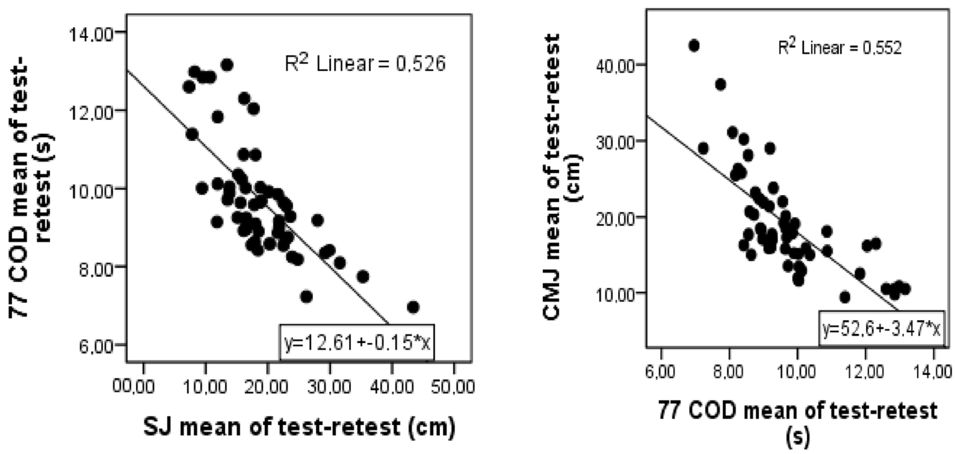
The correlation values of the tests are presented in Table 1. There was a significant high positive correlation of 0.95 between the CMJ and SJ. A significant moderate negative correlation (r = −0.74) was found between the CMJ and 77COD test. A significant moderate negative correlation (r = −0.72) was observed between the SJ and 77COD test ($p < 0.01$).

Table 1. Intercorrelation matrix of all tests.

Variables	CMJ	SJ	77COD
CMJ (cm)	1		
SJ (cm)	0.954 *	1	
77COD (s)	−0.743 *	−0.726 *	1

* Significant at the level $p < 0.01$.

The CMJ was positively related with the SJ ($p < 0.01$; $R^2 = 0.91$). These two vertical jump tests (CMJ-SJ) were negatively related with the 77COD test (CMJ, $p < 0.01$; $R^2 = 0.55$; SJ, $p < 0.01$; $R^2 = 0.52$), indicating that as vertical jump height increased, the time taken to complete the 77COD test decreased (Figure 2).



(**A**) (**B**)

Figure 2. Scatter plots with simple linear regression adjusted R^2 for (**A**) SJ vs. 77COD and (**B**) 77COD vs. CMJ.

The continuous line represents the mean difference of the test and retest scores. The dotted lines represent the 95% limit of agreement for the upper and lower ranges (Figure 3). Based on the T-test values, no significant differences were found between the test and retest scores across all tests ($p > 0.05$). The within-subject variation for all tests was observed to be between 6.1% and 7.0%. The Cronbach's α reliability coefficients for the variables were excellent, ranging between 0.91 and 0.95 (Table 2).

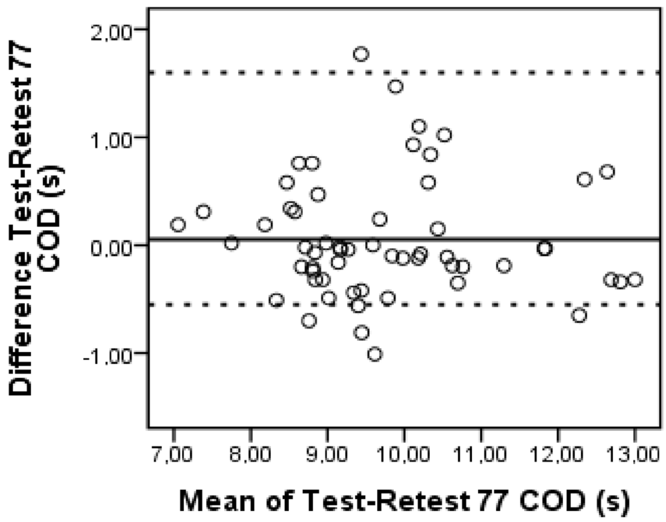


Figure 3. Bland–Altman plots of test–retest scores.

Table 2. Descriptive and reliability statistics for all the tests.

Variables	Test ± SD	Retest ± SD	*p*	95% CI (Lower ± Upper)	ICC	95% CV	α
CMJ (cm)	23.23 ± 3.51	23.41 ± 3.07	0.396	−0.59 ± 0.24	0.938	7.0%	0.93
SJ (cm)	22.77 ± 2.83	23.04 ± 2.46	0.176	−0.66 ± 0.12	0.914	6.8%	0.91
77COD (s)	9.76 ± 1.38	9.74 ± 1.40	0.460	−0.09 ± 0.19	0.959	6.1%	0.95

SD = standard deviation; CI = confidence interval; ICC = intraclass correlation coefficient; CV = coefficients of variation; α = Cronbach's alpha reliability coefficients.

4. Discussion

The goal of this study was to establish the test–retest reliability of a newly developed tennis-specific 77COD test incorporating vertical jump tests (SJ-CMJ) among adolescent tennis athletes. All jump tests and the 77COD tests had high within-subject reliability variance.

CMJ and SJ are among the most commonly applied test methods for assessing the mechanical capacities of the lower body [43,44]. Since CMJ height can reflect lower extremity muscle power, a significant positive correlation exists between the CMJ and SJ [45]. The within-subject variances (CV) in the present study are acceptable. These results demonstrated stable repeatability across all protocols (CV < 10%) [41]. Artega et al. and Markovic et al. reported CV values for the SJ and CMJ of 5.4–3.3% and 6.3–2.8%, respectively [43,46]. The CV values in the current study are higher than those reported in other studies. However, studies on reliability in jump height among young athletes and children (CMJ, ICC = 0.90, CV% = 7.1) [47] (SJ, ICC = 0.97, CV% = 4.9) [48] are similar to our findings. Excellent reliability (ICC > 0.91) was achieved across all protocols performed in this study. The SJ, CMJ, and 77COD tests had similar within-subject reliability, as indicated by the values of ICC and Cronbach's α. Both CMJ and SJ tests are considered reliable and valid [43] in children [49].

Most of the scores were close to the average of the differences between the two tests in the Bland–Altman graphs, and the test–retest results were consistent. The relationship of COD to performance parameters in adolescent athletes depends on age, body composition, maturity status, and years of training experience [33]. These results suggest that repeated attempts should be made until the researcher's judgment is satisfied or the subject's true performance is revealed for a consistent COD performance (mean $\pm$ 3–4 repetitions).

SJ and CMJ vertical jumps are commonly used to measure explosive muscle power and jump height [50]. Similar to our study, CMJ height is generally superior to SJ performance [38]. Minor differences in performance between SJ and CMJ are thought to result from the effective use of the stretch-shortening cycle [50,51]. In a study conducted by Popowczak et al. on male athletes, 30 m CODS1-2 tests were found to have a weak correlation with CMJ ($r = -0.00$, $r = -0.16$) heights [52]. Similarly, McFarland et al. demonstrated that, in soccer players, COD tests (pro-agility shuttle and T-tests) were weakly correlated with SJ ($r = -0.32$, $r = -0.23$) and CMJ ($r = -0.30$, $r = -0.16$) heights, with the relationships being weaker in male athletes compared to female athletes. It has been suggested that the more consistent relationship between COD performance and vertical jump in female athletes, compared to males [53,54], is determined by factors such as explosive strength, the stretch-shortening cycle (SSC), and the use of elastic energy [38]. The findings of our study indicate that sport-specific COD tests, such as the 77COD test, are more strongly correlated with vertical jumps. Additionally, the strength of the relationship between the 77COD and vertical jump tests appears to depend on factors such as sport specificity, total distance, and the number of lateral, forward, backward, and/or straight sprints.

This study has some limitations. The reliability of the 77COD test could be influenced by variables such as gender and age. In our study, the differences between boys and girls were unclear. Further research is needed to determine whether the newly created 77COD test would indicate similar reliability among participants with different subject characteristics (i.e., performance level, gender, and age). Additionally, we did not measure the physical and mental fatigue that may occur during the test.

This study confirmed that the newly created 77COD test has good metric properties in association with vertical jump heights. Our findings showed that the 77COD test is suitable for determining COD ability in adolescent tennis players. Moreover, it is a repeatable test usable in coaching practices without the need for complex test equipment.

5. Conclusions

The application of vertical jump tests is simple. These tests are frequently used by coaches, athletic performance coaches, and sports scientists during the training, testing, and monitoring of elite, professional, amateur, and adolescent athletes. Our findings indicate that the 77COD test is reliable and feasible for identifying pre-planned COD in adolescent tennis players. Additionally, vertical jump heights serve as informative and practical performance indicators for the 77COD test. In conclusion, the 77COD test, which is cost-effective and practical in its applicability, can be utilized by coaches to assess COD ability.

Author Contributions: Conceptualization, S.K. and A.Ö.; methodology, S.K.; software, G.D.; validation, S.K., A.Ö. and G.D.; formal analysis, G.D.; investigation, S.K.; resources, S.K. and A.Ö.; data curation, A.Ö.; writing—original draft preparation, S.K.; writing—review and editing, S.K., A.Ö. and G.D.; visualization, A.Ö.; supervision, S.K.; project administration, G.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee on Human Research of Gazi University (ID: 2023-1468) (19 December 2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The raw (deidentified/anonymized) data supporting the conclusions of this article will be made available by the authors on request.

Acknowledgments: We thank all participants who participated in the research.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Cooke, K.; Davey, P.R. Tennis ball diameter: The effect on performance and the concurrent physiological responses. *J. Sports Sci.* **2005**, *23*, 31–39. [CrossRef] [PubMed]
2. Parsons, L.S.; Jones, M.T. Development of speed, agility, and quickness for tennis athletes. *Strength Cond. J.* **1998**, *20*, 14–19. [CrossRef]
3. Fernandez-Fernandez, J.; Granacher, U.; Sanz-Rivas, D.; Marín, J.M.S.; Hernandez-Davo, J.L.; Moya, M. Sequencing effects of neuromuscular training on physical fitness in youth elite tennis players. *J. Strength Cond. Res.* **2018**, *32*, 849–856. [CrossRef] [PubMed]
4. Giles, B.; Peeling, P.; Reid, M. Quantifying change of direction movement demands in professional tennis matchplay: An analysis from the Australian Open Grand Slam. *J. Strength Cond. Res.* **2024**, *38*, 517–525. [CrossRef]
5. Pereira, T.J.C.; Nakamura, F.Y.; de Jesus, M.T.; Vieira, C.L.R.; Misuta, M.S.; de Barros, R.M.L.; Moura, F.A. Analysis of the distances covered and technical actions performed by professional tennis players during official matches. *J. Sports Sci.* **2017**, *35*, 361–368. [CrossRef]
6. Ferrauti, A.; Weber, K.; Wright, P. Endurance: Basic, semi-specific and specific. In *Strength and Conditioning for Tennis*; ITF: London, UK, 2003; pp. 93–111.
7. Dos'Santos, T.; Thomas, C.; Jones, P.A.; Comfort, P. Assessing asymmetries in change of direction speed performance: Application of change of direction deficit. *J. Strength Cond. Res.* **2019**, *33*, 2953–2961. [CrossRef]
8. Fernandez-Fernandez, J.; Sanz-Rivas, D.; Sanchez-Muñoz, C.; Pluim, B.M.; Tiemessen, I.; Mendez-Villanueva, A. A comparison of the activity profile and physiological demands between advanced and recreational veteran tennis players. *J. Strength Cond. Res.* **2009**, *23*, 604–610. [CrossRef]
9. Fernandez-Fernandez, J.; Ulbricht, A.; Ferrauti, A. Fitness testing of tennis players: How valuable is it? *Br. J. Sports Med.* **2014**, *48* (Suppl. 1), i22–i31. [CrossRef]
10. Deng, N.; Soh, K.G.; Huang, D.; Abdullah, B.; Luo, S.; Rattanakoses, W. Effects of plyometric training on skill and physical performance in healthy tennis players: A systematic review and meta-analysis. *Front. Physiol.* **2022**, *13*, 1024418. [CrossRef]
11. Ellenbecker, T.; Roetert, E. Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. *J. Sci. Med. Sport* **2003**, *6*, 63–70. [CrossRef]
12. Hammami, R.; Gene-Morales, J.; Nebigh, A.; Rebai, H.; Colado, J.C. Speed improves with eccentric hamstring training in athletes of different maturity status. *Pediatr. Exerc. Sci.* **2021**, *34*, 99–107. [CrossRef] [PubMed]
13. Ayed, K.B.; Hammami, R.; Gene-Morales, J.; Ajailia, A.; Werfelli, H.; Rebai, H.; Jiménez-Martínez, P.; Flandez, J.; Colado, J.C. High-intensity forward-backward plyometrics after the warm-up entail better sprint and change-of-direction performance than low-intensity side-to-side plyometrics. *Mot. Control* **2023**, *28*, 63–77. [CrossRef] [PubMed]
14. Brughelli, M.; Cronin, J.; Levin, G.; Chaouachi, A. Understanding change of direction ability in sport: A review of resistance training studies. *Sports Med.* **2008**, *38*, 1045–1063. [CrossRef] [PubMed]
15. Sheppard, J.M.; Jay Dawes, J.; Jeffreys, I.; Spiteri, T.; Nimphius, S. Broadening the View of Agility: A Scientific Review of the Literature. Australian Strength & Conditioning Association. *J. Aust. Strength Cond.* **2014**, *22*, 6.
16. Sheppard, J.M.; Young, W.B. Agility literature review: Classifications, training and testing. *J. Sports Sci.* **2006**, *24*, 919–932. [CrossRef]
17. Robbins, D.W. The National Football League (NFL) combine: Does normalized data better predict performance in the NFL draft? *J. Strength Cond. Res.* **2010**, *24*, 2888–2899. [CrossRef]
18. Nimphius, S.; Geib, G.; Spiteri, T.; Carlisle, D. Change of direction" deficit measurement in Division I American football players. *J. Aust. Strength Cond.* **2013**, *21*, 115–117.
19. Sierer, S.P.; Battaglini, C.L.; Mihalik, J.P.; Shields, E.W.; Tomasini, N.T. The National Football League Combine: Performance differences between drafted and nondrafted players entering the 2004 and 2005 drafts. *J. Strength Cond. Res.* **2008**, *22*, 6–12. [CrossRef] [PubMed]
20. Vescovi, J.; Brown, T.; Murray, T. Positional characteristics of physical performance in Division I college female soccer players. *J. Sports Med. Phys. Fit.* **2006**, *46*, 221.
21. Vescovi, J.D.; Mcguigan, M.R. Relationships between sprinting, agility, and jump ability in female athletes. *J. Sports Sci.* **2008**, *26*, 97–107. [CrossRef]
22. Gabbett, T.J.; Kelly, J.N.; Sheppard, J.M. Speed, change of direction speed, and reactive agility of rugby league players. *J. Strength Cond. Res.* **2008**, *22*, 174–181. [CrossRef] [PubMed]
23. Sassi, R.H.; Dardouri, W.; Yahmed, M.H.; Gmada, N.; Mahfoudhi, M.E.; Gharbi, Z. Relative and absolute reliability of a modified agility T-test and its relationship with vertical jump and straight sprint. *J. Strength Cond. Res.* **2009**, *23*, 1644–1651. [CrossRef]

24. Pauole, K.; Madole, K.; Garhammer, J.; Lacourse, M.; Rozenek, R. Reliability and validity of the T-test as a measure of agility, leg power, and leg speed in college-aged men and women. *J. Strength Cond. Res.* **2000**, *14*, 443–450.
25. Jarvis, S.; Sullivan, L.O.; Davies, B.; Wiltshire, H.; Baker, J.S. Interrelationships between measured running intensities and agility performance in subelite rugby union players. *Res. Sports Med.* **2009**, *17*, 217–230. [CrossRef]
26. Lockie, R.G.; Schultz, A.B.; Callaghan, S.J.; Jeffriess, M.D.; Berry, S.P. Reliability and validity of a new test of change-of-direction speed for field-based sports: The change-of-direction and acceleration test (CODAT). *J. Sports Sci. Med.* **2013**, *12*, 88. [PubMed]
27. Wilkinson, M.; Leedale-Brown, D.; Winter, E.M. Validity of a squash-specific test of change-of-direction speed. *Int. J. Sports Physiol. Perform.* **2009**, *4*, 176–185. [CrossRef]
28. Buchheit, M.; Haydar, B.; Ahmaidi, S. Repeated sprints with directional changes: Do angles matter? *J. Sports Sci.* **2012**, *30*, 555–562. [CrossRef]
29. Young, W.; James, R.; Montgomery, I. Is muscle power related to running speed with changes of direction? *J. Sports Med. Phys. Fit.* **2002**, *42*, 282–288.
30. Little, T.; Williams, A.G. Specificity of acceleration, maximum speed, and agility in professional soccer players. *J. Strength Cond. Res.* **2005**, *19*, 76–78.
31. Peterson, M.D.; Alvar, B.A.; Rhea, M.R. The contribution of maximal force production to explosive movement among young collegiate athletes. *J. Strength Cond. Res.* **2006**, *20*, 867–873.
32. Meylan, C.; McMaster, T.; Cronin, J.; Mohammad, N.I.; Rogers, C.; Deklerk, M. Single-leg lateral, horizontal, and vertical jump assessment: Reliability, interrelationships, and ability to predict sprint and change-of-direction performance. *J. Strength Cond. Res.* **2009**, *23*, 1140–1147. [CrossRef] [PubMed]
33. Hammami, R.; Sekulic, D.; Selmi, M.A.; Fadhloun, M.; Spasic, M.; Uljevic, O.; Chaouachi, A. Maturity status as a determinant of the relationships between conditioning qualities and preplanned agility in young handball athletes. *J. Strength Cond. Res.* **2018**, *32*, 2302–2313. [CrossRef]
34. Hori, N.; Newton, R.U.; Andrews, W.A.; Kawamori, N.; McGuigan, M.R.; Nosaka, K. Does performance of hang power clean differentiate performance of jumping, sprinting, and changing of direction? *J. Strength Cond. Res.* **2008**, *22*, 412–418. [CrossRef] [PubMed]
35. Buchheit, M.; Mendez-Villanueva, A.; Delhomel, G.; Brughelli, M.; Ahmaidi, S. Improving repeated sprint ability in young elite soccer players: Repeated shuttle sprints vs. explosive strength training. *J. Strength Cond. Res.* **2010**, *24*, 2715–2722. [CrossRef] [PubMed]
36. Jones, P.; Bampouras, T.M.; Marrin, K. An investigation into the physical determinants of change of direction speed. *J. Sports Med. Phys. Fit.* **2009**, *49*, 97–104.
37. Suarez-Arrones, L.; Gonzalo-Skok, O.; Carrasquilla, I.; Asián-Clemente, J.; Santalla, A.; Lara-Lopez, P.; Núñez, F.J. Relationships between Change of Direction, Sprint, Jump, and Squat Power Performance. *Sports* **2020**, *8*, 38. [CrossRef]
38. Horníková, H.; Zemková, E. Relationship between physical factors and change of direction speed in team sports. *Appl. Sci.* **2021**, *11*, 655. [CrossRef]
39. Castillo-Rodríguez, A.; Fernández-García, J.C.; Chinchilla-Minguet, J.L.; Carnero, E. Relationship between muscular strength and sprints with changes of direction. *J. Strength Cond. Res.* **2012**, *26*, 725–732. [CrossRef]
40. Bland, J.M.; Altman, D. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **1986**, *327*, 307–310. [CrossRef]
41. Atkinson, G.; Nevill, A.M. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med.* **1998**, *26*, 217–238. [CrossRef]
42. Koo, T.K.; Li, M.Y. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J. Chiropr. Med.* **2016**, *15*, 155–163. [CrossRef] [PubMed]
43. Markovic, G.; Dizdar, D.; Jukic, I.; Cardinale, M. Reliability and factorial validity of squat and countermovement jump tests. *J. Strength Cond. Res.* **2004**, *18*, 551–555.
44. Anicic, Z.; Janicijevic, D.; Knezevic, O.M.; Garcia-Ramos, A.; Petrovic, M.R.; Cabarkapa, D.; Mirkov, D.M. Assessment of countermovement jump: What should we report? *Life* **2023**, *13*, 190. [CrossRef]
45. Sarvestan, J.; Svoboda, Z.; de Oliveira Claudino, J.G. Force-time curve variables of countermovement jump as predictors of volleyball spike jump height. *Ger. J. Exerc. Sport Res.* **2020**, *50*, 470–476. [CrossRef]
46. Arteaga, R.; Dorado, C.; Calbet, J.C.J. Reliability of jumping performance in active men and women under different stretch loading conditions. *J. Sports Med. Phys. Fit.* **2000**, *40*, 26.
47. Meylan, C.M.; Cronin, J.B.; Oliver, J.L.; Hughes, M.G.; McMaster, D. The reliability of jump kinematics and kinetics in children of different maturity status. *J. Strength Cond. Res.* **2012**, *26*, 1015–1026. [CrossRef]
48. Dos'santos, T.; Thomas, C.; Comfort, P.; McMahon, J.J.; Jones, P.A. Relationships between isometric force-time characteristics and dynamic performance. *Sports* **2017**, *5*, 68. [CrossRef]
49. Fernandez-Santos, J.R.; Ruiz, J.; Cohen, D.D.; Gonzalez-Montesinos, J.L.; Castro-Piñero, J. Reliability and validity of tests to assess lower-body muscular power in children. *J. Strength Cond. Res.* **2015**, *29*, 2277–2285. [CrossRef] [PubMed]
50. McGuigan, M.R.; Doyle, T.L.; Newton, M.; Edwards, D.J.; Nimphius, S.; Newton, R.U. Eccentric utilization ratio: Effect of sport and phase of training. *J. Strength Cond. Res.* **2006**, *20*, 992–995. [CrossRef]

51. Bobbert, M.F.; Casius, L.J.R. Is the effect of a countermovement on jump height due to active state development? *Med. Sci. Sports Exerc.* **2005**, *208*, 440–446. [CrossRef]
52. Popowczak, M.; Rokita, A.; Świerzko, K.; Szczepan, S.; Michalski, R.; Maćkała, K. Are linear speed and jumping ability determinants of change of direction movements in young male soccer players? *J. Sports Sci. Med.* **2019**, *18*, 109. [PubMed]
53. Shalfawi, S.A.; Enoksen, E.; Tonnessen, E. The relationship between measures of sprinting, aerobic fitness, and lower body strength and power in well-trained female soccer players. *Int. J. Appl. Sports Sci.* **2014**, *26*, 18–25. [CrossRef]
54. McFarland, I.T.; Dawes, J.J.; Elder, C.L.; Lockie, R.G. Relationship of two vertical jumping tests to sprint and change of direction speed among male and female collegiate soccer players. *Sports* **2016**, *4*, 11. [CrossRef] [PubMed]