Research article:

Review

Relationship between Physical Factors and Change of Direction Speed in Team Sports

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Abstract: The relationship between the change of direction speed (CODS) and sprint speed, jump ability, and muscle strength is well recognized. However, the strength of this relationship may depend on how the test is designed and which parameters are analyzed. This scoping review aims to: (1) map the literature that addresses the relationships between the CODS and physical fitness and performance variables in players of team sports; (2) specify the limiting factors of CODS; and (3) identify gaps in existing literature and propose future research on this topic. Altogether, 22 research studies met the defined inclusion criteria. Most studies revealed significant correlations between CODS and sprint speed, muscle strength, and jump ability. This relationship was mainly demonstrated between CODS and linear sprint speed for 30 m (r = 0.60 to 0.74), 10 m (r = 0.39 to 0.65), maximal leg strength (r = −0.51 to −0.89), particularly explosive (r = −0.44 to −0.81), and reactive strength (r = −0.37 to −0.65). However, the strength of this relationship depends on the type of CODS test, its structure (total running distance, number of changes in direction), and parameters analyzed (height, power, velocity, and relative or absolute values). The recommendation for future research is to focus on choosing the test and its parameters to be close to the fitness demands of the particular sport.

Keywords: change of direction speed; sprint speed; jump ability; muscle strength; team sports

1. Introduction

Historically, agility was characterized as a unique entity consisting of isolated pre-planned movements. More recently, agility is predefined as a rapid whole-body movement with change of velocity or direction in response to a stimulus [1]. It comprises two key components: speed in changing direction, and perceptual and decision-making factors [2]. In this definition, the cognitive component that determines the agility performance applies to open skills only. A change of direction task that is pre-planned has been described as a change of direction speed, and this phrase has become increasingly common in distinguishing this closed skill from agility involving a reaction [3,4]. However, a high level of agility performance is not strongly dependent just on acceleration and sprinting speed, but also on the ability to coordinate movement and react to visual cues of the opponents to provide a quick and appropriate response [1]. The most current model divides agility into cognitive, physical, and technical components [5], instead of the perceptual components of decision-making and change of direction speed [2].

Agility is an essential component in most field and team sports, combat sports, and court sports. Athletes are required to accelerate, decelerate, and change direction throughout the game. They need the ability to quickly change direction and place themselves in a good position to execute with required speed and accuracy [6]. This recognizes that players do not randomly change velocity or direction, but their movements are often...
in response to cues such as the movements of a ball or the actions of opposing players. Therefore, agility performance is important, especially for players of team sports.

However, a large number of agility tests do not include executing a change of direction while reacting to an external stimulus and cognitive component. Although these perceptual and cognitive considerations likely need to be included in a true agility test, most of them actually concern only change of direction speed \[7,8\]. Change of direction speed (CODS) ability can be described as a movement where no immediate reaction to a stimulus is required, and it is considered pre-planned in nature \[1\]. Therefore, the phrase “reactive agility” has been introduced to differentiate the tests with or without response to a stimulus \[5\]. To the best of our knowledge, there have only been a few studies in which an agility test was used that included the cognitive component \[9–12\]. The CODS tests are more common, and their structure has been well investigated \[1,2,5\]. In these structures, the CODS was in-turn determined by technical factors such as stride adjustments, physical elements such as straight sprinting speed, and leg-muscle qualities, which include strength, power, and reactive strength. However, we have found many contradictory results in this area. Not all studies confirmed the relationship between sprint speed, jump and strength parameters, and the time in CODS \[13–18\]. In these cases, the authors assumed that if an athlete performed well during one test, he might perform well in another test.

Therefore, this review is focused on the relationship between CODS and factors of physical fitness like sprint speed, jump ability, and muscle strength. For example, CODS performance includes many linear sprint sections. However, one of the major limitations associated with many CODS tests is that they tend to feature a relatively large amount of linear sprinting, and this has a substantial influence on the total time of the assessment. Furthermore, players must find the best possible position to shoot while avoiding opponents in the game, and it is rare to see them running for a longer distance without cutting. Therefore, we assumed that the strength of the relationship between linear speed and CODS can be affected by the type of CODS test or sprint distance.

Furthermore, it was documented that explosive strength training with vertical jump exercises improves CODS performance \[19\]. However, is a high level of explosive strength so important when a CODS test requires only a single directional change (e.g., the 505 Agility test)? Which mechanisms involved in the individual jumps are important in CODS performance, and which of the measured parameters are appropriate predictors of CODS performance? In addition, another unexplored factor is the type of muscles, the strength parameters of which are likely needed for effective change of direction.

The aims of this review are to: (1) identify the relationship between CODS and sprint speed, jump ability, and muscle strength in players of team sports; (2) identify the specification of the limiting factors of CODS performance; and (3) identify gaps in the existing literature and propose future research on this topic.

2. Materials and Methods

Electronic documents were searched using PubMed, Scopus, and Web of Science. Additional searches were performed on Elsevier, ScienceDirect, SpringerLink, and Google Scholar. The target population was young competitive players of team sports. The most frequent terms “sprint speed”, “jump ability”, and “strength” were combined with “change of direction speed.” The key inclusion criteria were that the studies investigated the relationship between change of direction speed and sprint speed, jump ability, or strength factors. The other inclusion criteria were a publication date of 2010–2020, and availability in full text (English) in the area of sports sciences, including only players of sports games. We will present studies investigating only players of sports games, more specifically in team sports, because CODS is a much more important ability in these sports than in track and field or combat sports. Studies that failed to meet these conditions were excluded from this review. Articles with training intervention or that did not use the correlation coefficient \((r)\) in data processing were also excluded. Search results were limited to studies closely
related to the main topic of this review: the relationship between change of direction speed, sprint speed, and jump or strength abilities.

Two of the 22 articles included in this review were not found through the database search, but instead through a search of bibliographies. All of these articles are included in Table 1. This would suggest a low risk of articles not being included. This is a scoping review, and as such did not need ethics approval.

3. Results and Discussion

3.1. Relationship between CODS and Linear Sprint Speed

The vast majority of studies confirmed the relationship between linear sprint speed and change of direction speed. However, it depended on the distance of the sprint and the type of CODS test. Significant positive correlations were found between the best trial in 505 Agility test and 10 m sprint test in female soccer players ($r = 0.39^*$ and $r = 0.55^*$, respectively) [20]. The same results were observed between the best trial with the change of direction to the left and right side in female netball players ($r = 0.58^*$ and $r = 0.53^*$, respectively) [17]. The study of Delaney et al. [13] confirmed it only with the single directional change by their non-dominant leg in male rugby players ($r = -0.53^*$).

It is important to mention that slightly more than half of these players were faster at this test using only their non-dominant leg. The 10 m sprint also showed a significant relationship with the other, shorter CODS test (3.5 m forward running and then cutting to the left or right side) in male Australian rules football players ($r = 0.50^*$) [18] and with the Zig-Zag agility test (5 m of multiple changes of direction) in teenaged soccer players ($r = 0.57^*$) [21]. In addition, the CODS tests correlated with acceleration speed for longer distances (from 18.3 m to 40 m) in handball and soccer players ($r = 0.25^*\text{ to } 0.84^{**}$) [16,21-24] and with maximal sprint speed in male rugby players ($r = -0.52^{**}$ and $r = -0.63^{**}$, respectively) [13]. However, reaching the maximal sprint speed is common in rugby, whereas it is not very possible in other team sports. For example, this relationship was not confirmed in female soccer players [24]. It may be due the fact that running in the soccer is often associated with working with the ball by foot, which distinguishes it from rugby.

The 5 m linear speed showed only a moderate (from 0.34* to 0.45*) or nonsignificant relationship with the Zig-Zag and 505 Agility tests [17,22]. The 5 m sprint correlated only with the short directional changes, while higher distance in linear speed results showed a stronger correlation with the many type of CODS tests. However, all of the players participated in team sports. Therefore, it is also applicable to players of individual sports (e.g., combat sports, tennis, squash, or table tennis).

Furthermore, the type of CODS test could potentially affect the relationship between CODS and linear sprint speed. For example, the 30 m COD$^2$, which included 10 m forward-5 m-backward-10 m-forward running correlated with the sprint for 10 and 30 m ($r = 0.56^{***}$ and $r = 0.60^{***}$), while the 30 m COD$^1$ (only forward running with a change of direction at an angle of 60° every 5 m) did not correlate with both of the linear sprints [16]. The possible reason is that the execution of 30 m COD$^2$ test, including a longer running distance without the need to decelerate every 5 m, as in the 30 m COD$^1$ test, had a structure closer to the execution of the 10 m and 30 m linear sprint tests. We assumed that the strength of correlation also depended on the similarity (or some degree of compliance) between the CODS test and the specific distance of the linear sprint. Surprisingly, some studies found a significant relationship between the CODS with lateral running and 10 m (15 m) sprint in team sport players ($r = 0.39^*\text{ to } 0.65^*$), although the method of performing the movement in these two tests is considerably different [20,25].

3.2. Relationship between CODS and Jump Ability

The squat jump (SJ), or vertical jump (VJ), provides an assessment of the capability to rapidly develop force solely during a purely concentric movement [26]. Relatively unclear results were observed in the relationship between the CODS test and SJ height.
Most of studies confirmed this relationship, especially in female soccer and netball players \((r = -0.50 \text{ to } -0.71 \text{ **})\) \([15,17,20]\) or in a mixed group of male and female handball players \((r = 0.38 \text{ * and } r = 0.65 \text{ *, respectively})\) \[22\]. However, this was in disagreement with another study on female basketball and soccer players \[24,27\]. Robbins \[23\] also observed a significant relationship in male football players \((r = -0.28 \text{ ** and } r = -0.38 \text{ **, respectively})\), but the sample size of this study was very large, which could have distorted the results in terms of overpowering. Although a more relevant study showed the same results in teenage male soccer players \((r = -0.71 \text{ **})\) \[21\], contradictory results were observed in elite male soccer players \[28\]. The authors admitted that the neuromechanical variables assessed in their study were not able to significantly explain performance in the Zig-Zag COD test, in which athletes had to efficiently (and successively) accelerate and decelerate over very short distances multiple times (e.g., \(4 \times 5 \text{ m}\)), and change direction as quickly as possible. These particular features possibly relied on more specialized motor skills, thus compromising the relationship with the standardized physical measurements used here. Based on these results, the relationship between CODS performance and squat jump height (SJH) was confirmed in most of the studies in females or in less-skilled teenage male players. However, more studies with male players are needed to reach a clearer conclusion for them.

The other parameter of the squat jump is peak power (absolute and relative), which significantly correlated with the pro-agility shuttle in female basketball players \((r = 0.56 \text{ * and } r = -0.67 \text{ *, respectively})\) \[27\] and with the 505 Agility test in female soccer players \((r = -0.64 \text{ ** and } r = -0.65 \text{ **, respectively})\) \[20\]. In another study, the pro-agility shuttle correlated with peak power in male and female soccer players only in relative values \((r = -0.48 \text{ * and } r = 0.53 \text{ *, respectively})\) \[15\]. Shalfawi et al. \[24\] did not find a relationship between the time in a CODS test with 180° turns and absolute peak power in a squat jump in either absolute or relative values in female soccer players. However, their performance in a vertical jump was significantly lower, and the standard deviation was twice as high than the performance of soccer players in previous studies \[15,20\]. Accordingly, the significant difference was in the CODS test. While the test of Shalfawi et al. \[24\] included five 180° directional changes, the other studies contained only one or two 180° directional changes.

Surprising findings were observed in studies using a t-test. There was a significant relationship between the CODS test and peak power in squat jump only in less skilled female players, and even that was only in relative values \((r = -0.72 \text{ * and } r = -0.52 \text{ *, respectively})\) \[15,20\]. Considering these findings, it is more useful to express the peak power in SJ in relative values, rather than in absolute ones. Then the association with the time in CODS is stronger in both genders. In addition, we assumed that this relationship is dependent on the type of CODS and the performance level of the players. It appears that CODS tests that include lateral running or many directional changes are less determined by the power in a squat jump.

Mean propulsive power in a squat jump (with additional weight on the bar) significantly correlated with the velocity in the Zig-Zag COD test and the t-test in a mixed group of male and female handball players \((r = 0.42 \text{ * and } r = 0.51 \text{ *, respectively})\) \[22\]. However, these findings did not confirm the study of Loturco et al. \[28\], even though they used the same Zig-Zag COD test. These contradictory results can be attributed to the large difference between the sample sizes. While the sample in Pereira et al. \[22\] consisted of a mix of male and female elite handball players that were over 20 and 30 years old, the sample in Loturco et al. \[28\] consisted only of male elite soccer players under 20 years old, with a mean age of 17.6 years. Moreover, the 1 RM power, peak power in relative values, and RFD peak force in a jump squat, except for average force and peak force, correlated with the time in the 505 Agility test \((r = -0.40 \text{ * to } -0.70 \text{ **})\) \[29\].

Countermovement jump (CMJ) performance is almost always better than squat jump performance. The difference in performance is thought to reflect an effective utilization of the stretch-shortening cycle \[26\]. This could primarily be related to the greater uptake of muscle slack and the buildup of stimulation during the countermovement in CMJ \[30\].
The relationship between a countermovement jump’s parameters and the CODS tests was different in male and female players. While the CMJ height, with peak power in absolute or relative to body mass values or reactive strength index (RSI), correlated with the time in CODS tests in almost all studies in female \( r = -0.39 \) to \(-0.79 \) [15,17,31] or mixed group of male and female players \( r = 0.56 \) \* and \( r = 0.84 \) \*, respectively) [22], it was slightly different in male players. This relationship was confirmed only in CMJ with additional weight \( r = -0.47 \) ** and \( r = 0.48 \) **, respectively) [13] or in relative values with the pro-agility test \( r = -0.45 \) *) but not with the t-test [15]. Although Köklü et al. [21] and Castillo-Rodríguez et al. [32] also found a correlation with CMJ height \( r = -0.39 \) to \(-0.77 \) **), the vast majority of studies did not find a significant relationship between the time in CODS tests and the most of the CMJ parameters [13,15,16,18,28]. There were relatively consistent findings showing the relationship between the CODS performance and CMJ in females rather than in males, which was also confirmed in another study [24]. Considering these findings, we think the explosive strength and use of elastic energy and stretch-shortening cycle (SSC) determine the CODS performance in female rather than in male players.

However, both reactive strength parameters in drop jump–height and RSI significantly correlated with the time in CODS tests in both genders \( r = -0.37 \) ** to \(-0.65 \) **) [13,18,32]. Reactive strength using the stretch shortening cycle (SSC) appears to be a limiting factor for CODS performance, as indicated in the model of Sheppard and Young [1].

Standing broad jump (SBJ) peak power had a significant relationship in relative values with the time in a CODS test of female basketball players \( r = -0.62 \) *) [27]. However, the distance of this jump did not correlate with the time in a CODS test of female basketball and male soccer players [16,27]. Although the study of Robbins [23] showed a significant relationship between these two parameters \( r = -0.54 \) ** and \( r = -0.65 \) **, respectively), the sample size was very large (over 500 participants), which could have distorted the results in terms of overpowering. Based on previous results, Banda et al. [27] recommended the use of the distance in SBJ in relation to the participant’s body mass. However, it was not recommended to use SBJ as a reflector of explosive strength, due to the method of execution. In many sports, vertical jumps occur much more frequently than horizontal jumps. Moreover, their study indicated that when the jump test is more specific to the sport (e.g., the two-steps approach in basketball players), the relationship to CODS performance is higher.

Other jump tests like the lateral jump, the single-leg hop, or the 10 m single leg jump, were used less often in the studies we found. The single-leg and lateral jump tests are useful in detection of left-right muscle imbalance, which can determine CODS performance [1]. The vast majority of the studies we found confirmed this relationship, especially in the CODS tests with lateral running or turning 180° [13,25,31].

### 3.3. Relationship between CODS and Muscle Strength and Power

In the model of Young and Sheppard [1], leg-muscle qualities are one of the subcomponents of the ability to change the direction speed. These qualities can also be expressed as a maximal lower body strength. The relationship between leg power, strength, and speed have been well investigated [14,33–35]. Leg power is often measured indirectly through jump testing. Absolute or relative lower body strength is usually measured using one or three repetitions of a maximum back squat.
Table 1. Correlations between CODS tests and speed, jump, and strength factors.

| Authors, Year | Sex/Sport | Age (years) | CODS Test | Pearson Correlation Coefficient (r) | Physical Factors |
|---------------|-----------|-------------|-----------|-----------------------------------|------------------|
| [13]          | Male Rugby league players \((n = 31)\) (24.3 ± 4.4) | 505 Agility test dominant/nondominant | −0.25/−0.53 ** | 10 m Sprint [s] |
|               |           |             |           | −0.63 **/−0.52 ** | Maximal sprint velocity 30–40 m [s] |
|               |           |             |           | −0.44 */−0.45 * | Drop Jump–RSI (height/contact time) |
|               |           |             |           | −0.13/−0.12 | Countermovement Jump 40 kg SSC Peak Power (0–0.25 s) [W] |
|               |           |             |           | −0.47 **/−0.48 ** | Countermovement Jump 40 kg SSC Peak Power (0–0.25 s) [W·kg⁻¹] |
|               |           |             |           | −0.28/−0.21 | Lower body strength-3RM back squat [W] |
|               |           |             |           | −0.52 **/−0.56 ** | Lower body strength-3RM back squat [kg·kg⁻¹] |
|               |           |             |           | −0.20/−0.51 ** | Lateral Jump dominant [W] |
|               |           |             |           | −0.34 */0.65 ** | Lateral Jump dominant [W·kg⁻¹] |
|               |           |             |           | −0.28/−0.43 * | Lateral Jump nondominant [W] |
|               |           |             |           | −0.42 */−0.56 ** | Lateral Jump nondominant [W·kg⁻¹] |
| [14]          | Male team sports players \((n = 16)\) (23.3 ± 5.3) | t-test | 0.31/−0.17 | Isokinetic quadriceps extension/hamstring flexion–concentric at 60°/s–work [N·m] |
|               |           |             |           | −0.06/0.13 | Isokinetic quadriceps extension/hamstring flexion–concentric at 180°/s–work [N·m] |
|               |           |             |           | −0.48/−0.01 | Isokinetic quadriceps extension/hamstring flexion–concentric at 240°/s–work [N·m] |
|               |           |             |           | 0.42/0.64 ** | Isokinetic quadriceps extension/hamstring flexion–eccentric at 30°/s–work [N·m] |
Table 1. Cont.

| Authors, Year | Sex/Sport | Age (years) | CODS Test       | Pearson Correlation Coefficient (r) | Physical Factors                      |
|---------------|-----------|-------------|-----------------|--------------------------------------|---------------------------------------|
| [15] Male II. Div. soccer players (n = 20) | 18–23 | Pro-Agility Shuttle t-Test | -0.32 | Squat Jump [cm] |
|               |           |             | -0.23 |                    |
|               |           |             | 0.01  | Squat Jump Peak Power [W] |
|               |           |             | -0.02 |                    |
|               |           |             | -0.48 * | Squat Jump Peak Power [W·kg⁻¹] |
|               |           |             | -0.34 |                    |
|               |           |             | -0.30 |                    |
|               |           |             | -0.16 |                    |
|               |           |             | 0.03  | Countermovement Jump [cm] |
|               |           |             | 0.02  |                    |
|               |           |             | -0.45 * | Countermovement Jump Peak Power [W] |
|               |           |             | -0.25 |                    |
|               |           |             | -0.50 * |                    |
|               |           |             | -0.68 * | Squat Jump [cm] |
|               |           |             | -0.44 |                    |
|               |           |             | -0.41 | Squat Jump Peak Power [W] |
|               |           |             | -0.53 * |                    |
|               |           |             | -0.72 * | Squat Jump Peak Power [W·kg⁻¹] |
|               |           |             | -0.58 * |                    |
|               |           |             | -0.76 * | Countermovement Jump [cm] |
|               |           |             | -0.50 * |                    |
|               |           |             | -0.46 | Countermovement Jump Peak Power [W] |
|               |           |             | -0.60 * |                    |
|               |           |             | -0.79 * | Countermovement Jump Peak Power [W·kg⁻¹] |
Table 1. Cont.

| Authors, Year | Sex/Sport | Age (years) | CODS Test | Pearson Correlation Coefficient (r) | Physical Factors |
|---------------|-----------|-------------|-----------|-------------------------------------|------------------|
| [16]          | Male soccer players (n = 60) | 17.4 ± 0.7 | 30CODS$^1$ 30CODS$^2$ | 0.56 *** | 10 m Sprint [s] |
|               |           |             |           | 0.11                                 |                  |
|               |           |             |           | 0.60 ***                             | 30 m Sprint [s]  |
|               |           |             |           | 0.18                                 |                  |
|               |           |             |           | −0.001                               | Counter movement Jump [m] |
|               |           |             |           | −0.16                                |                  |
|               |           |             |           | 0.16                                 | Standing Broad Jump [m] |
|               |           |             |           | −0.20                                |                  |
| [17]          | Female netball players (n = 26) | 16.1 ± 1.2 | 505 Agility test right/left | 0.30/0.25 | 5 m Sprint [s] |
|               |           |             |           | 0.58 */0.53 *                        | 10 m Sprint [s]  |
|               |           |             |           | −0.70 **/−0.71 **                    | Squat Jump [m]   |
|               |           |             |           | −0.60 **/−0.71 **                    | Counter movement Jump [m] |
|               |           |             |           | −0.66 **/−0.48                       | Maximal Isometric Mid-thigh Pull Strength [N·kg$^{-1}$] |
| [18]          | Male Australian football community players (n = 24) | 18–24 | COD Speed Test | 0.50 * | 10 m Sprint [s] |
|               |           |             |           | −0.20                                | Maximal Lower Body Strength–3RM half-squat [kg·kg$^{-1}$] |
|               |           |             |           | −0.21                                | Counter movement Jump AVG Power [W·kg$^{-1}$] |
|               |           |             |           | −0.65 **                             | Drop Jump–Reactive Strength (cm·s$^{-1}$) |
| Authors, Year | Sex/Sport | Age (years) | CODS Test | Pearson Correlation Coefficient (r) | Physical Factors |
|--------------|-----------|-------------|-----------|-------------------------------------|-----------------|
| [20] Female soccer players Div. I  
(n = 39) | 19.9 ± 1.3 | Modified t-test  
505 Agility test | 0.39 * | 10 m Sprint [s] |
| | | | 0.18 | Vertical Jump [cm] |
| | | | −0.65 ** | Vertical Jump-Peak Power [W] |
| | | | −0.43 | Vertical Jump Peak Power [W·kg⁻¹] |
| | | | −0.64 ** | Vertical Jump Peak Power [W·kg⁻¹] |
| | | | 0.22 | Vertical Jump Peak Power [W·kg⁻¹] |
| | | | −0.65 ** | Vertical Jump Peak Power [W·kg⁻¹] |
| [21] Male soccer players (n = 15) | 16.0 ± 0.8 | Zig-Zag agility test | 0.57 * | 10-m Sprint [s] |
| | | | 0.74 ** | 30-m Sprint [s] |
| | | | −0.71 ** | Squat Jump [cm] |
| | | | −0.77 ** | Countermovement Jump [cm] |
| Authors, Year | Sex/Sport | Age (years) | CODS Test | Pearson Correlation Coefficient (r) | Physical Factors |
|---------------|-----------|-------------|-----------|-------------------------------------|------------------|
| [22] Male and female elite handball players (n = 15; n = 23) | 28.3 ± 3.2 | 26.1 ± 5.4 | Zig-Zag COD Test [m·s⁻¹] t-test [m·s⁻¹] | 0.45 * | 5 m Sprint [m·s⁻¹] |
| | | | | 0.34 * | 10 m Sprint [m·s⁻¹] |
| | | | | 0.79 * | 20 m Sprint [m·s⁻¹] |
| | | | | 0.68 * | Squat Jump [cm] |
| | | | | 0.84 * | Countermovement Jump [cm] |
| | | | | 0.38 * | Mean Propulsive Power in Jump Squat [W·kg⁻¹] |
| | | | | 0.65 * | 36.6 m Sprint [s] |
| | | | | 0.56 * | 18.3 m Sprint [s] |
| | | | | 0.84 * | 9.1 m Sprint [s] |
| | | | | 0.42 * | Vertical Jump [cm] |
| | | | | 0.51 * | Standing Broad Jump [cm] |
| [23] Male National Football League players (n > 500) | Young | The 18.3-m Shuttle Three Cone Drill | 0.25 ** | 9.1 m Sprint [s] |
| | | | | −0.43 ** | Vertical Jump [cm] |
| | | | | −0.28 ** | Standing Broad Jump [cm] |
Table 1. Cont.

| Authors, Year | Sex/Sport | Age (years) | CODS Test | Pearson Correlation Coefficient (r) | Physical Factors |
|---------------|-----------|-------------|-----------|-------------------------------------|-----------------|
| [24]          | Well-trained female soccer players (n = 30) | 19 ± 4      | COD (9-3-6-3-9 m) with 180° turns | 0.43 * | 20 m Sprint [s] |
|               |           |             |           | 0.39 * | 40 m Sprint [s] |
|               |           |             |           | 0.29 | Maximal Sprint Speed (20–40 m) [s] |
|               |           |             |           | 0.13 | Squat Jump (cm) |
|               |           |             |           | −0.03 | Squat Jump Peak Power (W) |
|               |           |             |           | −0.08 | Squat Jump Peak Power (W·kg\(^{-1}\)) |
|               |           |             |           | −0.26 | Countermovement Jump (cm) |
|               |           |             |           | −0.29 | Countermovement Jump (W) |
|               |           |             |           | −0.04 | Countermovement Jump (W·kg\(^{-1}\)) |
|               |           |             |           | n.s. | 15-m sprint from standing start [s] |
|               |           |             |           | n.s. | 15-m sprint from flying start [s] |
| [25]          | Male and female team sports players (n = 20; n = 14) | 21.3 ± 1.7 | Frontal CODS | 0.63 * | 10 m single leg jump test R [s] |
|               |           |             | Universal CODS | n.s. | 10 m single leg jump test L [s] |
|               |           |             | Semi-circular CODS | n.s. |                   |
|               |           |             | Lateral CODS | n.s. |                   |
|               |           |             |           | −0.49 * |                   |
|               |           |             |           | n.s. |                   |
|               |           |             |           | 0.63 * |                   |
|               |           |             |           | n.s. |                   |
|               |           |             |           | −0.42 * |                   |
|               |           |             |           | n. s. |                   |
|               |           |             |           | 0.57 * |                   |
|               |           |             |           | n. s. |                   |
|               |           |             |           | −0.45 * |                   |
|               |           |             |           | n.s. |                   |
|               |           |             |           | 0.66 * |                   |
Table 1. Cont.

| Authors, Year | Sex/Sport | Age (years) | CODS Test                 | Pearson Correlation Coefficient (r) | Physical Factors                  |
|---------------|-----------|-------------|---------------------------|-------------------------------------|-----------------------------------|
| [27]          | Female basketball players (n = 12) | collegiate | Pro-agility Shuttle      | −0.37                               | Vertical jump [cm]                |
|               |           |             |                           | 0.75 **                            | Vertical jump AVG Peak [W]         |
|               |           |             |                           | 0.56 *                             | Vertical Jump Peak Power [W]       |
|               |           |             |                           | −0.67 *                            | Vertical Jump Peak Power [W·kg⁻¹]  |
|               |           |             |                           | −0.81 **                           | Two Steps Approach Jump [cm]       |
|               |           |             |                           | −0.27                              | Standing Broad Jump [m]            |
|               |           |             |                           | −0.62 *                            | Standing Broad Jump [m·kg⁻¹]       |
| [28]          | Male elite soccer players (n = 25) | 17.6 ± 0.8 | Zig-Zag COD test [m·s⁻¹] | −0.01                              | 5 m Sprint velocity [m·s⁻¹]       |
|               |           |             |                           | 0.3                                | 5 m fly start sprint velocity [m·s⁻¹] |
|               |           |             |                           | −0.05                              | 10 m Sprint velocity [m·s⁻¹]       |
|               |           |             |                           | −0.09                              | 10 m fly start sprint velocity [m·s⁻¹] |
|               |           |             |                           | −0.08                              | 20 m fly start sprint velocity [m·s⁻¹] |
|               |           |             |                           | −0.05                              | Squat Jump [cm]                    |
|               |           |             |                           | −0.09                              | Countermovement Jump [cm]          |
|               |           |             |                           | 0.05                               | Mean Propulsive Power in Jump Squat [W·kg⁻¹] |
|               |           |             |                           | −0.18                              | Mean Propulsive Power in Half-Squat [W·kg⁻¹] |
| Authors, Year | Sex/Sport | Age (years) | CODS Test | Pearson Correlation Coefficient (r) | Physical Factors |
|-------------|-----------|-------------|-----------|----------------------------------|------------------|
| [29] Male Rugby Union players \( (n = 30) \) | 24.2 ± 3.9 | 505 Agility test | | | \( -0.75^{**} \) | Deadlift–1RM \([N \cdot kg^{-1}]\) |
| | | | | | \( -0.20 \) | Deadlift–Average Power \([W]\) |
| | | | | | \( -0.48^{**} \) | Deadlift–Peak Power \([W \cdot kg^{-1}]\) |
| | | | | | \( -0.12 \) | Deadlift–Average Velocity \([m \cdot s^{-1}]\) |
| | | | | | \( -0.28 \) | Deadlift–Peak Velocity \([m \cdot s^{-1}]\) |
| | | | | | \( -0.27 \) | Deadlift–Average Force \([N \cdot kg^{-1}]\) |
| | | | | | \( -0.36 \) | Deadlift–Peak Force \([N \cdot kg^{-1}]\) |
| | | | | | \( -0.38^{*} \) | Deadlift–RFD Peak Force \([N \cdot s^{-1}]\) |
| | | | | | \( -0.70^{**} \) | Jump Squat 1RM \([N \cdot kg^{-1}]\) |
| | | | | | \( -0.40^{*} \) | Jump Squat–Average Power \([W]\) |
| | | | | | \( -0.45^{*} \) | Jump Squat–Peak Power \([W \cdot kg^{-1}]\) |
| | | | | | \( -0.51^{**} \) | Jump Squat–Average Velocity \([m \cdot s^{-1}]\) |
| | | | | | \( -0.63^{**} \) | Jump Squat–Peak Velocity \([m \cdot s^{-1}]\) |
| | | | | | \( -0.33 \) | Jump Squat–Average Force \([N \cdot kg^{-1}]\) |
| | | | | | \( -0.35 \) | Jump Squat–Peak Force \([N \cdot kg^{-1}]\) |
| | | | | | \( -0.51^{**} \) | Jump Squat–RFD Peak Force \([N \cdot s^{-1}]\) |
| [31] Male team sport players \( (n = 56) \) | University students | 505 Agility test R/L | | | \( -0.26/-0.54^{***} \) | Countermovement Jump R/L \([m]\) |
| | | | | | \( -0.28/-0.39 \) | Countermovement Jump–RSI \([m \cdot s^{-1}]\) |
| | | | | | \( -0.48^{***}/-0.55^{***} \) | Single Leg Hop R/L \([m]\) |
| | | | | | \( -0.47^{***}/-0.57^{***} \) | Isometric Mid-Thigh Pull Peak Force R/L \([N \cdot kg^{-1}]\) |
| | | | | | \( -0.22/-0.38^{*} \) | Isokinetic Strength–eccentric knee extensor R/L \([N \cdot m \cdot kg^{-1}]\) |
| Authors, Year | Sex/Sport | Age (years) | CODS Test | Pearson Correlation Coefficient (r) | Physical Factors |
|--------------|-----------|-------------|-----------|------------------------------------|------------------|
| Female team sport players (n = 59) | University students | 505 Agility test R/L | $-0.44^{*}/-0.57^{**}$ | Countermovement Jump R/L [m] |
| | | | $-0.39^{*}/-0.42^{*}$ | Countermovement Jump–RSI [m·s$^{-1}$] |
| | | | $-0.56^{**}/-0.43^{*}$ | Single Leg Hop R/L [m] |
| | | | $-0.01/-0.07$ | Isometric Mid-Thigh Pull Peak Force R/L [N·kg$^{-1}$] |
| | | | $-0.19/-0.13$ | Isokinetic Strength–eccentric knee extensor R/L [N·m·kg$^{-1}$] |
| Male amateur soccer players (n = 42) | 20.1 ± 3.7 | 90° COD (5 + 5 m) R/L 180° COD (5 + 5 m) | $-0.39^{*}/-0.57^{*}$ | Countermovement Jump [cm] |
| | | | $-0.49^{*}/-0.64^{*}$ | Countermovement Jump R [cm] |
| | | | $-0.25/-0.33^{**}$ | Countermovement Jump L [cm] |
| | | | $-0.41^{*}/-0.45^{*}$ | Depth Jump h30 [cm] |
| | | | $-0.54^{*}$ | Depth Jump h15 [cm] |
| | | | $-0.37^{**}/-0.45^{*}$ | |
| Female soccer players (n = 17) | 19.7 ± 1.2 | 505 Agility test right/left Modified t-test | $-0.51^{*}/-0.59^{*}$ | Maximal lower body strength–1RM back squat [kg] |
| | | | $-0.55^{*}$ | |
| | | | $-0.58^{*}/-0.68^{**}$ | Maximal lower body strength −1RM back squat [kg·kg$^{-1}$] |
Table 1. Cont.

| Authors, Year | Sex/Sport | Age (years) | CODS Test | Pearson Correlation Coefficient (r) | Physical Factors |
|---------------|-----------|-------------|-----------|--------------------------------------|------------------|
|               |           |             |           | Maximal Lower Body Strength–1RM back squat [N·kg⁻¹] |                  |
| [37]          | Female National Basketball players (n = 12) | 24.3 ± 2.6 | t-test 505 Agility test | −0.80 *** |                  |
|               |           |             |           | −0.80 *** |                  |
|               |           |             |           | −0.79 *** |                  |
|               |           |             |           | Maximal Concentric Strength–Box Squat [N·kg⁻¹] |                  |
|               |           |             |           | −0.79 *** |                  |
|               |           |             |           | Maximal Eccentric Strength–Box Squat [N·kg⁻¹] |                  |
|               |           |             |           | −0.88 *** |                  |
|               |           |             |           | −0.85 *** |                  |
|               |           |             |           | −0.79 *** |                  |
|               |           |             |           | Maximal Isometric Strength–Mid-thigh Pull [N·kg⁻¹] |                  |
|               |           |             |           | −0.47 |                  |
|               |           |             |           | −0.17 |                  |
|               |           |             |           | 3 Countermovement Jumps Power [W·kg⁻¹] |                  |
| [38]          | Female Division II collegiate volleyball players (n = 10) | 19.1 ± 1.2 | 505 Agility test right/left Modified t-test | −0.57 / −0.61 | Hex Bar Deadlift 1 RM [kg] |
|               |           |             |           | −0.73 * |                  |
|               |           |             |           | −0.69 * / −0.74 * |                  |
|               |           |             |           | −0.84 ** |                  |
| [39]          | Male Rugby players (n = 15) | 20.7 ± 1.2 | Pro-Agility t-test | −0.11 | Isometric Mid-Thigh Pull–Peak Force [N] |
|               |           |             |           | −0.07 |                  |
|               |           |             |           | −0.52 * |                  |
|               |           |             |           | 0.03 |                  |
|               |           |             |           | −0.40 |                  |
|               |           |             |           | 0.02 |                  |
|               |           |             |           | −0.40 |                  |
|               |           |             |           | Isometric Mid-Thigh Pull–RFD (0–100 ms) [N·s⁻¹] |                  |
| [40]          | Male American football players (n = 17) | 19.9 ± 0.9 | Pro-Agility 3-Cone Test | −0.40 | Maximal Isometric Toe Flexor Strength [N·kg⁻¹] |
|               |           |             |           | −0.41 |                  |
|               |           |             |           | −0.50 * |                  |
|               |           |             |           | −0.50 * |                  |

(Note: * p ≤ 0.05; ** p ≤ 0.01; *** p ≤ 0.001).
Similar to the CMJ, some gender differences were recorded in the relationship between the maximum back squat and the CODS test. While the time in the CODS test significantly correlated with the weight lifted in the 1 RM back squat (relative and absolute values) in female players ($r = -0.51^* \text{ to } -0.80^{**}$) [36,37], these results were not so clear in male players. Maximal lower body strength measured using the 3 RM back squat correlated in relative values with the 505 Agility test in male rugby players ($r = -0.56^{**}$) [13]. However, the same strength test did not correlate in relative values with the CODS test in male Australian football players [18]. These contradictory results could be due to the different CODS tests and body mass of participants in that study. While Delaney et al. [13] used the 505 Agility test (10 m forward running and 180° COD movement with a 5 m sprint), and the player’s mean body mass was 98.1 kg, Young et al. [18] used a shorter CODS test (3.5 m forward running and 45° COD movement with a short sprint for approximately 3.5 m), and the player’s mean body mass was lower by more than 20 kg. This resulted in higher relative values in Young’s football players (1.94 kg·kg$^{-1}$ vs. 1.34 kg·kg$^{-1}$ of Delaney’s rugby players). Moreover, the importance of maximal leg strength appears more in CODS tests that include longer distances than shorter distance running or change of direction at a higher angle.

In addition, the deadlift can also reflect lower body strength, more specifically lower back strength. The study of Swinton et al. [29] showed a significant relationship between 1 RM, peak power, and RFD in relative values in the deadlift and the CODS test in male rugby players ($r = -0.38^* \text{ to } -0.75^{**}$). This relationship was not confirmed in relation to the other parameters in relative values, like average and peak force and velocity and peak power in absolute values. On the other hand, the relative force correlated with the time in the 505 Agility test and the modified t-test in female volleyball players ($r = -0.74^*$ and $r = -0.84^{**}$, respectively) [38]. However, absolute force in 1 RM correlated with the time only in the modified t-test, which also concerned lateral running ($r = -0.73^*$). Taking these findings into account, a maximal lower back strength can potentially determine the CODS performance.

Although isometric strength does not play a significant role in the change of direction speed, some authors reported a relationship between this mode of strength and CODS performance. The relative peak force in the isometric mid-thigh pull significantly correlated with the time in the t-test and the 505 Agility test in female basketball players ($r = -0.79^{***}$ and $r = -0.85^{***}$, respectively) [37] and with the 505 Agility test to the right side in female netball players ($r = -0.66^{**}$) [17]. This relationship was significant with the relative isometric mid-thigh pull using one leg in male team sport players, but was nonsignificant in female team sport players [31]. In addition, the rate of force development (RFD) in the isometric mid-thigh pull (0–100 ms) correlated with the time in the pro-agility test ($r = -0.52^*$), but not in the t-test in male rugby players [39]. However, the absolute peak force and RFD for a longer duration (0–250 ms) did not correlate with the time in these CODS tests [39]. In addition, toe flexor strength and toe pushing relative isometric force correlated with the CODS performance in male American football players ($r = -0.50^*$) [40].

This indicates that relative lower body isometric strength contributes to CODS performance in female players, whereas no conclusion can be made for male players due to an absence of data or contradictory results in available data. On the other hand, maximal isokinetic strength of knee extensors and flexors did not correlate with the time in CODS tests [14,31]. This could be ascribed to different movement patterns in comparison with natural dynamic movements in sports.

4. Conclusions

The literature showed the relationship between CODS and linear sprint speed, jump ability, and muscle strength. However, our review found some specifications for this relationship. The CODS significantly correlated with the sprint time for 10 m, 20 m, and 30 m, but not with the time for the shorter sprint (5 m). The 5 m sprint was included in a small number of studies. However, these short sprints are usually not very common in team
sports, whereas sprints for longer distances are. This relationship was stronger if the CODS tests contained a similar running distance to the linear sprint test.

The CODS also correlated with maximal leg strength, both explosive and reactive. However, the strength of the relationship between the CODS variables and the variables of physical fitness tests depends on the structure of the CODS test (the total distance, lateral running, the number of changes in direction, and the distance of linear running between these changes in direction) and the parameters analyzed, such as height, average or peak power, average or peak force, velocity, RSI, etc.

Interestingly, while parameters of reactive strength (height, RSI) correlated with CODS in both genders, explosive strength correlated in female rather than in male players. Furthermore, the CODS tests that included longer running distances or changes of direction of high angle were associated with maximal leg strength, rather than with CODS tests that included shorter running distances.

In addition, CODS performance showed a stronger relationship with strength parameters in relative values rather than in absolute values. The obtained parameters from the strength tests should be assessed with respect to body weight.

An analysis of the literature identified gaps in research studies so far, which have not always focused on choosing the most appropriate tests and analyzed parameters. Selected tests should be close to the fitness demands of the particular sport. In addition to the already-mentioned specifications (the structure of the CODS test, and the parameters analyzed), gender and years of practice could also be considered.

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