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STUDENTERRAPPORT

Title: Resistance training for change of direction performance: A systematic narrative review

Abstract Background: the aim of this systematic narrative review is to identify the effects of isotonic resistance training interventions on change of direction performance and differentiate the effect of different types of RT interventions, used within the literature, on force and velocity-based CODs. **Method**: A systematic block search was performed in Scopus, PubMed and SPORTDiscus. Studies were eligible for inclusion if they contained RT interventions with specific measures of COD and RT. Studies not containing control groups, outcome measures related to RT and COD performance, or isotonic loading schemes were excluded. **Result**: 23 studies were included in this review, seven studies used combined PT and RT, nine studies used conventional RT and seven studies used variations of RT. 12 studies found significant improvements to COD following RT interventions. **Discussion**: The 23 included studies were divided into three groups, Combined, Conventional and Mixed. The combined group found significant improvements in 42.8% of studies, conventional found 77% of studies improving COD performance significantly, and mixed found 28.5% of studies improved COD performance significantly. Of the nine studies in conventional RT, only one study reported training experience. Five studies in the mixed group reported using RT experienced subjects, and one study in the combined group reported RT experience in their subjects. There is a tendency for the training experience to influence the results of RT induced improvement to COD.

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Resistance training for change of direction performance: A systematic narrative review

By: Alexander Thomasen, Jan Hansen

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Keywords: Agility, performance, team sport

Introduction

Team sports such as handball, soccer, and basketball, are high-intensity sports consisting of sprints, jumps and changes of direction (COD) (Merino-Munoz et al., 2020). Based on sprints, jumps and changes of direction, physical parameters in form of strength and power in the lower extremities become an essential part of improving these parameters in team sports (Hermassi et al., 2017). Castagna et al. (2003) examined match activity profiles for young soccer players, differentiating match events into two intensity scales, low and high intensity. Low intensity consists of jogging and walking, which is where players covered most distance. High intensity, where players spend 9% of the match, and covered the least distance, primarily consists of sprints, duels, and changes of direction (Castagna et al., 2003). Top speed and acceleration have been two of the primary focus areas in relation to running and sprint training in team sports (Sheppard & Young, 2006). Increasingly, the focus has shifted from linear sprint speed and acceleration in team sports, to agility and the ability to change direction during sprint training (Sheppard and Young, 2006). Most team sports consist of repeated sprints and changes of direction; therefore, agility and COD have become a more significant part of sprint training for team sports (Sheppard and Young, 2006). Young et al. (2002) defines agility with two categories, a physical category containing COD, further divided into technique, physical parameters and linear sprinting speed. As well as a perceptual category, further divided into pattern recognition, anticipation, visual scanning and knowledge of situations (Young et al., 2002). And a perceptual cognitive category, containing pattern recognition, anticipation, visual scanning, and knowledge of situations (Young et al., 2002). With the above definition, when testing for agility, there must be an external stimulus, while this does not apply to COD testing. Agility is a performance parameter used to differentiate between amateur and professional players, as there is a validated relationship between agility and performance level (Sheppard & Young, 2006). Bourgeois et al. (2017) investigated the possibility of dividing agility and COD tests into a force or velocity category, based on the demands placed upon maintenance of momentum, through deceleration and acceleration into and out of the COD. Bourgeois et al. (2017) found COD tasks with angles above 90° to be force oriented, while tasks below 90° were oriented towards velocity.

With exceedingly high physical demands for team sports athletes to be able to perform rapid changes of direction, as well as sprints and jumps (Castagna et al., 2003, Sheppard and Young, 2006, Spiteri et al., 2015), it's important for coaches to apply the optimal training regimes. For team sports athletes to be able to generate, the required braking and propulsive force rapidly, their rate of force development (RFD) as well as eccentric muscle force capacities need to be highly developed (Aagaard et al., 2002, Spiteri et al., 2015). For this purpose, resistance training can be used to increase RFD, eccentric strength and reduce injury risk (Aagaard et al., 2002, Andersen & Aagaard 2006, Spiteri et al., 2015, Liu et al., 2020). A study by Andersen et al. (2010), found that subjects increased their maximal voluntary contraction (MVC) by 18%, as well as their RFD at 250ms from contraction onset by 11% with 14 weeks of RT. The same subject group decreased their relative RFD (RFD/MVC) by 10-18% in the early phase of muscle contraction (<150ms) (Andersen et al., 2010). Andersen et al. (2010) found this reduction in early phase relative RFD to be correlated to transitions in Myosin heavy chain (MHC) phenotypes, mainly a transition from MHC IIX to MHC IIA, which is thought to be an adaptation to resistance training (Andersen & Aagaard, 2006, Andersen et al., 2010).

The type of RT used affects the physiological adaptations, which influences different phases of COD, with some affecting RFD (Andersen & Aagaard, 2006, Andersen et al., 2010) and others affecting braking mechanisms (Liu et al., 2020). Therefore, choosing the correct type of RT, for team sports athletes, is of significant importance. Eccentric strength is important in the braking/deceleration phase of CODs (Spiteri et al., 2013, Spiteri et al., 2015, Liu et al., 2020), with concentric strength and RFD being related to the propulsion phase, following braking (Sheppard & Young, 2006, Andersen & Aagaard, 2006, Andersen et al., 2010, Spiteri et al., 2013, Spiteri et al., 2015).

Different RT interventions have been applied to team sports athletes to investigate the effect on general athletic performance and COD ability. A study carried out by Al Ameer, (2020) used bi-weekly plyometric or resistance training on soccer players and found that both groups increased strength and power abilities. The study by Al Ameer, (2020), found that 30m sprint time decreased more in the plyometric group, compared to the RT group, but found that the time to complete the Illinois test decreased more in the RT group (Al Ameer, 2020). A study by Ali et al. (2019) used complex training, intra-session RT and plyometric training with specific intra-complex resting intervals (Lim et al., 2016) and contrast training, intra-sessions RT and PT, without regards for intra-complex resting intervals (Pagaduan et al., 2019), in an investigation of the effect on sports performance (Ali et al., 2019). In the study Ali et al. (2019) found that both contrast and complex training increased sports performance, with no significant difference between groups in T-test performance (Ali et al., 2019). Bourgeois et al. (2017b) applied an eccentric phase emphasis RT intervention and a conventional RT intervention in the same U16 rugby players.

This study found that conventional RT improved approach and exit times, for both the 505 and the 45° COD tests, but eccentric phase emphasis reduced overall COD time more compared to conventional RT (Bourgeois et al., 2017b). Liu et al. (2020) performed a systematic review and meta-analysis of eccentric overload training and its effect on COD performance, the review included11 studies on eccentric overload training, that all improved COD performance (Liu et al., 2020). A study by de Hoyo et al. (2016) used an in-season intervention consisting of RT, sled towing or plyometric drills with a cohort of U19 soccer players. For all groups de Hoyo et al. (2016) found unclear changes in effect size for COD performance, suggesting that other factors than strength and power abilities influence COD performance (de Hoyo et al., 2016).

Two recent reviews have been published (Chaabene et al., 2018, Liu et al., 2020), showing a positive effect of eccentric overload training on COD performance. Even though eccentric training is a viable method to improve COD performance, eccentric training requires specific experience as well as adherence to strict protocols to avoid detrimental effects of eccentric training (Hody et al., 2019). Due to the experience demands and exercise-induced muscle damage following eccentric training, eccentric overload training will not be a focus of this review. A systematic review and meta-analysis was carried out by Falch et al. (2019) investigating the effect of different training modalities on COD performance in trained individuals. Seventy-four studies were included in the review by Falch et al. (2019), of these studies, the studies assessing RT found a range of performance change in COD between –1.74% and 12.73%, and a positive average change of 3.32% for RT interventions (Falch et al., 2019). The largest change to COD performance following an intervention came from plyometric training, with an improvement in COD performance of 14.88% (Falch et al., 2019). The review by Falch et al. (2019) covered plyometric training, specific COD training, sprint training and RT, with little time devoted to RT specifically. The range presented for RT by Falch et al. (2019) indicates that RT can be both effective and ineffective in improving COD performance. Further investigation into which RT methods are effective in improving COD and which methods are ineffective are relevant, as this will aid in uncovering potential insufficiencies in the current literature. Therefore, the aim of this systematic narrative review is to identify the effects of isotonic resistance training interventions on change of direction performance and differentiate the effect of different types of RT interventions, used within the literature, on force and velocity-based CODs.

Method

This Systematic Narrative Review was written in accordance with the Preferred reporting items for systematic review and meta-analysis (PRISMA) and PRISMA-Protocol (PRISMA-P) (Moher et al., 2010, Moher et al., 2015, Shamseer et al., 2015). The systematic approach was chosen to reduce selection and evaluation bias common in narrative style reviews (Ferrari, 2015).

Study selection criteria

The types of resistance training selected for this review, were conventionally used types of strength training with isotonic loading patterns. Studies using jump squats, resistance bands, eccentric only training, suspended loading or resisted sprinting/COD were not included in this review.

Studies were selected based on the following inclusion criteria: (1) study design: randomized controlled trials, randomized crossover trials, nonrandomized controlled trials, case studies, case control studies and cohort studies. (2) participants: athletes, team sports athletes, healthy controls. (3) intervention types: resistance training, strength training,

	Keyword search		
	Block 1	Block 2	Block 3
	AND		
	Team Sport	Resistance Training	Change of direction
	Team Sports	Physical Training	Change of direction speed
	Field Sport	Strength Training	Agility
	Field Sports	Resistance Exercise	Quickness
	Team Handball	Isoinertial Exercise	Cutting
	Handball	Isoinertial	
O	Football	Weightlifting	
R	Floorball	Concentric	
	Basketball	Concentric Exercise	
	Baseball	Eccentric	
	Soccer	Eccentric Exercise	
	American Football	Eccentric Overload	
	Hockey	Strength Exercise	
	Field Hockey		
	Australian Football		
	Australian Rules Football		
	Rugby		

Table 1 Keyword search

weightlifting, combined resistance training and plyometric training, concentric only resistance training, change of direction training combined with resistance training, agility combined with resistance training. (4) outcome: COD performance and resistance training performance. (5) literature type: Peer-reviewed published articles. (6) language: English articles only.

Exclusion criteria were as follows:(1) No comparison between intervention types, (2) No outcome measures relating resistance training to CODs performance. (3) Test measuring agility, with a perceptual or visual aspect. (4) Only eccentric resistance interventions, interventions using resistance bands, jump squats, plyometric exercises or horizontal or vertical resisted sprint loading.

Systematic Search

A systematic search was conducted using a block search, with keywords combined with "OR" within blocks and "AND" across blocks (Table 1). The first block contained keywords related to population group, the studies were carried out upon. The second block contained keywords related to the type of resistance training used in the intervention. The third block contained keywords related to the research question, I.e., change of direction, change of direction speed or agility. Agility, cutting and quickness were included due to the interchangeable use of the terms within the COD literature. An overview of the full block search and the keywords used can be seen in (Table 1).

The block search was performed in three electronic databases: SPORTDiscus, PubMed and Scopus.

Data Extraction

To ensure standardized data extraction from the selected literature, a standardized data extraction form was created. The form included extraction of: Title, authors, publication year, research question, study design, sample size, athlete type, gender, age group, intervention type, intervention components, interventions dose (frequency of intervention application), intervention duration, follow-up duration, COD measure, main study results, main findings of the study. All data extraction was collected in an Excel Spreadsheet (Excel version 18.2008, Microsoft, Redmond, WA, USA).

Study quality assessment

To assess the quality of included articles the assessment tool, Quality Assessment for Before-After (Pre-post) Studies with no Control Group, by the National Heart, Lung and Blood

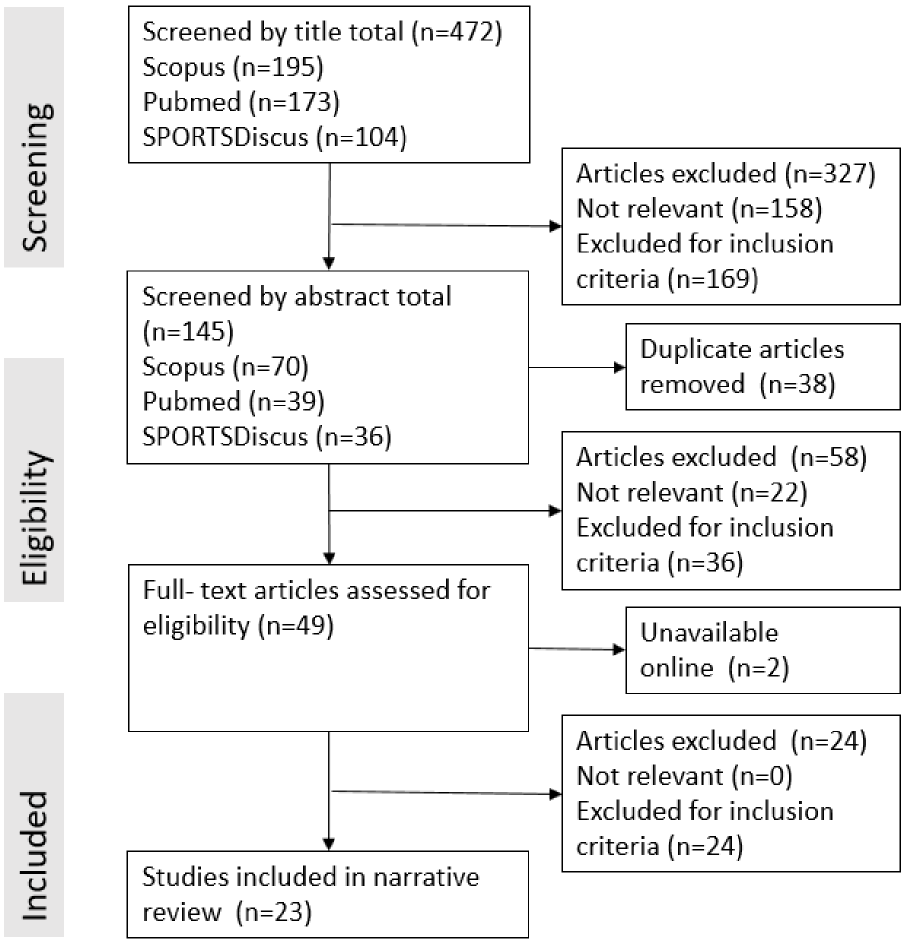

Figure 1 Flow chart depicting the study selection process.

institute (NHLBI) was applied. The quality assessment tool consists of 12 questions, with rating scores of yes, no or other (CD: cannot determine, N/A: not applicable, ND: not disclosed, NR: Not reported). The tool was created for assessment of medical pre-post studies, due to this, it is expected that the literature found in this review will hold low overall scores.

Following study selection, quality assessment of included studies was performed using the NHLBI quality assessment tool. Each reviewer performed a quality assessment of each included study. Once completed both reviewers discussed each study before committing the final score.

Study selection

From the three databases, a total of 472 titles were eligible for title screening. From PubMed 173 titles were included, from Scopus 195 titles and from SPORTDiscus 104 titles. Following the full title screening from each database, both reviewers discussed the selection. If both reviewers agreed upon selection of a study, the study would be included. If the reviewers did not agree, exclusion or inclusion would be made following a discussion of the title, based on inclusion criteria. The reviewers agreed upon a total of 145 abstracts, for full abstract screening. Distribution of abstracts from each database can be seen in figure 1. Following duplicate removal, 49 studies were selected for full text review. Two studies were excluded due to not being available online. Full text review was, therefore, completed on 47 studies. Of the 47 studies, 23 were found eligible for inclusion in the current review. Included studies were pooled into three groups combined, conventional and mixed, based on the use of RT intervention.

Database

Three databases have been used in this systematic narrative review, PubMed, Scopus and SPORTSDiscus. The choice of these databases was made in relation to the coverage rate within sports Science. With PubMed, a sub-database in the form of Medline was also searched. Where with the use of Scopus, the sub-database Embase is searched. Based on Bramer et al. (2016) the coverage rate between Google Scholar, Embase and Medline, was 97.2%, 97.5% and 92.3%, respectively, for all available literature within the results of 120 systematic reviews.

Results

Study selection

Of the 23 studies included, seven studies used complex training or contrast training, combining RT and plyometric training within RT sessions. Nine of the included studies used a conventional RT intervention, consisting only of resistance training within the sessions. The remaining seven studies were categorized as mixed, these studies included olympic weightlifting, strongman, or a bilateral vs. unilateral setup. A description of each study and group distribution can be seen in tables 2-4.

A total of 1088 subjects were included in the 23 studies, with only 14 of the subjects being female. The mean age of the subjects were 18.5 years, with range of 13.5-23.9 years. The mean duration of interventions was 13 weeks, with the shortest being four weeks and the longest being 104 weeks. Five of the 23 studies used three or four weekly training sessions, with the remaining 18 studies using two training sessions per week. A total of 15 different COD tests were used, with the T-test and its derivatives being used with the highest frequency. The T-test was used a total of eight times, in either the full T-test, modified T-test, half T-test or as a modified half T-test. 18 of the 23 studies used a COD test, with an angle of change of direction surpassing 90°, making them force dominated. An overview of included test can be seen in tables 2-4.

Of the 23 studies included, eight studies used a randomized controlled trial design, the remaining 15 studies used a pre-post design or a variation of pre-post designs, either with a control group or without.

The 23 included studies had a mean quality assessment score of 6.3±0.8. Results for individual studies can be seen in tables 2-4

Combined

Reference	Study design	Participants	Age	Intervention component	Intervention duration	COD measure	Intervention description	Quality score
Brito et al. 2014	Pre-post	Soccer (n=57)	RT:20.3±0.9 PT:20.0±0.6 CT:19.9±0.5	RT or PT or CT or CG	2x weekly, 9 weeks	T-test	RT group performed 3 stations with 1 set of high intensity, PT performed 3 stations of plyometric training. CT performed both RT and PT stations. Intensity increased by 5% every 3 weeks	6
Freitas et al. 2018	Quasi experimental	Basketball (n=18)	21.3±4.3	OPT or CT	2x weekly, 6 weeks	T-test	OPT and CT groups performed 9-12 sets per session starting with 80% 1RM intensity. With load adjustment after 4 weeks	6
Hammami et al. 2017	Randomized controlled trial	Soccer (n=44)	16±0.5	CG or RT or CST	2x weekly, 8 weeks	4x5m w. 180°COD	CST group performed 3-5 sets of RT ascending and decending intensity half squat between 70-90% 1RM followed by CMJ. RT group performed the same protocol without CMJ.	6
Hammami et al. 2019	Pre-post	Soccer (n=40)	CST:16.1±0.5 PT:15.7±0.2 CG:15.8±0.2	CST or PT or CG	2x weekly, 8 weeks	4x5m repeated sprint	CST group performed 3-5 sets of RT ascending and decending intensity half squat between 70-90% 1RM followed by CMJ or 15m sprint. PT group performed 5-10 sets of hurdle jumps	6
Kobal et al. 2017	Pre-post	Soccer (n=27)	18.9±0.6	Trad. RT or CST or CT	2x weekly, 8 weeks	505 agility	Trad. Group performed PT followed by RT, CT group performed ST followed by PT, CST performed alternating RT and PT	6
Ramirez- Campillo et al. 2018	Randomized Trial	Soccer (n=18)	BIL:17.6±0.5 UNI:17.3±1.1	BIL RT and PT or UNI RT and PT	2x weekly, 8 weeks	Modified T-test	Both groups performed 3x10 knee extensor and 3x10 knee flexor training at 70% 1RM, followed by 3-5 sets of horizontal jumping. Performed either unilateral or bilateral	6
Zghal et al. 2019	Matched Randomized controlled trial	Soccer (n=31)	CT:14.5±0.5 PT:14.5±0.5 CG:14.6±0.5	CT or PT or CG	2x weekly, 7 weeks	505 agility	CT performed 2-4 sets of 6-8 repetitions at 30-60% 1RM for half squat, leg extensions and leg press followed by 2-4 sets of 3 exercises PT. PT group performed the same PT session as CT. CG added 2 additional soccer sessions	7

Table 2 Study description RT=Resistance training, PT=Plyometric training, CT=Complex training, CG= Control group, OPT = Optimal load training, CST = Contrast training, Trad=Traditional, BIL = Bilateral, UNI= Unilateral

Conventional

Reference	Study design	Participants	Age	Intervention component	Intervention duration	COD measure	Intervention description	Quality score
Al Ameer, 2020	Pre-post	Soccer (n=60)	18-24	RT or PT	2x weekly, 12 weeks	Illinois test	RT group performed 10 exercises, for 2 sets of 15 repetitions. PT performed 3 sets of 10 repetitions	5
Barbalho et al. 2018	Randomized controlled trial	Soccer (n=23)	RT:18.8±0.8 CG:19.1±0.9	RT or CG	3x weekly, 15 weeks	T-test	RT performed 3 sets of multijoint exercises and 2 sets of single joint exercises. 2 sessions of lower extremity training and 1 sessions upper extremity training. Repetitions ranged between 4-6RM, 6-8RM and 12-15RM	9
Christou et al. 2006	Controlled pre-post	Soccer (n=26)	RT:13.8±0.4 CG:13.5±0.9	RT or CG	2x weekly, 20 weeks	10x5m maximal shuttle run	RT group performed 2-3 sets of 8-15 repetitions with an intensity of 55-80% 1RM	6
Hammami et al. 2018	Controlled pre-post	Soccer (n=31)	RT:16.2±0.6 CG:15.8±0.2	RT or CG	2x weekly, 8 weeks	9-3-6-3-9 w. 180° turns	RT group performed 3-5 sets of RT ascending and decending intensity half squat between 70-90% 1RM	6
Hermassi et al.2017	Controlled pre-post	Handball (n=22)	RT: 20.3±0.1 CG: 20.1±0.2	RT or CG	2x weekly, 8 weeks	Modified half T-test	RT performed 3-4 sets of 3-6 repetitions at 70-85% 1RM half squat	6
Hermassi et al.2019a	Randomized controlled trial	Handball (n=22)	CRT:20.3±0.5 CG:20.1±0.5	CRT or CG	2x weekly, 8 weeks	T-half test	CRT: 2-4 sets of 4-10 repetitions of half squat	6
Keiner et al. 2014	Controlled pre-post	Soccer (n=148)	15-19	RT or CG + reference group	2x weekly, 104 weeks	Equilateral triangle (each side 5m)	RT groups followed a linear periodized plan, starting with 5 sets of 10 repetitions, progressing to 5 sets of 6 repetitions and 5 sets of 4 repetitions.	6
Loturco et al. 2016	Parallel group randomized trial	Soccer (n=23)	23.9±4.4	Trad. RT or OPT	3x weekly, 6 weeks	Zigzag	Trad and OPT performed 6 sets of 4-8 repetititions of squat at 60-90% 1RM, week 5 and 6 consisted of 6 sets of 6 repetitions jump squat with 30% 1RM	7
Millar et al. 2020	Randomized trial	Soccer (n=14)	HIP:15.7±0.8 SQ:15.3±0.7	Hip-thrust group or squat group	2x weekly, 6 weeks	Pro agility shuttle	Hip thrust and squat group performed 3-4 sets of 4-8 of their respective exercise, either explosive first followed by high intensity or high intensity followed by explosive.	8

Table 3 Study description RT=Resistance training, PT=Plyometric training, CG=Control group, OPT=Optimal load training, Trad=Traditional, CRT=Circuit RT

Mixed

Reference	Study design	Participants	Age	Intervention component	Intervention duration	COD Measure	Intervention description	Quality score
Appleby et al. 2020	Randomized controlled trial	Rugby (n=33)	22.40±4.1	BIL RT or UNI RT	2x weekly, 8 weeks	Customised 50° COD	Both groups performed 2-4 sets of either unilateral or bilateral exercises, with 5-10 repetitions (10-25 for calf raises). Intensity ranged between 45 and 88% 1RM	6
Gonzalo-Skok et al. 2017	Randomized controlled trial	Basketball (n=18)	16.9±2.1	BIL RT or UNI RT	2x weekly, 6 weeks	4x5m w. 180°COD & V-cut	Both groups performed 3 sets of either bilateral or unilateral squat until power dropped <10%. Followed by either bilateral or unilateral drop jumps in 2 sets of 5 repetitions	6
Hermassi et al. 2019b	Randomized controlled trial	Handball (n=22)	OLY:20.9±0.6 CG:20.6±0.5	OLY or CG	2x weekly, 12 weeks	T-half test	OLY completed 3-4 sets of 3 or 6 repetitions of snatch and clean & jerk. With intensities of 55-75% 1RM	6
Hoffman et al. 2004	Pre-post	American Football (n=20)	OLY:19.3±1.2 PL:18.9±1.4	OLY or Powerlifting	4x weekly, 15 weeks	T-test	OLY and Powerlifting groups performed 4-5 sets of 5-10RM repetitions	6
Johnson et al. 2013	Pre-post	American Football (n=39)	Trad:16±2 CRT:16±1	Trad. RT or CRT	3x weekly, 6 weeks	Pro agility drill	Trad. Group followed the conventional RT sequencing completing every exercise before initiating the next. CRT completed a set of each exercise before initiating the second set.	6
Loturco et al. 2020	Randomized Trial	Soccer (n=25)	18.5±0.6	Trad. RT or Elastic band groups	3x weekly, 4 weeks	Zigzag	Both groups performed 4-6 sets of half squat with 4-6 repetitions and intensity based on mean propulsive power, for the first 4 weeks. The last 2 weeks both groups performed jump squats with 4-6 sets of 4-6 repetitions.	7
Winwood et al. 2015	Randomized controlled trial	Rugby (n=30)	22.9±4.6	Strongman RT or Trad RT	2x weekly, 7 weeks	505 agility	Trad. Group performed 2-3 sets of 5-8 repetitions with intensities of 70-85%. Strongman group performed similar repetitions and intensity with strongman utilities	6

Table 4 Study description RT=Resistance training, CG=Control group, Trad=Traditional, CRT=Circuit RT, BIL=Bilateral, UNI=Unilateral, OLY=Olympic weightlifting

Combined

Reference	COD	Mean pre (s)	SD	Mean post (s)	SD	Δ change (%)	P-value	Effect size
Brito et al. 2014	T-Test			NR			p>0.05	
Freitas et al. 2018	T-Test	OPT: 9.71 CT: 9.45	±0.67 ±0.35	OPT: 9.46 CT: 9.16	±0.3 ±0.5	OPT: 3.03% CT: 3%	p>0.05	OPT: 0.42±0.24 CT: 0.75±0.6
Hammami et al. 2017	S180°	CST: 8.37 CG: 8.39	±0.21 ±0.35	CST: 7.94 CG: 8.40	±0.25 ±0.37	CST: 5.31 CG:-0.11	**p<0.05**	0.134
	SBF	CST: 8.45 CG: 8.60	±0.22 ±0.29	CST: 8.08 CG: 8.67	±0.29 ±0.45	CST: 4.37 CG: -0.81	**p<0.05**	0.11
	S4x5m	CST:6.24 CG: 6.18	±0.26 ±0.29	CST: 5.84 CG: 6.13	±0.05 ±0.22	CST: 6.41 CG: 0.80	**p<0.05**	0.149
	RCOD FT	CST: 6.27 CG: 6.64	±0.12 ±0.31	CST: 5.9 CG: 6.62	±0.18 ±0.27	CST: 5.90 CG: 0.30	**p<0.05**	0.14
	RCOD M	CST: 6.42 CG: 6.81	±0.13 ±0.27	CST: 6.09 CG: 6.98	±0.17 ±0.29	CST: 8.28 CG:-2.49	**p<0.05**	0.27
Hammami et al. 2019	S4x5m	CST: 6.25 PT: 6.25 CG: 6.15	±0.26 ±0.23 ±0.25	CST: 5.83 PT: 6.04 CG: 6.21	±0.47 ±0.20 ±0.24	CST: 6.72 PT: 3.36 CG: -0.97	**CST: 0.061** **PT: <0.001**	CST: 0.073 PT: 0.168 CG: 175
Kobal et al. 2017	505 agility test			NR			p>0.05	CT: -0.59 CST: -0.67 TD: -0.11
Ramirez-Campillo et al. 2018	Modified T-Test	BIL: 5.67 UNI: 5.80	±0.29 ±0.29	BIL: 5.46 UNI: 5.67	±0.20 ±0.16	BIL: 3.70 UNI: 2.24	**BIL: p<0.05** UNI: P>0.05	
Zghal et al. 2019	505 agility test	CT: 2.50 PT: 2.45 CG: 2.50	±0.13 ±0.16 ±0.14	CT: 2.46 PT: 2.47 CG: 2.50	±0.08 ±0.16 ±0.13	CT: 1.6 PT: -0.81 CG: 0	p>0.05	

Table 5 Study results CG=Control group, CST=Contrast training, PT=Plyometric training, CT=Complex training, BIL=Bilateral, UNI=Unilateral, OPT=Optimal load training

Conventional

Reference	COD	Mean pre (s)	SD	Mean post (s)	SD	Δ change (%)	P-value	Effect size
Al Ameer, 2020	Illinois agility test	TD: 23.53 PT: 23.13	±1.63 ±2.34	TD: 20.77 PT: 21.91	±1.77 ±1.44	TD: 11.72 PT: 5.27	**TD: 0.001 PT: 0.01**	0.70
Barbalho et al. 2018	T-Test	TD: 11.5 CG: 11.6	±0.6 ±0.6	TD: 11.7 CG: 12.1	±0.8 ±0.6	TD: -1.73 CG: -4.31	0.588	
Christou et al. 2006	10x5m	TD: 19.92 Soc: 19.78 CG: 20.86	±0.24 ±0.21 ±0.63	TD 8W: 19.43 Soc 8W: 19.34 CG 8W: 20.43	±0.16 ±0.16 ±0.18	TD: 2.45 Soc: 2.22 CG: 2.06	**p<0.05**	TD 8W: -0.83 Soc 8W: -1.08 CG 8W: 0.02
				TD 16W: 18.84 Soc 16W: 18.99 CG 16W: 21.12	±0.16 ±0.24 ±0.40	TD 16W: 5.42 Soc 16W: 3.99 CG 16W: -1,24	**p<0.05**	TD 16W: -1.74 Soc 16W:-1.13 CG 16W: 0.17
Hammami et al. 2018	S180°	RT: 8.39 CG: 8.33	±0.07 ±0.29	RT: 8.16 CG: 8.35	±0.13 ±0.35	RT: 2.74 CG: -0.24	**p=0.016**	0.096
	SBF	RT: 8.54 CG: 8.50	±0.14 ±0.28	RT: 8.26 CG: 8.62	±0.09 ±0.41	RT: 3.27 CG: -1.4	**p=0.002**	0.153
	S4x5m	RT: 6.23 CG: 6.15	±0.12 ±0.25	RT: 5.59 CG: 6.21	±0.07 ±0.24	RT: 10.27 CG: -0.97	**p<0.001**	0.187
Hermassi et al. 2017	Modified T-Test	RT: 6.51 CG: 6.68	±0.33 ±0.18	RT: 6.06 CG: 6.71	±0.08 ±0.18	RT: 6.91 CG: -0.44	**p<0.001**	0.581
Hermassi et al. 2019a	Half T-Test	RT: 7.16 CG: 7.06	±0.40 ±0.40	RT: 6.64 CG: 7.07	±0.44 ±0.26	RT: 7.26 CG: -0.14	**p=0.001**	1.24

Table 6 Study results RT=Resistance training, PT=Plyometric training, CG=Control group, TD=Traditional

Conventional

Reference	COD	Mean pre (s)	SD	Mean post (s)	SD	Δ Change (%)	P-value	Effect size
Keiner et al. 2014	Equilateral triangle (Left 5m)	U19 RT: 1.73 U19 CG: 1.67 U17 RT: 1.77 U17 CG: 1.67 U15 RT: 1.84 U15 CG: 1.86	±0.08 ±0.08 ±0.05 ±0.05 ±0.09 ±0.09	U19 RT: 1.61 U19 CG: 1.66 U17 RT: 1.69 U17 CG: 1.72 U15 RT: 1.72 U15 CG: 1.77	±0.01 ±0.05 ±0.08 ±0.07 ±0.06 ±0.09	U19 RT: 6.9 U19 CG: 0.59 U17 RT: 4.51 U17 CG: -2.99 U15 RT: 6.52 U15 CG: 4.83	**p<0.05**	
	Equilateral triangle (Right 5m)	U19 RT: 1.71 U19 CG: 1.65 U17 RT: 1.77 U17 CG: 1.69 U15 RT: 1.84 U15 CG: 1.85	±0.04 ±0.03 ±0.07 ±0.05 ±0.07 ±0.08	U19 RT: 1.63 U19 CG: 1.69 U17 RT: 1.69 U17 CG: 1.73 U15 RT: 1.72 U15 CG: 1.80	±0.06 ±0.05 ±0.07 ±0.07 ±0.11 ±0.09	U19 RT: 4.67 U19 CG: -2.42 U17 RT: 4.51 U17 CG: 2.36 U15 RT: 6.52 U15 CG: 2.70	**p<0.05**	
	Equilateral triangle (Left 10m)	U19 RT: 3.24 U19 CG: 3.16 U17 RT: 3.30 U17 CG: 3.14 U15 RT: 3.50 U15 CG: 3.49	±0.09 ±0.10 ±0.11 ±0.09 ±0.16 ±0.18	U19 RT: 3.06 U19 CG: 3.16 U17 RT: 3.17 U17 CG: 3.28 U15 RT: 3.21 U15 CG: 3.40	±0.68 ±0.08 ±0.16 ±0.12 ±0.14 ±0.15	U19 RT: 5.55 U19 CG: 0 U17 RT: 3.93 U17 CG: -4.45 U15 RT: 8.28 U15 CG: 2.5	**p<0.05**	
	Equilateral triangle (Right 10m)	U19 RT: 3.27 U19 CG: 3.14 U17 RT: 3.37 U17 CG: 3.20 U15 RT: 3.48 U15 CG: 3.45	±0.07 ±0.07 ±0.11 ±0.11 ±0.13 ±0.19	U19 RT: 3.07 U19 CG: 3.22 U17 RT: 3.18 U17 CG: 3.33 U15 RT: 3.22 U15 CG: 3.45	±0.12 ±0.10 ±0.11 ±0.10 ±0.19 ±0.14	U19 RT: 6.11 U19 CG: -2.54 U17 RT: 5.63 U17 CG: -4.06 U15 RT: 7.47 U15 CG: 0	**p<0.05**	
Loturco et al. 2016	Zigzag			NR		TD: 6.6±1.8 OPT: 6.8±2.6	**TD: p<0.0001** **OPT: p<0.001**	TD: 2.4 OPT: 1.6
Millar et al. 2020	Pro agility	NR		Hip: 5.25 SQ: 5.27	±0.078 ±0.069	Hip: 1.75 SQ: 1.54	p>0.05	

Table 7 Study results RT=Resistance training, PT=Plyometric training, CG=Control group, TD=Traditional

Mixed

Reference	COD	Mean pre (s)	SD	Mean post (s)	SD	Δ change (%)	P-value	Effect size
Appleby et al. 2020	Custom 50° COD			NR			p>0.05	BIL: -0.90±0.4 UNI: -0.54±0.61 CG: -0.18±0.19
Gonzalo-skok et al. 2017	V-cut	BIL: 6.63 UNI: 6.57	±0.24 ±0.23	BIL: 6.56 UNI: 6.50	±0.2 ±0.18	BIL: 1.05 UNI: 1.06	p>0.05	
	V-cut left	BIL: 3.48 UNI: 3.55	±0.12 ±0.17	BIL: 3.48 UNI: 3.46	±0.11 ±0.15	BIL: 0 UNI: 2.6	p>0.05	
	V-cut right	BIL: 3.50 UNI: 3.54	±0.12 ±0.15	BIL: 3.45 UNI: 3.47	±0.09 ±0.10	BIL: 1.42 UNI: 1.97	p>0.05	
Hermassi et al. 2019b	Half T-Test	OLY: 6.85 CG: 6.33	±0.44 ±0.26	OLY: 6.05 CG: 6.50	±0.37 ±0.39	OLY: 11.67 CG: -2.68	**p=0.002**	OLY: 1.98
Hoffman et al. 2004	T-Test	OLY: 9.36 PL: 9.42	±0.44 ±0.38	OLY: 9.21 PL: 9.23	±0.54 ±0.41	OLY: 1.60 PL: 2.01	p>0.05	
Johnson et al. 2013	Pro agility	CRT: 5.16 OLY: 5.43		CRT: 5.17 OLY: 5.45		CRT: -0.19 OLY: -0.36	p>0.05	
Loturco et al. 2020	Zigzag			NR			**OPT: p<0.05** **EBG: p>0.05**	OPT W1-W4: 0.86 EBG W1-W4: 0.42
Winwood et al. 2015	505 agility test			NR			p>0.05	STRM: -0.25 TD: -0.25

Table 8 Study results CG=Control group, BIL=Bilateral, UNI=Unilateral, CRT = Circuit RT, OLY=Olympic weightlifting, PL=Powerlifting

Discussion

This systematic narrative review, systematically synthesized available literature conducting resistance training interventions on team sports athletes, with an objective of investigating COD performance. From the systematic search a total of 23 studies were found eligible for inclusion into this review, of those 23 studies, seven studies used combined RT and PT, nine studies used conventional RT and seven studies used mixed types of RT.

General

In the combined group, 42.8% of the studies found a significant improvement in COD after RT. Four of the studies used complex training, but none of them demonstrated significant improvements. Two studies used contrast training, with Hammami et al. (2017) showing significant improvements in COD performance for both contrast training and conventional RT compared to a control group. The second study using contrast training found no significant improvements following contrast training, but found a significant improvement following plyometric training (Hammami et al., 2019). One study combining unilateral or bilateral training with plyometric training found significant improvements to COD only after bilateral training (Ramirez-Campillo et al., 2018).

For the conventional group, seven studies (77%) found significant improvements in COD performance, using conventional RT methodology. Loturco et al. (2016) used optimal load training and traditional RT, finding a significant improvement of COD performance for both groups. One study using circuit resistance training, Hermassi et al. (2019a), found a significant improvement of COD.

In the mixed group, 28,5% of the studies reported a significant improvement in COD performance following RT, with no method being superior to the others. All studies used vertical vector training, with either Olympic weightlifting, strongman, powerlifting, bilateral or unilateral training. Loturco et al. (2020) found a significant improvement following optimal power load training compared to a group using optimal power load training with added elastic bands. Three studies examined Olympic weightlifting; here, Hermassi et al. (2019b) found a significant improvement in COD performance compared to a control group. Hoffman et al. (2004) and Johnson et al. (2013) found no significant improvements to COD performance, compared to group training in powerlifting and group circling between exercise sets.

Based on the included studies, it appears that conventional RT, where studies found on average 5.49% improvements to COD performance, has the largest increase in COD performance for team sports athletes. Followed by the combined group where studies showed improvements to COD performance following interventions of 4.59%. Interventions utilizing mixed training were found to have the lowest improvement to COD with 2.31%.

As shown in Table 6, Al Ameer, (2020) found the highest percentage improvement in COD of all the included studies, with 11.72%, following conventional RT. In the remaining eight studies in conventional RT, there is an improvement in COD between -1.73% and 10.27%. The results of the seven studies included in the combined group range between 2.24% and 8.28% improvements. The mixed group consists of seven studies, where improvements between -0.36% and 11.67% have been reported. It thus appears that there is an intragroup variance, and the average percentage difference between conventional RT and combined is 0.9%. In addition, it should be noted that of the studies in the conventional RT group, Barbalho et al. (2018) reported a decrease in COD performance. RT experience appears to influence the success of RT interventions, with only few studies reporting subjects having RT experience. In the combined group three of the seven studies reported RT experience, in the conventional group only three of nine studies reported RT experience and in the mixed group five of the seven studies reported RT experience. The lack of experience with RT, will likely be connected to improvements in both strength and COD performance.

Methodological differences

The combined category consists of complex training, contrast training, plyometric training and bilateral training combined with plyometric training. Of these types of RT, only complex training found no significant improvements in COD performance (Freitas et al., 2018, Brito et al., 2014, Kobal et al., 2017, Zghal et al., 2019). Contrast training, bilateral training combined with plyometric training and unilateral training combined with plyometric training, were found to significantly improve COD performance (Hammami et al., 2017, Hammami et al., 2019, Ramirez-Campillo et al., 2018). Contrast training is a kind of complex training, with similar underlying mechanisms, however, contrast training alternates a high intensity exercise with a light intensity exercise (Hammami et al., 2017). Complex training involves the same alternation, but the light intensity exercise consists of plyometric drills with similar biomechanics as the high intensity exercise (Ebben, 2002, Docherty et al., 2004, Carter & Greenwood, 2014, Lim et al., 2016). Hammami et al. (2017) compared contrast training to conventional RT and found both methods to be effective in improving COD performance. Brito et al. (2014) compared the effect of plyometric training, conventional RT and complex training on COD performance and found no significant changes following either intervention. Brito et al. (2014) and Hammami et al. (2017) used comparable intensities between 70-95% 1RM, but the intervention groups in Brito et al. (2014) performed lower volume (1 set / exercise) compared to Hammami et al. (2017) (three-five sets/ exercise). Zghal et al. (2019) used intensities between 30-60% and two-four sets of six-eight repetitions, Freitas et al. (2018) used 80% 1RM intensities and three-four sets of either complex training or optimal load training but found neither to be effective in improving COD performance. Plyometric training alone, has been found to be effective in improving COD performance, with Al Ameer, (2020) finding significant improvements on the Illinois test following plyometric training. General volume completed in complex training studies, could be an explanation as to why complex training found no significant improvements in COD performance. The studies not finding significant improvements to COD performance, used low training volume I.e., Brito et al. (2014) or low intensities I.e., Zghal et al. (2019). Studies finding improvements using complex training found improvements by using high intensities (Hammami et al., 2017, Freitas et al., 2018) combined with higher volumes of three to five sets. As well as demands for high intensity exercises, complex training is based on eliciting post-activation potentiation which requires athletes to be experienced with RT (Carter & Greenwood, 2014). Brito et al. (2014), Kobal et al. (2017) and Zghal et al. (2019) all used subjects with no RT experience, making them less likely to achieve the adaptations thought to elicit power improvements from complex training (Carter & Greenwood, 2014).

For complex training, optimizing the intra-complex resting interval to allow conditions for the potentiation effect to occur, is essential. Only Freitas et al. (2018) used intra-complex resting intervals, they implemented resting intervals of two min 30s, which is shorter than the recommended durations of three to eight min rest to optimize performance (Ebben, 2002, Docherty et al., 2004, Carter & Greenwood, 2014, Lim et al., 2016). Fatigue following the high intensity exercise could inhibit some of the adaptations to power and velocity, reducing the potential effect of complex training on COD performance for team sports athletes (Ebben, 2002, Docherty et al., 2004, Carter & Greenwood, 2014, Lim et al., 2016).

Seven of the nine studies in the conventional group, found conventional RT methods to be effective in improving COD performance. The sets performed were between two and six per exercise, with repetitions ranging between three to 15. Of the nine studies only Loturco et al. (2016) reported subjects having RT experience, with the remaining study either declaring no experience or not reporting the experience. The lack of RT experience could be an explanation for the overall improvements in the conventional RT group, however, Loturco et al. (2016) found significant improvements in trained subjects. This suggests that regardless of RT experience, conventional RT is a viable option for improving COD performance.

Of the seven included studies in the mixed category, two found significant improvements in COD performance (Hermassi et al., 2019b, Loturco et al., 2020). The two studies varied in RT methods, with Hermassi et al. (2019b) using Olympic weightlifting, and Loturco et al. (2020) using traditional training with an optimum power load approach with or without additional resistance from elastic bands. Loturco et al. (2020) found a reduction in performance after their initial two-week strength foundation training for their elastic band group. Both optimal power load and elastic band groups then increased COD from pre- test significantly to post-test ($p<0.05$), following two weeks of power-oriented training (Loturco et al., 2020). Initial differences in COD performance could be due to initial fatigue caused by the strength-oriented phase, with three weekly RT sessions consisting of four to six sets and repetitions of half squat (Loturco et al., 2020). The final two weeks of the intervention consisted of jump squats with load or resistance bands, involving lower loads than the strength foundation phase (Loturco et al., 2020). Hermassi et al. (2019b) was the only study using Olympic weightlifting to find significant improvements in COD performance. Hermassi et al. (2019b) implemented a linear Olympic weightlifting approach with handball players, Hoffman et al. (2004) tried a similar approach in American football players, with an Olympic weightlifting group and a powerlifting group. Hoffman et al. (2004) additionally performed sprint and COD training, but still found that neither Olympic weightlifting or powerlifting could improve COD performance, when combined with sprint and COD training (Hoffman et al., 2004). Hoffman et al. (2004) used American football players, who likely were already proficient in COD performance. Indeed, Hoffman et al. (2004) showed initial times for the T-test of 9.36s and 9.42s for their Olympic weightlifting and power lifting group, respectively. Freitas et al. (2018) reported similar results to Hoffman et al. (2004) for the T-test, but Barbalho et al. (2018) who also used the T-test showed slower initial test scores of 11.5s for their intervention group. This suggests that, both Freitas et al. (2018) and Hoffman et al. (2004) used highly proficient athletes, which could represent diminishing effects on COD performance from additional RT.

Conventional RT was found to be highly effective in improving COD performance, with seven of nine studies finding significant improvements following conventional RT interventions. Contrast training found significant improvements in COD performance in two studies, which could indicate that it is a viable method for improving COD. Complex training, Olympic weightlifting, strongman training and unilateral training all revealed mixed results, suggesting that complex and strongman training are not viable RT methods to improve COD performance. While comparisons between different methods and types of tests are speculative, results from the conventional group suggest that three to four sets of RT is enough volume to improve COD performance in team sports athletes, who concurrently perform their team sport.

Keiner et al. (2014) performed a conventional intervention on several groups of young soccer players through two years, finding significant improvements in COD performance for all groups. Keiner et al. (2014) found a moderate to high significant correlation between relative maximum strength in front squat and back squat with COD performance (Keiner et al., 2014). The findings from Keiner et al. (2014) expand the research on relative maximum strength being a greater indicator of explosive power than absolute strength, suggested by Peterson et al. (2006). Peterson et al. (2006) suggests that specific training transfer as well as neuromuscular adaptations are vital for performance improvements in explosive events, such as CODs (Peterson et al., 2006). Hoffman et al. (2004) suggested that specific training transfer to the force-velocity spectrum following resistance training could help explain changes to COD performance throughout interventions (Hoffman et al., 2004). However, of three studies using Olympic weightlifting only Hermassi et al. (2019b) found significant improvements in COD performance. Two studies utilizing velocity based training and optimum power load training found using optimal power load training significantly improves COD performance (Loturco et al., 2016, Loturco et al., 2020), however, Freitas et al. (2018) found only a 3.03% improvement following optimal power load training and a 3% improvement following complex training (Freitas et al., 2018). Conventional training typically consists of high force and low velocity exercises, performed at high intensities (Hoffman et al., 2004). Regardless of this, seven studies using conventional methodologies reported significant improvements in COD performance (Al Ameer, 2020, Christou et al., 2006, Hammami et al., 2018, Hermassi et al., 2017, Hermassi et al., 2019a, Keiner et al., 2014, Loturco et al., 2016). Some of the improvements based on conventional RT, could be attributed to neuromuscular adaptations following high intensity RT. Among these adaptations are improved neural activation patterns following RT, this occurs both through improved cortical signaling but also though reduced antagonist coactivation (Carroll et al., 2001). Improved intramuscular coordination is equally thought to result from RT, all potential attributers to improving COD performance following RT interventions (Carroll et al., 2001). Hoffman et al. (2004) reported body weight for their subject groups, not finding significant differences between pre and post data, however, Hoffman et al. (2004) reported significant improvements in squat for both Olympic weightlifting and powerlifting groups. This translates to increased relative maximum strength, still, Hoffman et al. (2004) reported no significant improvements to COD performance. This suggests possible plateau for COD performance could be reached for proficient athletes, where additional improvements to strength do not contribute to additional performance improvements.

Technical aspects to COD

With several RT methods being viable options to improve COD performance in team sport athletes, it is worthwhile to look at studies that fail to improve performance. Young et al. (2002) and Sheppard & Young, (2006) presented a model of agility, differentiating agility into a visual perceptual and a physical branch. All studies found significant improvements in strength following their interventions, with some studies finding improvements to linear sprint as well (Brito et al., 2014, Christou et al., 2006, Gonzalo-Skok et al., 2017, Winwood et al., 2015, Appleby et al., 2020, Kobal et al., 2017, Loturco et al., 2016, Hammami et al., 2017, Hammami et al., 2018, Hammami et al., 2019, Zghal et al., 2019). Of the studies that improved sprint and strength significantly, five studies found no significant improvements to COD performance (Brito et al., 2014, Zghal et al., 2019, Appleby et al., 2020, Kobal et al., 2017, Winwood et al., 2015). The lack of improvement to COD performance following improvements to strength and linear sprinting speed, could be attributed to technical parameters (Young et al., 2002, Sheppard & Young, 2006). Technical parameters consist of foot placement, adjustments of strides to acceleration and deceleration, as well as body lean and posture (Young et al., 2002). Zghal et al. (2019) supported the notion that technical parameters were important while developing strength. Rationalizing that improvements in COD performance could be attributed to motor control, rather than maximal strength and power abilities (Zghal et al., 2019). Changes to strength and thereby force mechanics of the musculature involved in deceleration and acceleration, could alter the mechanics involved in changing direction. All studies concurrently performed their primary sport, with only Hoffman et al. (2004) performing additional COD training. For the remaining studies only the test sessions were left to adjust performance improvements to the specific test mechanics. However, studies not concurrently training COD with RT interventions still found significant improvements to COD performance. Another potential implication in improving COD performance with RT, is training transfer. Transfer from RT is specific to muscles used, muscle activation pattern, velocities and angles (Young, 2006). All studies included, used exercises with a vertical force vector, i.e., squat and leg press, with only Millar et al. (2020) and Freitas et al. (2018) using hip thrusts with a horizontal force vector. Neither Millar et al. (2020) or Freitas et al. (2018) found significant improvements for COD following either hip thrusts or squat, however, other studies using full- and half squats have found significant improvements to COD performance (Hammami et al., 2018, Hermassi et al., 2017, Hermassi et al., 2019a, Loturco et al., 2016). This proves that RT exercises with predominantly vertical vectors can improve COD performance, and that the subsequent transfer is not diminished. Velocities used in RT are slower than those observed in CODs (Hoffman et al., 2004), still only one study using Olympic weightlifting found significant increases in COD performance (Hermassi et al., 2019b). Olympic weightlifting is a power based training type, moving heavy bars at high velocities, involving extension of the ankles, knees, and hip (Hoffman et al., 2004, Johnson et al., 2013). Regardless of the higher movement velocities, conventional RT appears to have a greater transfer to COD performance, with 77% of the included studies using conventional RT finding significant improvements.

CODs are unilateral movements, studies comparing unilateral RT with bilateral RT have found both bilateral and unilateral training to be effective in improving strength and COD (Gonzalo-Skok et al., 2017, Ramirez-Campillo et al., 2016), with Appleby et al. (2020) only finding moderate improvements in COD following unilateral or bilateral training. Only Gonzalo-Skok et al. (2017) tested COD for both the dominant and non-dominant leg, with unilateral training improving COD performance for both legs and bilateral only showing likely improvements for the dominant leg.

Based on the results of this review, technical aspects as presented by Young et al. (2002), could explain a small amount of the improvements or lack thereof.

COD Testing

Bourgeois et al. (2017a) categorized the different tests within COD by dividing them according to force or velocity dominance, depending on the degrees of the angles in the COD. For it to be a force dominant test, there must be a change of direction greater than <90°, while CODs with angles lower than >90° are defined as velocity dominant (Bourgeois et al., 2017a). Of the 15 included studies, 11 utilized force dominant COD tests (505 agility, t-test, Illinois test, 9-3-6-3-9 w. 180° turns, modified half T-test, T-half test, modified t-test, 10x5m maximum shuttle run, Pro agility drill, 4x5m repeated sprint, 4x5m w. 180° COD) and four utilized velocity dominant COD tests (Zigzag, Equilateral triangle with 5m sides, Customized 50° COD, V-cut). The T-test or a variation of it, is the most frequently used with 8 out of 23 tests being a T-test; four different types of t-tests were performed in the included articles in the form of modified half t-test, half t-test, modified t-test and t-test. There is great diversity in tests; both within sports and between researchers. The prevalence of force dominant tests are higher in the present review, compared to velocity dominant tests. Within the conventional group, nine different tests have been applied, with seven of the tests being force dominant, the variation in test choice occurs between sports but also within sports.

T-test is the type of test that has been used most times by the included studies; none of the four studies that have used a full t-test found significant improvements in COD (Brito et al., 2014, Freitas et al., 2018, Barbalho et al., 2018, Hoffman et al., 2004). Of the four studies using the T-test, two applied a complex training intervention (Brito et al., 2014, Freitas et al., 2018), one study used conventional RT (Barbalho et al., 2018) and one study used Olympic weightlifting and powerlifting (Hoffman et al., 2004). The T-test is a technically difficult test with sideways and backward movement. As shown in table 2-4, other variations of t-tests have been used in the form of a half t-test, modified t-test and modified half t-test. The included studies that used other forms of t-tests, than the full t-test, have found significant improvements ($p<0.05$). There are indications that a full t-test may be too technically demanding for the individuals to find significant improvements.

Before choosing a test, it's important to make sure that the test is reliable and valid for the specific sport and type of athlete (Bourgeois et al., 2017a). Therefore, there must be a connection between the intervention and the test that is to be performed. The force from the training must help change the momentum for the change of direction, which means that RT interventions can use force-dominant tests. For velocity-based tests, there is a transfer from improvements to linear sprint speed to COD performance, as more of the speed attained during the acceleration is retained through the COD (Bourgeois et al., 2017a). Similarly, improvements to linear sprinting speed correlate to improvements to CODs with longer straight accelerations, than improvements to strength (Bourgeois et al., 2017a). Based on the included studies, 15 different tests have been used, significant improvements in COD have been found with 11 of those tests. The present study has gathered the literature on RT training and the improvements of COD. Of the four velocity based test, there has been found significant for improvements in three (Zigzag, Equilateral triangle, V-cut). Significant improvements were found in eight out of 11 used force dominant tests (Illinois test, 9-3-6-3-9 w. 180° turns, modified half T-test, T-half test, modified t-test, 10x5m maximum shuttle run, 4x5m repeated sprint, 4x5m w. 180 ° COD). There are indications that force dominant (72,7%) and velocity dominant (75%) tests are equal in finding COD improvements following RT training.

In choosing a sport specific COD test, several parameters influence the outcome, the duration of the COD test, the angles of the directional changes and the number of changes of direction (Bourgeois et al., 2017a). It is possible to argue that an Illinois test is relevant for soccer players, as it is a slightly longer test with a force dominant direction change and several velocity dominant direction changes, which will be used in relation to dribbling. A 505 test will be more suitable for American football players and rugby players as two 180° changes of direction are force dominant, which is relevant in evading and outmaneuvering an opponent.

Limitations

Based on Young et al. (2002) and Sheppard & Young, (2006) definition of agility, none of the included studies used an agility test, as defined by Young et al. (2002) and Sheppard & Young (2006) with a visual and perceptual factor as well as COD. As stated earlier, 15 different tests have been found in 23 studies including several different forms of the same test; this may be because no golden standard has been set within COD. COD testing is situational, and each sport will have different needs in regard to testing. This presents a challenge to set up a golden standard test, which at best could represent individual sports, requiring sport specific golden standard test.

In the present study, the NHLBI Quality Assessment for Before-After (Pre-post) Studies with no Control Group has been used to assess the quality of the included articles. In the current review an average score of 6.3±0.8, with the highest possible rating being 12. There are shortcomings to using this tool in sports science, as it is intended for medical studies. Creation of a similar tool for quality assessment of sport science literature, based on established norms in the field of sport science is recommended for further evaluation of study quality. The control groups included in the present study are all control groups that continue to practice their primary sport. Which makes it difficult to assess whether RT works in relation to COD, as improvements in COD are seen in soccer. There is a need for control groups that are not active or practice their primary sports.

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