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Article

Chronic Effects of Rotational Inertial Training on Adolescents' Physical Capacities in Team Sports: A Systematic Review

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Abstract: Inertial training is one of the most popular training methodologies in recent years and one of the objects of study in recent literature. The aim of the current systematic review is to evaluate the current literature surrounding the chronic effect of rotational inertial devices on physical capacities of team sports through jumping performance, sprinting time and change of direction performance. This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA). Two databases were screened up to January 2023. Eight studies were included for final analysis. The results revealed the effectiveness of Rotational Inertial Devices as Flywheel or Pulley Conic, showing significant improvements (from trivial to large effect size) in jump performances, significant improvements in some tests for change of direction ability and non-consistent results for sprint tests with significant improvements mainly in short distances. In conclusion, inertial training has been shown to be a useful way to improve performance in young athletes on team sports.

Keywords: inertial training; eccentric overload; strength training; young athletes; team sports

1. Introduction

Strength training (ST) is one of the most common strategies to improve different actions which are key in team sports performance such as jumps, sprints, accelerations or change of directions (CODs) [1]. Largely studies support these findings in young population where it seems clear that ST induces great improvements in strength, power output, speed, jumps or kicking [2,3], indeed young athletes have shown improvements in athletic performance and body composition with self-loading [4].

In recent years, the eccentric overload training (EOT) has become a popular method for the athlete population due to the benefits in athletic performance in youth athletes [5]. In fact, the effect of EOT showed improvements in young soccer players and it had impact in muscle injury incidence and severity [6]. Inertial Training (IT) is probably the most commonly used to achieve eccentric overload besides it is known his capability to stimulate the Stretching-shortening cycle (SSC) [7,8]. The eccentric (ECC) phase of the muscle action has emerged as an alternative method that may produce greater muscle adaptations [9]. Rotational inertial devices like Flywheel or Pulley Conic are increasing in popularity recently [8,10]. Although these devices were created in 1994 for reducing the atrophy in the astronauts in space [11], it has only been in the last decade when it has been used for athletes when we could know the exercise using non-gravity dependent device produced similar, if not greater benefits than using free weight exercise [7].

Due to the aforementioned studies, EOT has been extensively reviewed in the scientific literature [9]. Some researchers have suggested that this eccentric overload provides a great mechanical

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stimulus for both the muscular and tendinous tissues which benefits early neuromuscular (e.g., strength and power increases) and performance (e.g., jumping and COD ability) adaptations [12]. Resistance programs which incorporate flywheel exercises are one of the most effective methods for improving sport-specific performance in sporting populations [13]. However, optimization of resistance training using a strictly EOT regime is rather complex and technically difficult to apply [9]. Several authors have reported the need to apply certain strategies, in order to provide instructions that encourage the participants to delay the braking action to the last third of the ECC phase [8]. The purpose of this research was to investigate the effects after an IT intervention in actions which play a key role on team sports performance in youth athletes. Therefore, our hypothesis is that the use of rotational inertial devices could improve the power and strength in young athletes, thus improving jump, sprint and CODs performance.

2. Materials and Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA) [14].

2.1. Search strategy

A systematic and computerized search of the databases Web of Science and Scopus was conducted by two separate reviewers (AR and MO), using a date filter from 1st January 2019 to 30th January 2023, although, additionally, earlier studies published on the topic were screened for further potentially relevant information to help the researchers introduce the topic and make the discussion of this article. Only full-text articles from peer-reviewed studies written in English or Spanish were included.

The search included the following keywords collected through expert opinion: “isoinertial”, “flywheel”, “conic-pulley”, “eccentric-overload”, “training”, “team sports”, “soccer”, “futsal”, “handball”, “basket”, “hockey”, “rugby” and “volleyball”. The specific Boolean search algorithm was [“isoinertial” OR “flywheel” OR “conic-pulley” OR “eccentric-overload”] AND [“training”] AND [“team sports” OR “soccer” OR “futsal” OR “handball” OR “basket” OR “hockey” OR “rugby” OR “volleyball”].

2.2. Eligibility criteria

Studies meeting the inclusion criteria (Table 1) were included, focusing the review on healthy team sport adolescents who have been trained with EOT for a period of 4 weeks or longer with inertial devices (flywheel or conic-pulley) to elicit chronic adaptations. The training intervention and load (volume and intensity) needed to be quantified. Moreover, data was collected through at least one specific functional test such as a sprint test (e.g., 10m, 20m, 40m, RSA), power test (e.g., jump height) or change of direction test (e.g., T-test, Illinois test).

Table 1. Eligibility criteria.

Age	Participants included were between 12 and 20 years old.
Injury status	Participants were free from injury or illness.
Subjects	Participants included were male or female team sports athletes of various training levels (academy amateur or academy elite).
Team sports	Basketball, soccer, futsal, handball, hockey, volleyball and rugby union.
Training	The study utilised an inertial device (e.g. flywheel or conic-pulley).
Training period	The intervention period was ≥4 weeks.
Test/metrics	The measures come from specific functional tests (CMJ, COD, sprint…)
Article type	Peer-reviewed publication
Article language	English or Spanish

Studies that did not meet any of the previous criteria were excluded from the review. For example, studies with no outcome pertaining to EOT in relation to functional test performance such as isokinetic, TMG, EMG, body composition, questionnaires or studies where inertial devices are only

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used for testing instead of training. Intervention duration less than four weeks was a further reason to exclude a study.

2.3. Study selection

Initially, in order to avoid duplicates, a first filter was carried out because there is usually approximately a 46.9% coincidence [15]. Thus, all studies during the initial search were uploaded to a reference manager software (Zotero, version 6.0.23, Corporation for Digital Scholarship, Vienna, Virginia, USA), reviewed and screened for duplicates. Based on the study title, author, year of publication and DOI, duplicates were identified and merged using the "Duplicate Items" function.

Secondly, an assessment of eligibility was performed in an unblinded manner by two reviewers (AR and MO) separately. Titles and abstracts of the articles identified through the initial search were screened against the eligibility criteria (Table 1). Potentially relevant articles were retrieved for an evaluation of the full text. Interrater agreement was assessed using the Cohen's kappa ($\kappa = 0.82$). If there was uncertainty about whether a study met the standard for inclusion, that was clarified with a third reviewer (SL). The three reviewers determined the final pool of articles included in the review. The study selection process is presented in Figure 1.

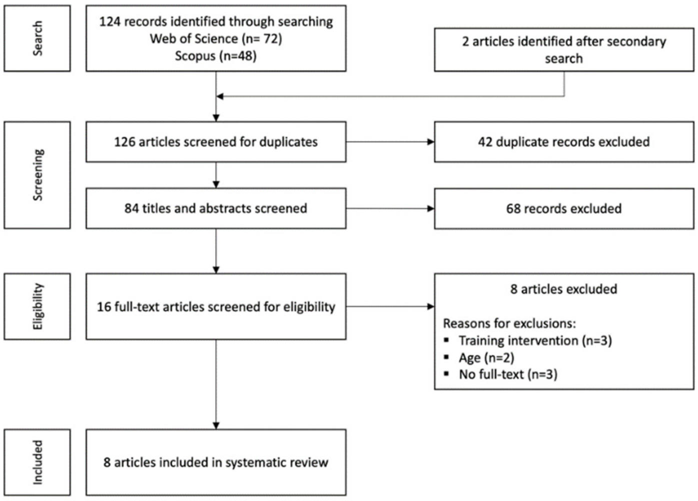

Figure 1. Study selection process.

2.4. Quality Assessment

Preventing the risk of bias and providing quality assessment of the research are critical factors for a systematic review [16]. There are several scales to assess the methodological quality of studies like the PEDro scale, the Delphi scale or the Cochrane scale. However, previous studies have demonstrated that specifically strength and conditioning studies or non-healthcare studies in general, usually score low using these methodological scales [17,18].

Consequently, following Allen et al. [17], who use methods similar to Brughelli et al. [19], the eight selected studies were evaluated separately by the same two reviewers (AR and MO) using an evaluation derived from the aforementioned scales. This scale utilises 10-item criteria and the reviewers select between three options (0 = clearly no; 1 = maybe; and 2 = clearly yes, scoring each study from 0 to 20. To determine the study quality, previous researchers [17] have proposed three different levels: high quality (score >15), moderate quality (score 10-15), low quality (score <10). In the same way as during study selection, any differences between reviewers were clarified and settled with a third reviewer (SL).

The individual scores for the quality assessment could be reviewed (Table 2). The average score was 18 points (high quality), with values ranging from 17 to 20 points, all of them were categorized as high quality, although the lack of control groups in some studies could be interpreted as a source of bias.

Table 2. Methodological quality of studies.

Study	Inclusion Criteria	Random Allocation	Intervention Defined	Groups Tested for Similarity at Baseline	Control Group	Outcome Variable Defined	Assessments Practically Useful	Duration Intervention Practically Useful	Between-Group Stats Analysis Appropiate	Point Measures of Variability	Total Score Quality Assesment
Gonzalo-Skok et al, 2019	2	2	2	2	0	2	2	2	2	2	18 (high)
Murton et al, 2021	2	2	2	2	0	2	2	2	2	2	18 (high)
Nunez et al 2019	2	2	2	2	2	2	2	1	2	2	19 (high)
Gonzalo-Skok et al, 2022	2	2	2	2	0	2	2	2	2	1	17 (high)
Stojanovic et al, 2021	2	2	2	2	2	2	1	1	2	2	18 (high)
Fiorilli et al, 2020	2	2	2	2	0	2	2	2	2	2	18 (high)
Arede et al, 2020	2	2	2	2	0	2	2	2	1	2	17 (high)
Raya-Gonzalez et al, 2021	2	2	2	2	2	2	2	2	2	2	20 (high)

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3. Results

The reviewers extracted data from the included studies in a standardized template created with Microsoft Excel, in order to code and organize the information and compare the results.

3.1. Participants

A total of 8 studies met the inclusion criteria and were included in the review, with a summary of the participant characteristics provided in Table 3. A total of 206 adolescents were recruited and included in the analysis but only one study recruited female athletes (19 participants). 33 of the total participants were included in the control group. Participants took part in a range of team sports including soccer, rugby and basketball. Academy athletes were recruited in four studies [20–23], whereas Athletes from elite academies were recruited in another four studies [13,20,24,25].

3.2. Intervention

Intervention characteristics are provided in Table 4. Training programs lasted from 4 to 10 weeks (7.3 mean ± 2.2 SD), including 8 to 16 training sessions (11.1 mean ± 2.5 SD). The studies with fewer weeks of intervention (4-8 weeks) had two sessions per week, whereas the longest studies (9-10 weeks) had only one. Studies utilised several inertial devices: Conical Pulley – VersaPulley used in 3 studies [20,25,26], K-Box in 2 studies [13,24], Flywheel D1 Desmotec in 1 study [21], Flyconpower conical machine in 1 study [22] and Ecconomy Byomedic [23] in 1 study. The inertial load was highly different for every device. The prescribed training volume ranged from 1 to 5 sets of 6-10 repetitions, being gradually increased every 1-2 weeks in 5 studies [13,20,21,24,26] and maintaining the same load in 3 studies [22,23,25]. During intervention protocols, a huge variety of exercises were used which included unilateral lateral squat, backward lunges, defensive-like shuffling steps, Romanian deadlift, Bulgarian Split Squat, front-step acceleration, side-step, crossover cutting, landing, half squat or multidirectional-unilateral COD. Backward lunges and lateral squat were the most used.

3.3. Outcome Measures

The interventions characteristics and the outcome measures of the functional tests are presented in Table 4 and Table 5 respectively.

Table 3. Study characteristics.

Authors	Sample size	Gender	Age (years)	Height (cm)	Body Mass (Kg)	Sport	Level	Groups
Gonzalo-Skok et al, 2019	35	Male	15.4 ± 0.7	174.9 ± 5.8	64.2 ± 7.0	Soccer	Academy players	SVW (Same Volume Weaker) = 10 DVW (Double Volume Weaker) = 11 SVS (Same Volume Stronger) = 14
Murton et al, 2021	16	Male	18.0 ± 1.0	--	93.0 ± 13.1	Rugby Union	Elite Academy players	FIT (Flywheel Inertial Training) = 8 TRT (Traditional Resistance Training) = 8
Nunez et al 2019	20	Male	17.0 ± 1.0	178.1 ± 2.3	62.8 ± 6.6	Soccer	Elite Academy players	CPG (Conic-Pulley Group) = 10 CG (Control Group) = 10
Gonzalo-Skok et al, 2022	24	Male	16.0 ± 1.0 (VUH) 16.0 ± 1.0 (VUL)	190.1 ± 10.1 (VUH) 191.2 ± 10.8 (VUL)	83.2 ± 9.9 (VUH) 84.2 ± 10.1 (VUL)	Basket	Elite Academy players	EOT VUH (Unilateral Horizontal) = 12 EOT VUL (Unilateral Lateral) = 12
Stojanovic et al, 2021	36	Male	17.58 ± 0.52 (FST) 17.52 ± 0.58 (TST) 17.56 ± 0.54 (CON)	190.54 ± 4.98 (FST) 190.58 ± 6.56 (TST) 192.81 ± 3.99 (CON)	75.53 ± 5.43 (FST) 78.78 ± 8.01 (TST) 80.00 ± 8.76 (CON)	Basket	Academy players	FST (First Experimental Group) = 12 TST (Second Experimental Group) = 12 CON (Control Group) = 12
Fiorilli et al, 2020	34	Male	13.21 ± 1.21 (FEO) 13.36 ± 0.80 (PT)	165.21 ± 10.00 (FEO) 168.36 ± 7.00 (PT)	51.25 ± 6.71 (FEO) 52.10 ± 5.23 (PT)	Soccer	Academy players	FEO (Flywheel Eccentric Overload) = 18 PT (Plyometric Training) = 16
Arede et al, 2020	19	Female	15.0 ± 0.5	165.7 ± 5.4	61.7 ± 7.3	Team Sports	Academy players	EOT Variable = 8 EOT Standard = 11
Raya-Gonzalez et al, 2021	22	Male	--	--	--	Soccer	Elite Academy players	EG (Experimental Group) = 11 CG (Control Group) = 11

Table 4. Intervention characteristics.

Authors	Weeks	EOT/Week	Exercises	Sets & Reps	Inertial Device	Inertia Load	Test / Measures
Gonzalo-Skok et al, 2019	10 weeks	1 session	Unilateral lateral squat	Weeks 1-2 (2 sets x 6 reps) Weeks 3-6 (2 sets x 8 reps) Weeks 7-10 (2 sets x 10 reps) 30" rest between legs 3' rest between sets	Conic-Pulley (VersaPulley, Costa Mesa)	0.27 kg/m2	SLH (single-leg horizontal jump test) TSLH (triple single-leg horizontal jump) CMJL/R (unilateral) CMJ (bilateral)
Murton et al, 2021	4 weeks	2 sessions	Squat Romanian deadlift Bulgarian Split Squat	Week 1 (4 sets x 8 reps) Week 2 (5 sets x 6 reps) Week 3 (4 sets x 8 reps) Week 4 (5 sets x 8 reps)	K-box (Bromma, Sweden)	0.05 kg/m2	CMJ (Countermovement Jump) SJ (Squat Jump) DJ (Drop Jump)
Nunez et al 2019	9 weeks	1 session	Front-step acceleration	2-3 sets x 6 reps (each leg)	Conic-Pulley	0.22 kg/m2	20m linear sprint test

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Gonzalo-Skok et al, 2022	6 weeks	2 sessions	VUH exercises (Side-step, Backward lunges, Crossover cutting, Landing and backward lunges) VUL exercises (Lateral squat, Defensive-like shuffling steps, Lateral crossover cutting, 90º lunge)	Week 1-2 (1 set x 6 reps) Week 3-4 (1 set x 8 reps) Week 5-6 (1 set x 10 reps)	Conic-Pulley (VersaPulley, Costa Mesa)	0.27 kg/m2	CMJ (Countermovement Jump) UMJ (Unilateral Multidirectional Jump) RJ (Rebound Jump) 25m linear sprint test COD (180º test) COD (V-Cut test)
Stojanovic et al, 2021	8 weeks	2 sessions	Romanian deadlift Half squat	Week 1-2 (2 sets x 8 reps) Week 3-6 (3 sets x 8 reps) Week 7-8 (4 sets x 8 reps)	Flywheel (D11, Desmotec)	0.075 kg/m2	CMJ (Countermovement Jump) 5m linear sprint test 20 m linear sprint test COD (T-Test)
Fiorilli et al, 2020	6 weeks	2 sessions	Multidirectional-unilateral COD Shooting movement	4 sets x 7 reps 120'' rest between sets	Flyconpower conical machine (Cuneo; Italy)	?	SJ (Squat Jump) DJ (Drop Jump) 7R-HOP (7 Repetated Hop Test) COD (Y agility test) COD (Illinois test) 60m linear sprint test Shot Test (Loughborough Soccer Shooting)
Arede et al, 2020	6 weeks	2 sessions	Backward Lunges Defensive-like Shuffling Steps Side-step (The participants included in variable group were instructed to perform the movement randomly in one of the three directions (0°, 45° right, and 45° left))	1 set (5-6 reps each leg)	Eccommi (Byomedic System)	315 kg*cm2	CMJ (Countermovement Jump) SLCMJ (Single-leg Countermovement) SLRJ (Single-leg Rebound Jump) COD (T-test) 10m linear sprint test
Raya-Gonzalez et al, 2021	10 weeks	1 session	Lateral Squat	Week 1 (2 sets x 8 reps) Week 2-3 (2 sets x 10 reps)	K-Box 4 (ExxentricTM, Sweden)	0.025 kg/m2	CMJ (Countermovement Jump) 10m linear sprint test

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Week 4 (3 sets x 8 reps) Week 5-6 (3 sets x 10 reps) Week 7-8 (4 sets x 8 reps) Week 9 (3 sets x 8 reps) Week 10 (2 sets x 8 reps) 180'' rest between sets	20m linear sprint test 30m linear sprint test COD10 (5+5m) COD20 (10+10m) COD90 (90º)

Table 5. Results and conclussions.

Authors	Results	Results Summary	Conclusions
Gonzalo-Skok et al, 2019	**Within-group:** Possibly to likely improvements in CMJ and CMJW (all groups) Possibly CMJ asymmetry reduction (all groups) Possibly to very likely improvements in SLHW, TSLHR, TSLHL, TSLHS & TSLHW (SVW and DVW groups) Possibly CMJL improvement (DVW and SVS groups) Substantially improvement in CMJR (SVW group) Substantially TSLH asymmetry reduction (DVW group) Substantially SLH asymmetry increment (DVW and SVS group) **Between-groups:** The improvement in TSLH asymmetry was substantially greater in DVW than in SVW A substantially greater SLHR, TSLHR, TSLHS and TSLHW in SVW and DVW in comparison to SVS. Substantial greater improvements in SLH asymmetry and CMJR in SVW compared to SVS Substantially greater performance in TSLHL in DVW than SVS **Correlational analysis** At pre-test, negative relationships were found between SLHR and SLHL with single-leg horizontal asymmetry, between TSLHL with triple single-leg horizontal asymmetry, and between CMJR with CMJ asymmetry At post-test, no significant relationships were found between asymmetries and jumping performance	There are improvements in jump performances and reductions of asymmetries for all groups but mainly in the DVW group	Unilateral strength training programs were shown to substantially improve bilateral jumping performance
Murton et al, 2021	**Within-group:** Significant improvements for CMJ-H (moderate) and SJ-H (moderate) in TRT group Significant improvements for CMJ-PP (small) with a trend for improvement in CMJ-H (small) in FIT group **Between-group:** No statistically significant for all measures Greater improvements for CMJ-PF, CMJ-H, SJ-H and RSI in TRT group Greater improvements for SJ- PP in FIT group	There are improvements in jump performances for both groups but higher for TRT (traditional) training	TRT may be favourable to FIT. In well-trained youth male adolescent athletes, increases in lower-limb strength and power measures can occur within as little as four weeks following either TRT or FIT

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Nunez et al 2019	**Within-groups:** Substantially enhanced T10m and T20m in the CPG Substantially enhanced T10–20m and T20m in the CG **Between-groups:** At Pre-test no substantial differences in any of the variables with the lower limb power test At Pre-test substantially better T10m, T10–20m and T20m for CG than the CPG At Post-test in MPECC and ECC/CONrat substantially greater in CPG than CG	Improvements in sprint performance and lower limb power for the CPG group	Adding a weekly one-step acceleration exercise with a conical pulley device provides insufficient data for an improvement in the ability to sprint in 10m and 20m, compared to strength training with the use of sled training, full squats, and plyometric exercises
Gonzalo-Skok et al, 2022	**Within-groups:** Substantial improvements in CMJL, HJR, HJL, LSIHJ, LJL, LSILJ, 180CODR, 180CODL in both groups Substantial enhanced in CMJR, LSICMJ and 5m split time in the VUH group Substantially better LJR in VUL group **Between-groups:** Substantially better results for LSICMJ in VUH group than VUL group Substantially greater for LJR and LJL in VUL group than VUH group Possibly greater performance in CMJR and 5m split time in VUH group than VUL group	No substantially improved bilateral vertical jumping performance in any group Unilateral vertical jumping performance was substantially improved in both groups Lateral & horizontal unilateral jumps related to linear sprinting and COD performance VUH group achieved a substantial improvement in 5m Both training programs induced substantial improvements in COD 180º performance V-cut test was not substantially improved in any group	A specific force vector training program induced substantial improvements in both specific and non-specific inter-limb asymmetries and functional performance tests, although greater improvements of lateral and horizontal variables may depend on the specific force vector targeted
Stojanovic et al, 2021	**Within-groups:** Improvements for CMJ in FST, TST and CON group (very large, large and trivial effect size) Improvements for SPR5m in FST, TST and CON group (very large, moderate and moderate effect size) Improvements for T-Test in FST, TST and CON (very large, large and moderate effect size) **Between-groups:** No significant differences in pretest for any variable analyzed	Flywheel group displayed significantly higher improvements in strength, vertical jump, 5m sprint time and COD ability compared to the control group Neither training modality was proved	Eight weeks of flywheel training (1–2 sessions per week) induces superior improvements in CMJ, 5m sprint time

	Significant differences in CMJ between FST and TST group, FST and CON, CST and CON group Significant differences in SPR5m between FST and TST, FST and CON groups No significant differences in SPR5m between the TST and CON groups No significant differences for SPR20m Significant differences for T-Test between the FST and CON, TST and CON, FST and TST groups	effective for enhancing 20m sprint performance	and COD ability than an equivalent traditional weight training in well trained junior basketball players
Fiorilli et al, 2020	**Within-groups:** Significant differences for DJh, DJct, 7R-HOPh, SJh, ILL, YT, SPRINT and in SHOT No differences for DJRSI, 7R-HOPtc and 7R-HOPRSI **Between-groups:** Differences between groups in DJh, 7R-HOPh, SJh, ILL and SHOT Significant interactions in DJh, ILL, YT, SPRINT and SHOT No differences in DJct, DJRSI, 7R-HOPh, 7R-HOPtc, 7R-HOPRSI and SJh	FEO (Flywheel Eccentric Overload) group improved significantly Jumps, CODs & Sprint	Positive effect of Flywheel training showing greater improvements in these tests compared with the Plyometric training
Arede et al, 2020	**Within-groups:** Significant improvements for CMJ_L, CMJ_R, LJ_R, LJ_L, HJ_L, $SLRJ_L$, 0-10m in EOT Standard Significant improvements for CMJ_L, CMJ_R, $SLRJ_L$, $SLRJ_R$, T-Test in EOT Variable **Between-groups:** Differences for LJ_L favoring EOT Variable	EOT improved significantly Jumps, CODs & Sprint	The rotational flywheel training includes improvements
Raya-Gonzalez et al, 2021	**Within-groups:** Significant improvements for CMJ_d, CMJ_{nd}, COD (all metrics) and CODdef in EG group Improvementes for COD10d and CODdef10d in CG group **Between-groups:** Differences between groups in CMJ_d and CMJ_{nd} Differences for COD10d, COD10nd, CODdef10d, COD20nd, CODdef20d and CODdef20nd in favour of EG group No differences between groups in SPR10 and SPR30	EG improved significantly Jumps and CODs but no improvements in Sprint	One flywheel training session per week, over 10 weeks, can effectively enhance jump and COD performance without affecting reported well-being state in U16 elite soccer players in-season

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3.3.1. Power

Lower limb power was measured using a variety of tests including counter-movement jump (CMJ) unilateral and bilateral, single-leg horizontal jump (SLH), triple single-leg horizontal jump (TSLH), squat jump (SJ), drop jump (DJ), rebound jump (RJ), 7 repeated hop test (7R-HOP). CMJ was the most used functional test and only in one of the eight selected studies did not include a lower-limb power test, showing significant and substantial improvements in jump performances in the other 7 studies (from trivial to large effect size). However, Murton et al. 2021 showed greater results for the traditional training group than for the inertial training group.

3.3.2. Change of direction

5 of the total studies included tests to measure the change of direction ability. T-Test, Y-Agility Test, Illinois Test, V-Cut Test, 180º Test and 90º Test were mainly used, including a description of the protocol and set up in the articles. The heterogeneity of the test makes comparison difficult as to which is the best training to increase the performance. On the other hand, some studies showed significant improvements in change of direction ability for the inertial training group. In this regard, Arede et al. 2020 and Stojanovic et al. 2021 showed significant improvements in the T-Test (from moderate to very large effect size), Fiorilli et al. 2020 showed significant improvements in Illionois and the Y-Agility Test, Raya-González et al. 2021 showed significant improvements in all COD test and Gonzalo-Skok et al. 2022 showed substantial improvements in the 180º Test, whereas there was no effect in the V-Cut test.

3.3.3. Sprint

Sprint actions were evaluated in 6 studies, throughout several linear sprint tests with different distances (5m, 10m, 20m, 25m and 60m), thus a different stimulus for the athletes. Short distances are related to power and acceleration process whereas long distances are more focused on maximum speed. Nunez et al. 2019, Gonzalo-Skok et al. 2022, Arede et al. 2020 and Stojanovic et al. 2021 had significant improvements in sprint performance in short distances. Whereas Stojanovic et al. 2021 did not show inertial training as an effective way to enhance 20m sprint, Fiorilli et al. 2022, showed greater improvements in long distance sprints (60m linear sprint) and Raya-González et al. 2021 did not significatively improve sprint performance.

4. Discussion

Following a comprehensive literature search, the most recent studies that made an intervention with at least four weeks of training using inertial devices was analyzed to know how this methodology can help coaches and athletes to achieve enhancements. The primary findings suggest IT is a useful way to improve performance variables such as jumps, sprints or COD, although there are a few controversies in some studies.

In recent years, previous research has analysed the effect of IT in adult population [13,17,18,27–30] whereas it is not so common in youth athletes. The structural benefits from IT seem to be clear, such as improvements in strength also appear to occur alongside rapid structural and strength changes thus improving the morphological characteristic of athletes. ST programs which adequately load the lengthening phase of movement, called eccentric training, might induce superior neuromuscular adaptations (faster cortical activity, inversed motoneuron activity pattern, improved muscle-tendon unit morphology and structure) compared with traditional strength training [21].

IT has been shown previously to be useful for enhancing jumping ability, sprint and COD performance [30]. These findings support our study and the same findings have been observed in young athletes [21–23]. Previous studies have applied flywheel eccentric overload in the training of youth soccer players, showing significant improvements in body composition and both concentric and eccentric strength. Inertial devices could be a great tool to perform ST in young athletes because it is an easy way to work in different vectors [12] and it is not necessary to use weighted load given

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that this method is characterised for the use of their own force produced [7]. The better adaptations induced by IT are explained by the powerful stretch reflex produced in the eccentric-concentric transition, during flywheel resistance training.

Jumping performance is commonly used as a key indicator for lower-limb power and strength [28] and it is a usual action on team sports, in fact it plays a key role in performance on team sports, enhancement of high intensity actions such as jumps can be a determinant to achieve success in competition. In this sense IT have shown to be an effective tool to improve muscular power. Our findings are in line with previous research in the adult population, all the studies were analysed showed improvements in jump ability. Nevertheless, vector force and the specificity of the exercise is quite important [10], actually bilateral CMJ did not show significant improvement whereas unilateral and different vectors jump abilities were improved in studies which did not perform bilateral exercises [26]. This is also supported by previous authors who indicate that when multi-exercise programmes (including flywheel training) are implemented, no significant improvements in jump ability are seen [28]. On the other hand, Raya-González et al. 2021 suggest that improvement of jumping performance is explained by the nature of flywheel devices, with the squat being one of the most analysed exercises by literature due to the similarity with jump pattern. The similarity of the movement and the production of the stretch-shortening cycle may be related to the transition from eccentric to concentric phases during flywheel training, which could have a positive transfer to jumping performance [28]. In fact, Murton et al. 2021 [24], demonstrated that only four weeks are necessary to achieve enhancement in jump performance, a better way than traditional ST. According to our findings, improvements in jump ability show important improvements after IT protocols.

Sprint plays a key role in performance on team sports as well, a lot of successful actions are preceded for sprinting. In this case, the literature shows controversial results which is also supported by some of our findings displaying greater improvements in sprint [21–23,25], and other findings either not demonstrating improvements or showing little improvement in 5m linear sprint instead of 10m, 20m & 25m linear sprints [26]. These results could be explained for the volume of training. Gonzalo-Skok et al., 2022 performed one set, meanwhile Fiorilli et al., 2020 and Stojanović et al., 2021 [21,22] even performed four sets. On the other hand, Arede et al., 2020 [23] performed one set as well but their subjects has the additional stimulus of the regular soccer trainings where sprints are more habitual than basketball trainings. Moreover, Raya-González et al., 2021 [13] performed one weekly training session whereas the rest of the studies had a minimum of two training sessions per week. The training volume can be relevant to improve sprint performance in youth athletes. For achieving enhancements in sprint athletes, there needs to be an adequate volume per week, but more studies are necessary to know the volume for improving sprint performance.

CODs are commonly performed as well in many situations during competition on team sports [31]. During COD an athlete needs a great SSC because the ability to generate an eccentric force to rapidly decelerate and concentric strength to accelerate in a new direction [22]. Indeed, Flywheel devices have been utilised to replicate similar movement patterns and transition from eccentric to concentric phases, which are believed to be particularly beneficial for improving change of direction results [28]. Resistance programs which incorporate flywheel exercises are one of the most effective methods for improving sport-specific performance in sporting populations [13]. The results of the reviewed studies with younger athletes suggest the same conclusions as previous literature in adult athletes. In fact, a weekly training session may be enough for improving COD in elite young soccer players [13]. Flywheel training appears to improve performance by reducing braking time and enhancing braking impulse during COD movements [28]. This better exploitation of the SSC may have allowed a greater training stimulus to occur over time, resulting in improved cutting performance [23]. IT has shown improvements in CODs performance in the youth athlete population. On the other hand, another important enhancement which play a key role in sports were found such as shoot [22] or asymmetry lower limbs [20], as an indicator of injury risk.

Between-study differences might be due to the training volume performed, the season moment, or the participants' training experience/age [26]. To optimize training outcomes, it is recommended practitioners individualize (i.e., create inertia-power or inertia-velocity profiles) and periodize flywheel training using the latest guidelines [28].

Finally, our systematic research supports the use of IT as a great tool for improving jump, sprint and COD performance in youth athletes. Coaches can take advantage from benefits of this training methodology combining strength training and specific training on the pitch. Two session per week could be enough to achieve enhancements. At least 2-3 exercises and 2-3 sets per exercise should be necessary to improve young athletes. However, some limitations were found in this study, including the tests used to analyse were not exactly the same and the level of athletes was different. It would be interesting with new research to clarify an adequate volume to achieve improvements in sprint performance.

5. Conclusions

This systematic review analysed eight studies with an IT intervention and the effects on jump, sprint and CODs performance pre and post-test on youth athletes. In our review, we support the usefulness of rotational inertial devices for enhancing the ability of players in high intensity action such as jumps, sprint and CODs, however future research is needed to determine the adequate volume to develop sprint performance.

The results of our study showed that IT can be a useful tool to improve important abilities in team sports performance in young athletes like jumps, change of direction or sprints. From our point of view and based on our findings, the direction, the volume and laterality (bilateral or single strength) of the exercise has an impact in test performance. For this reason, the methodology of training is quite important to achieve enhancements, the selection of exercises, volume and load play a key role in the variables that we want to improve.

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