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Chronic Effects of Eccentric-Overload Training with Inertial Devices 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 the last years and one of the objects of study in recent literature, however more studies are necessary to know its usefulness in young athletes. The aim of the current systematic review is to evaluate the current literature surrounding the chronic effect of inertial training on physical capacities of team sports through functional test. This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA). The results revealed the effectiveness of these tools for improving abilities such jumps, sprints, change of directions and power measure. In conclusion, inertial training can be an adequate stimulus for the better 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 like 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 the last years, the eccentric overload training (EOT) has become in a popular method for athlete population due to the benefits in athletic performance in youth athletes as well (5) and Inertial Training (IT) is probably the most used to achieve eccentric overload besides it is known his capability to stimulate the Stretching-shortening cycle (SSC) (6,7). The eccentric (ECC) phase of the muscle action have emerged as an alternative method that may produce greater muscle adaptations (8). Rotational inertial devices like Flywheel or Pulley Conic are increasing his popularity recently. Although these devices were created in 1994 for reducing the atrophy in the astronauts in spaces (9), it has 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 use free weight exercise (6). All this makes EOT has been extensively studied in the scientific literature (8). Some researchers have suggested that this eccentric overload provides a great mechanical 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 (10). Resistance programs which incorporate flywheel exercises are one of the most effective methods for improving sport-specific performance in sporting populations (11). However, optimization of resistance training using a strictly EOT regime is rather complex and technically difficult to apply (8), several authors have reported the need to apply certain strategies, such as to provide instructions that encourage the participants to delay the braking action to the last third of the ECC phase (7). Therefore, the aim of the current systematic review is to evaluate the current literature surrounding the chronic effect of inertial training (flywheel or conic-pulley) on physical capacities of team sports through functional test in young athletes.

2. Materials and Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA) (12).

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 researcher to introduce the topic and make the discussion. Only full-text articles from peer-reviewed studies written in English or Spanish were included.

The search included the following keywords collected through expert's 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 is needed to be collected through at least a specific functional test such 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).

Studies that didn´t 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, questionaries… or studies where inertial devices are only used for testing instead of training. Intervention duration less than four weeks was a reason to exclude a study.

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 (i.g. 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 test (i.g. CMJ, COD, sprint…)
Article type	Peer-reviewed publication
Article language	English or Spanish

2.3. Study selection

Firstly, in order to avoid duplicates, a first filter was carried out because there is usually approximately a 46.9% coincidence (13). 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 (κ = 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.

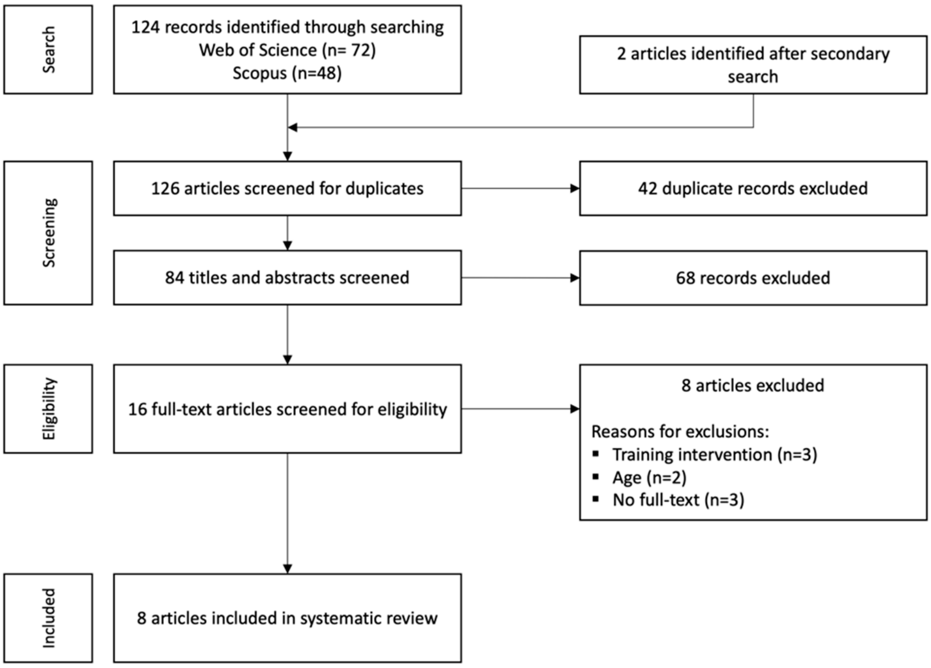

Figure 1. Study selection process.

2.4. Quality Assessment

Preventing the risk of bias and providing quality assessment of research are critical factors for a systematic review (14). 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 (15,16).

Consequently, following Allen et al. (15), who use methods similar to Brughelli et al. (17), 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 research (15) have proposed three different levels: high quality (score >15), moderate quality (score 10-15), low quality (score <10). In the same way than 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), being values ranged 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 sources 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 (18–21), whereas Athletes from elite academies were recruited in other four studies (11,18,22,23).

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

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3.2. Intervention

Intervention characteristics is 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 less week of intervention (4-8) had twice sessions per week, whereas the longest studies (9-10 weeks) had only once. Studies utilised several inertial devices, being the Conical Pulley – VersaPulley used in 3 interventions (18,23,24), K-Box in 2 studies (11,22) and Flywheel D1 Desmotec (19), Flyconpower conical machine (20) and Ecconomy Byomedic (21) in one study each one, being the inertial load highly different for every device. The prescribed training volume ranged from one to five sets of 6 to 10 repetitions, being gradually increased every 1-2 weeks in 5 studies (11,18,19,22,24) and keeping the same load in 3 studies (20,21,23). Regarding exercises used during intervention protocols, a huge variety of exercises were used like 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, being backward lunges and lateral squat the most used.

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
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, Desmo-tec)	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 Shoot-ing)
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) 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	K-Box 4 (ExxentricTM, Sweden)	0.025 kg/m2	CMJ (Countermovement Jump) 10m linear sprint test 20m linear sprint test 30m linear sprint test COD10 (5+5m) COD20 (10+10m) COD90 (90º)

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3.3. Outcome Measures

Functional test and outcome measures were presented in Table 4 and Table 5 respectively.

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 asymetries for all groups but mainly in 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	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

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Authors	Results	Results Summary	Conclusions
	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		measures can occur within as litte as four weeks following either TRT or FIT
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 using a conical pulley device, 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	A specific force vector training program induced substantial improvements in both specific and nonspecific inter-limb asymmetries and functional performance tests, although greater improvements of lateral and horizontal variables may depend on the specific force vector targeted

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		V-cut test was not substantially improved in any group	

Authors	Results	Results Summary	Conclusions
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 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	Flywheel group displayed significantly higher improvements in strength, vertical jump, 5m sprint time and COD ability compared to control group Neither training modality was proved effective for enhancing 20m sprint performance	Eight weeks of flywheel training (1–2 sessions per week) induces superior improvements in CMJ, 5m sprint time and COD ability than equivolumed 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 significativily Jumps, CODs & Sprint	Positive effect of Flywheel training that tends to have greater improvements in these tests compared with the Plyometric training

| Authors | Results | Results Summary | Conclusions |

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 significativily 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 significativily 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 like 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 repetated hop test (7R-HOP). CMJ was the most used functional test and only in one of the eight selected studies was not included a lower-limb power test, showing significant and substantial improvements in jump performances in the rest of 7 studies (from trivial to large effect size). However, Murton et al. 2021 (22) 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. Mainly, there were been utilized T-Test, Y-Agility Test, Illinois Test, V-Cut Test, 180º Test, 90º Test, including a description of the protocol and set up in the papers. The heterogeneity of the test makes difficult to compare which is the best training to increase the performance. Anyway, 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 T-Test (from moderate to very large effect size), Fiorilli et al. 2020 significant improvements in Illionois and Y-Agility Test, Raya-González et al. 2021 significant improvements in all COD test and Gonzalo-Skok et al. 2022 showed substantial improvements in 180º Test whereas there was not any effect in 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), being totally different stimulus for the athletes. Short distances are related with power and acceleration process whereas long distances are more focused in max 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 showed 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 improved significatively sprint performance.

4. Discussion

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. Following a comprehensive literature search, the most recent studies what made an intervention 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 jumps, sprints or COD although there is smalls controversy in some test.

Previous researches were being popular in the last years to analyze the effect of IT in adult population (11,15,16,25–28) whereas it is not so common in youth athletes. The structural benefits from IT seem to be clear, such improvements in strength also appear to occur alongside rapid changes in pennation angle, fascicle length, alterations in muscle morphology and to the length-tension (26), 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 (19). IT is useful for enhancing jumping ability, sprint and COD performance (28), these findings support our study and the same findings have been observed in young athletes (19–21). 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 (20). Inertial devices could be a great tool to perform ST in young athletes because it is an easy way to work in different vectors (10) and it is not necessary use weighted load given that this method is characterized for the use of their own force produced (6). The better adaptations induced by IT are explained by the powerful stretch reflex produced in the eccentric-concentric transition, during flywheel resistance training (20).

Jumping performance is often utilized as a key indicator for lower-limb power, strength and physical ability with both healthy and athletic populations (26), in this sense IT have shown to be an effective tool to improve muscular power (28), key in the enhancement of intensity sports action as jump. Our findings are in line with previous researches in adult population, all the studies were analyzed showed improvements in jump ability. Nevertheless, vector force and the specificity of the exercise is quite important, actually bilateral CMJ did not show significant improvement meanwhile unilateral and different vectors jump abilities were improved (24). That is also supported by previous authors who indicate when multi-exercise programs (including flywheel training) were implemented, no significant improvements in jump ability were seen (26). On the other hand, Raya-González et al. 2021 (28) suggest that improvement of jumping performance is explained by the nature of flywheel devices, being Squat one of the most analyzed exercises by literature because the similarity with jump pattern. Improvements in energy production and storage during 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 (26). In fact, Murton et al. 2021 (22), demonstrated that only four weeks are necessary to achieve enhancement in jump performance, being better way than traditional ST.

Sprint is an important action on team sports, in this case the literature shows controversial (26) and that is also a support for our findings referring greater improvements in sprint (19–21,23), whereas some studies did not demonstrate improvements (28) or just improvements in 5 m linear sprint instead of 10m, 20m & 25 m linear sprints (24). These results could be explained for the volume of training. Gonzalo-Skok et al., 2022 (24) performed one set, meanwhile Fiorilli et al., 2020 and Stojanović et al., 2021 (19,20) even performed four sets. On the other hand, Arede et al., 2020 (21) performed one set as well but their subjects keep training regular soccer trainings where sprints are more reproducible than basketball trainings. Moreover, Raya-González et al., 2021 (11) performed one weekly training session whereas the rest of studies made two training sessions per week at least. The training volume can be relevant to improve sprint performance in youth athletes.

CODs are commonly performed as well in many situations during competition on team sports (29). During COD an athlete needs eccentric force to rapidly decelerate and concentric strength to accelerate in a new direction (20). Flywheel devices have been utilized to replicate similar movement patterns and transition from eccentric to concentric phases, which are believed to be particularly beneficial for enhancing change of direction outcomes (26). Resistance programs which incorporate flywheel exercises are one of the most effective methods for improving sport-specific performance in sporting populations (11). The results of the reviewed studies with younger athletes suggest the same conclusions than previous literature in adult athletes. In fact, only a weekly training session may be enough for improving COD in elite young soccer players (11). Flywheel training appears to improve performance by reducing braking time and enhancing braking impulse during COD movements (26). This better exploitation of the SSC may have allowed a greater training stimulus to occur over time, resulting in improved sprinting, jumping, and cutting performance (21).

Improvements in jump ability, sprint and COD are not the only ones in our findings, another important enhancement which play a key role in sports were found such shot (20) or asymmetry lower limbs (18).

Between-study differences might be due to the training volume performed, the season moment, or the participants' training experience/age (24). 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 (26).

5. Conclusions

The results of our study showed that IT can be a useful tool to improve important abilities in team sports performance in young athletes. The methodology of training is quite important to get enhancements, the selection of exercises, volume and load play a key role in the variables that we want to improve.

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