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Effects of plyometric and directional training on speed and jump performance in elite youth soccer players.

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Soccer players perform approximately 1350 activities (every 4-6 s), such as accelerations/decelerations, and changes of direction (COD) during matches. It is well established that COD and plyometric training have a positive impact on fitness parameters in football players. This study analyzed the effect of a complex COD and plyometric protocol (CODJ-G) compared to an isolated COD protocol (COD-G) training on elite football players. A randomized pre-post parallel group trial was used in this study. Twenty-one youth players were enrolled in this study (mean ± SDs; age 17 ± 0.8 years, weight 70.1 ± 6.4 kg, height 177.4 ± 6.2 cm). Players were randomized into two different groups: CODJ-G (n = 11) and COD-G (n = 10), training frequency of 2 times a week over 6 weeks. Sprint 10, 30 and 40 m, long jump, triple hop jump, as well as 505 COD test were considered. Exercise-induced within-group changes in performance for both CODJ-G and COD-G: long jump (effect size (ES) = 0.32 and ES = 0.26, respectively), sprint 10 m (ES = -0.51 and ES = -0.22 respectively), after 6 weeks of training. Moreover, CODJ-G reported substantially better results (between-group changes) in long jump test (ES = 0.32). In conclusion, this study showed that short-term protocols (CODJ-G and COD-G) are important and able to give meaningful improvements on power and speed parameters in a specific soccer population. CODJ-G showed a larger effect in sprint and jump parameters compared to COD-G after the training protocol. This study offers important implications for designing COD and jumps training in elite soccer.

Keywords: football, sprint, jumps.

Introduction

Soccer is characterized by an intermittent-activity profile with metabolic contributions from both the aerobic and anaerobic systems (22). Players cover distances of 10–13 km during matches and perform approximately 1350 activities (every 4-6 s), such as accelerations/decelerations, changes of direction (COD) and jumps, all of which are interspersed with short recovery periods (21). Therefore, the capacity to perform quick and powerful movements in soccer, as well as in other team sports is one of the most important abilities to acquire to improve performance (6,20,31).

A popular and an effective way for improving power and sprint performance is plyometric training (17). Plyometric exercises are a specific training methodology largely supported by scientific literature (17,24,30). Such a methodology is a widespread form of physical conditioning that involves jumping exercises using the stretch-shortening cycle (SSC) muscle action (17). SSC can be summarized as an enhancement of the ability of the neural and musculotendinous systems to produce maximal force in the shortest amount of time (28). Literature reports positive effects on explosive power associated with improved performance of the vertical jump, agility and sprint performance after plyometric training (24,28,30). A recent systematic review reported that plyometric training produced a relative increase in muscle power in 13 out of the 16 studies analyzed, and these positive effects ranged between 2.4% and 31.3% (17). Moreover, the combination of high-intensity unilateral and bilateral jump drills seems advantageous to induce significant performance improvements also in short-term (<8 weeks) (17,28).

Players who require power and strength for moving in the horizontal plane mainly engage in bounding plyometric exercises (e.g. multiple jumps), as well as high-impact plyometric exercises (e.g. drop jumps) (11,14,17). Especially, rebounding exercises showed higher neuromuscular activation, greater force and power (twofold increases in eccentric muscular activity) than no rebounding exercises (14,24,28). Eccentric muscular activations play a paramount role during the SSC, and such mechanism is a key component also during soccer-specific actions such as COD, short shuttle runs and sprint activities (17,24,28). It is already reported in the literature that athletes accustomed to performing COD and short shuttle runs become more economical during such specific actions (7,8,25,31). Therefore, including specific COD exercises in a training program can elicit greater developments in fitness components associated with neuromuscular factors (such as sprint and jumps) (13,17,32). Moreover, combined training programs including linear speed drills, COD, and jumps, seem to provide better results than a single-component training (e.g. COD protocol) in in young and senior athletes' performance (17,30).

As documented in literature, the duration of the training protocol (e.g. greater effects with long training duration), period of the season (e.g. larger fitness variations are reported in pre-season compared to in-season), and players' level (e.g. amateurs report larger adaptation following specific soccer activities than elite players) are key points associated with the training effectiveness (5,7,18). However, despite the popularity and wide appeal of soccer, as well as COD and plyometric training attractiveness, few studies published used randomized trial designs involving elite young soccer players during the official competitive season. Moreover, as reported by Markovic (17), several studies have analyzed the plyometric effect with a training frequency of 2-3 times a week, while few provide evidence that support less frequent training such as one time a week. Another reason because it is important to evaluate the effect of a single plyometric session a week is associated with the awareness that elite teams are involved in several tournaments (e.g. national and international) and travels during the season, and this is a challenging situation for the coaches (27).

Currently, the evidences about short-term (<8 weeks) training effects are very limited in the scientific literature in both plyometric and directional training using elite young players during the competitive season (1,26). Moreover, the effect of a single plyometric session a week when combined with COD training is not well known. Therefore, the aim of this study was to assess the effects of a COD and a complex COD and jumps protocol with a duration of 6 weeks in young elite soccer players.

Methods

Participants

Twenty-three youth soccer players (elite academy, Switzerland) were considered during the enrollment process. Two players were excluded because they did not meet the inclusion criteria (goalkeepers were excluded). Therefore, twenty-one participants were included in the current study (mean ± SDs; age 17 ± 0.8 years, weight 70.1 ± 6.4 kg, height 177.4 ± 6.2 cm, fat mass = 10 ± 3%). All participants were informed about the potential risks and benefits of the study and signed an informed consent (parental consent has been given). The Ethics Committee of the Department of Science and Technology, University of Suffolk (UK) approved this study. All procedures were conducted according to the Declaration of Helsinki for human studies. No economic incentives were provided.

Please, figure 1 here

Design and training protocol

The design of this study was a randomized pre-post parallel group trial. The randomization was performed according to a computer-generated sequence. The participants were randomized into a complex change of directions and jump training group (CODJ-G = 11 participants) and into a COD training group (COD-G = 10 participants). Nineteen participants completed the study (from February to March 2017), while two participants of COD-G dropped out due to injuries (fracture clavicle and foot) not associated with the protocol. CONSORT participant flow is reported in figure 1 (19).

In this study, the design selected (pre-post parallel group trial) did not involve a control group. Considering players' level, period of the season, proximity to international tournaments, and the necessity of elite players to maximize their performance for the next competitions, authors took the decision to randomized the sample in two training groups (COD-G and CODJ-G) without any control group. Authors considered the utilization of a control group, in such circumstances, as an unethical approach because it could have decreased the players' performance and impacted the clubs success in the wider fixture programme. This approach is largely used in clinical trials when an existing treatment that has already been demonstrated to have efficacy exists. Under these circumstance it is more appropriate to evaluate the superiority of a proposed new treatment versus a previous one than to compare a new treatment versus a control (16). Therefore, the aim of this study was to assess the effects (within and between) of a COD and a complex COD and jumps protocol with a duration of 6 weeks in young elite players.

The duration of this study was 8 weeks. Training protocol, as well as the baseline tests and post-training assessments, were performed between two international U18 soccer-tournaments. Squad participation of both international tournament was considered a priority from technical and sports science staff. Researchers chose to plan this protocol duration (6 weeks intervention) to avoid any interference associated with these tournaments (a possible confounding factor).

Players performed the same training throughout the season until the beginning of the study. Baseline test were performed before the beginning of the protocol (week 1). After 6 weeks training, both the groups replicated the baseline tests (week 8). Long-jump test was utilized to evaluate improvement of horizontal non-rebounding ability (players' isolated explosive strength abilities of the leg muscles). Triple hop distance test (triple hop test) was performed with both the legs (left and right) to evaluate improvement in rebounding jump ability

Players were asked to avoid any heavy physical activity on the day prior to testing and to refrain from caffeine 8 hours before testing. Players were familiarized to the following test battery because it was part of the fitness test routine of the club,. As a consequence of the frequent performance of these tests no additional familiarization was included before the baseline and follow-up evaluation.

COD-G performed 2 times per week a protocol of short shuttle runs and sprints with COD with different angles such as 45°, 90° and 180°. In detail, they performed 3/4 sets of 3 short shuttle runs with 4 COD each, for an amount of 36 COD and 48 COD on Monday and Wednesday, respectively. CODJ-G performed the same number and type of COD but combined with a specific plyometric training (36 COD and 60 jumps) and 48 COD on Monday and Wednesday, respectively. COD ability refers (in this protocol) to a movement where no immediate reaction to a stimulus is required, so the direction change is pre-planned, while agility requires external and perceived stimuli prior to any direction change (3,15,29). Plyometric training consisted of 4 x 5 drop jumps from 60 cm high followed by a subsequent jump over an obstacle (15 cm height), as well as 4 x 5 jumps over obstacles of 15 cm height. Authors manipulated the two training protocols a priori, where COD-G performed a specific training that only involved COD (twice a week), while CODJ-G performed the same amount of COD with an additional plyometric volume (COD and plyometric training twice and once a week, respectively). Therefore, CODJ-G performed a higher training volume than COD-G in this study. Every training session was preceded with a 20-minutes standardized warm-up composed by aerobic running, dynamic stretching, as well as technical exercises. All the training sessions were performed at the same time (3.00 pm). Researchers asked both groups to maintain their normal lifestyle and nutrition behaviors throughout the duration of the protocol. During this study, the team performed 4 training session a week as team practices as well as an official match every Saturday, while Sunday was a day off. Internal training load was evaluated by ratings of perceived exertions (RPE-10) after all the training sessions to evaluate possible differences in training load (2).

Before test evaluation, a standardized warm-up (15 minutes) was conducted by the fitness coach of the team. The participants replicated the same test 3 times, with an adequate recovery among the trials and the peak score in every test was set in the data analysis. The operators fixed a standard cloth tape measure to the ground, perpendicular to a starting line. The participants stood on the designated testing leg, with the great toe on the starting line (10). Long jump test was utilized to evaluate improvement of horizontal non-rebounding ability (players' isolated explosive strength abilities of the leg muscles). Triple hop distance test (triple hop test) was performed with both the legs (left and right) to evaluate improvement in rebounding jump ability (10). Players performed 3 consecutive maximal hops forward on the same limb. Arm swing was allowed. The investigators measured the distance hopped from the starting line to the point where the heel struck the ground upon completing the third hop. The validity of this test, as well as its reliability (intraclass correlation coefficient = 0.98), has been shown previously (10), and is in agreement with what established in our study (intraclass correlation coefficient = 0.95). Sprint 10, 30 and 40 m were performed to evaluate players' improvements in short-sprint ability. For this purpose, infrared timing gates (Microgate, Bolzano, Italy) were placed at the start and the end of the designed running track (on the soccer field). Tests started from a standing position, with the front foot 0.2 m from the first photocell beam. 505 COD test was utilized to evaluate improvement in the change of direction ability (25). On the "Go" command, the subjects were instructed to sprint for 15 m (through the timing gates at 10 m), turn on their preferred foot, and sprint back through the timing gates. The validity and specifically of this test was proved previously in football (25). 505 COD test is a highly reliable assessment with a coefficient of variation of 2.8%. For the motivation reported by Stewart (25), no additional COD tests were added to this protocol.

Body fat estimation was determined using a skinfold-based method (skinfold calibre, Gima S.p.A., MI, Italy). Skinfolds were measured in seven different sites: triceps, subscapular, midaxillary, chest, supra iliac, abdomen, and anterior thigh. Body weight and height were recorded by Stadiometer (Seca, Italy). The measures were obtained three times using the average value for the analysis.

Statistical analysis

Shapiro-Wilk test was used for checking the normality (assumption). Data were presented as mean ± standard deviation (SD). Outcomes were expressed as value, with 90% confidence interval (CI). Analysis of covariance (ANCOVA), using baseline values as covariate, was employed to detect possible between-groups differences after training (12). Threshold values for benefit or harmful effect was evaluated based on the smallest worthwhile change (0.2 multiplied by the between-subjects SD) (12). Effect size (ES) based on the Cohen d principle was interpreted as trivial <0.2, small 0.2-0.6, moderate 0.6-1.2, large 1.2-2.0, very large >2.0 (12). Data were analyzed for mechanistic (practical) significance using magnitude-based inferences (within and between interaction) (12). Quantitative chances of beneficial or detrimental effect were assessed qualitatively as follows: <1%, almost certainly not; >1% to 5%, very unlikely; >5% to 25%, unlikely; >25% to 75%, possible;

>75% to 95%, likely; >95% to 99%, very likely; and >99%, almost certainly (12). If the chance of having beneficial or detrimental performances was >5%, the true difference was considered unclear. A traditional approach based on the null hypothesis and P-value was not reported in this study (12). This approach, as well as its advantages have been previously explained (4). Statistical analyses were performed by SPSS software version 20 for Windows 7, Chicago, USA.

Results

Please figure 2 here.

CODJ-G and COD-G had the following characteristics: mean ± SDs; age 17 ± 0.8 years, weight 69.2 ± 6.1 kg, height 175.2 ± 5.9 cm, fat mass = 10 ± 3%, and age 17 ± 1.0 years, weight 71.3 ± 6.8 kg, height 178.6 ± 6.5 cm, fat mass = 10 ± 4%, respectfully.

A compliance of 93% and 96% for CODJ-G and COD-G, respectively, was reported at the end of this study. The average RPE was 5.5 ± 0.99 and 5.50 ± 1 for CODJ-G and COD-G, respectively.

Exercise-induced changes in performance for both COD-G and CODJ-G after 6 weeks of training. Within-group changes for CODJ-G and COD-G are reported in Tables 1 and 2, respectively.

After 6 weeks of training, CODJ-G reported substantially better results in long jump test (ES = 0.32 (small), [CL90% -0.05;0.69], with chances for beneficial, trivial, detrimental performance of 71/27/2%) than COD-G. All the other tests did not report any substantial variation between groups after the protocol. Forest plot with between-groups standardized changes is reported in figure 2.

Table 1 here.

Discussion

The aim of this study was to examine the effect of a short-term COD and combined COD-J protocol in elite youth soccer players in season. As hypothesized, after 6 weeks of training, meaningful within-group differences were found, with positive effects for CODJ-G in all the jump tests (small ES), as well as for 10, 30 and 40 m sprint tests. COD-G reported positive improvements in long jump and 10 m sprint (small ES). This study supports previous findings that even short-term (<8 weeks) protocols are able to give some meaningful improvements in jump and speed parameters in elite soccer players. Moreover, this study showed that is slightly more beneficial to combine different plyometric modalities (vertical and horizontal jumps) with COD than use only a single training modality in isolation (COD).

The protocols proposed in the current study used a training frequency of two sessions a week that seems a sufficient stimulus to improve power parameters in young players. These meaningful adaptations in jump and sprint performance by COD and plyometric training programs might be primarily associated (considering the short-term protocol proposed) with neural adaptations (e.g. motor unit recruitment strategy, and Hoffman reflex) (11,17). Neural adaptations are associated with improvement in maximal voluntary contraction, inter-muscular coordination, stretch reflex excitability, as well as changes in leg muscle activation strategies (17). Eccentric-emphasized exercise can elicit acute responses which differ from concentric-only exercise, therefore a combination of COD and plyometric training, which using the SSC muscle action, can produce higher force level during lengthening contractions (above isometric force capabilities), thus offering larger benefit than traditional exercises (9).

Specificity is a key pillar in training, therefore football drills should simulate the biomechanical and physiological demands of the sport (e.g. specific COD angles should be considered in the design of such drills) (3,32). Soccer players perform several COD, sprints and power type activities during a match involving decelerations, re-accelerations and constant adjustments of steps and body posture (20,23). Therefore, appropriate plyometric training, sprint and multi-directional exercises (mixed protocols) should provide benefits to power and sprint capacities (1,17,26,28,29).

A recent systematic review has analyzed 24 studies and suggests that plyometric training improves COD ability with a mean effect (ES) ranges from 0.26 to 2.8 (1). Our study supports the statements that plyometric training can improve power ability in football players such as 10, 30 and 40 m sprint, as well as long jump and triple hop test. However, the present study cannot prove a positive transfer on COD ability in football players because we have not found a meaningful improvement in 505 COD test (unclear effect). Such results are quite unexpected because both training protocols used COD exercises. A possible explanation about this unclear results could be associated with the dose-response principle (17). The little amount of COD and jumps, as proposed in this study, could have offered a small stimulus to players accustomed to this type of actions, while a heavier protocol could have offered larger benefits (32). Another motivation might be associated with the training level of our sample (elite players). It is well reported that athletes that practice a specific sport are accustomed to performing specific sport related actions, thus, they show higher movements economy than novices (31). Consequently, amateur players report larger benefits by specific training programs than elite athletes (7,17,31). Throughout the football season it is generally reported a fitness improvement in pre-season, with a subsequently stabilization of such fitness variables in-season (18). Consequently, higher benefits are expected (as well as they were reported) in trials performed during the pre-season compared to in-season, when it is harder to find large fitness variations (17,30).

As reported above, both CODJ-G and COD-G showed improvements in the post-training tests. Nevertheless, we have not found a significant between-group difference after the protocol except for long jump test that showed a positive effect (small ES) in favor of

CODJ-G (figure 2). This positive difference agrees with previous reports that found improvements in jump capacities, effect equivalent to 5.6% (range from 2.6% to 9.4%), subsequently a plyometric training (24). Contrariwise, all the other parameters showed trivial and unclear differences between the two groups. Therefore, this study showed a slightly better effect of combined COD-J training versus COD. However, this study cannot state with absolutely certainty that the complex training proposed, using an integration of COD and plyometric training, is more advantageous than a COD in isolation (also if it is plausible from a theoretical point of view) (24). These results, as well as the small effects reported, could be explained considering the short-term of the protocol (usually a training duration >8 weeks is requested), as well as, considering the small plyometric volume adopted (60 jumps a week) (17,32). The present study was designed a priori considering the period of the season and the sample characteristic (elite players), where the main aim of the team was to research the best fitness shape for the future matches and international competitions. The decision to develop a short-term training was chosen to satisfy the professional duties (based on the competitive calendar) of the players/team, and it is not considered a limitation by the authors (it is an ecological protocol).

This study has some limitations. The first limitation is associated with the small sample enrolled. A bigger sample could have offered a better view about the effect obtained by COD and CODJ protocols. A justification of such sample size is associated with the specificity of the population enrolled and with the restrictive access to elite youth players in season. The second limitation is gender related. We cannot speculate that our results can be extended to other specific populations (e.g. elite female players). Therefore, future studies should examine the effects of short-term training on senior male professional players as well as young and senior professional female players. The third limitation is associated with the design selected for this study. Authors compared two training protocols (COD-G and CODJ-

G) without the involvement of a control group. The randomized controlled trial is the gold standard design in science, though in clinical studies is common to design trials that compare an existing treatment versus a new one (superiority trial) (16). Therefore, for reasons associated with the sample involved, the proximity of international tournaments, and the necessity to maximize players' performance, the authors considered this type of design more suitable than a randomized controlled trial.

In conclusion this study supports previous findings that even short-term (<8 weeks) protocols are important and able to give some meaningful improvements in jump and speed parameters in elite soccer players (28,30). However, the observed changes reported in this study are less pronounced than in previous studies (1,17,30). The small effects reported could be explained taking into account the period of the season (protocol performed in season) and participant enrolled (elite soccer players) (17,30). Therefore, fitness coaches and sports scientists can propose both the protocols reported in this study with the awareness of this limitation (small effects).

Practical applications

This study offers several practical applications for strength and conditioning training in soccer. Both COD-G and complex CODJ-G are effective training modalities that get benefits in jump tests, as well as in 10, 30 and 40 m sprint tests for elite young soccer players. These protocols show that it is possible to have positive effects using a short protocol (6 weeks) also in season when usually it is harder to find meaningful effects. Fitness coaches and sports scientists can integrate their training proposals with the protocols described in this study. However, the observed changes reported are less pronounced than in previous studies with more frequent training and higher workload (dose-response effect).

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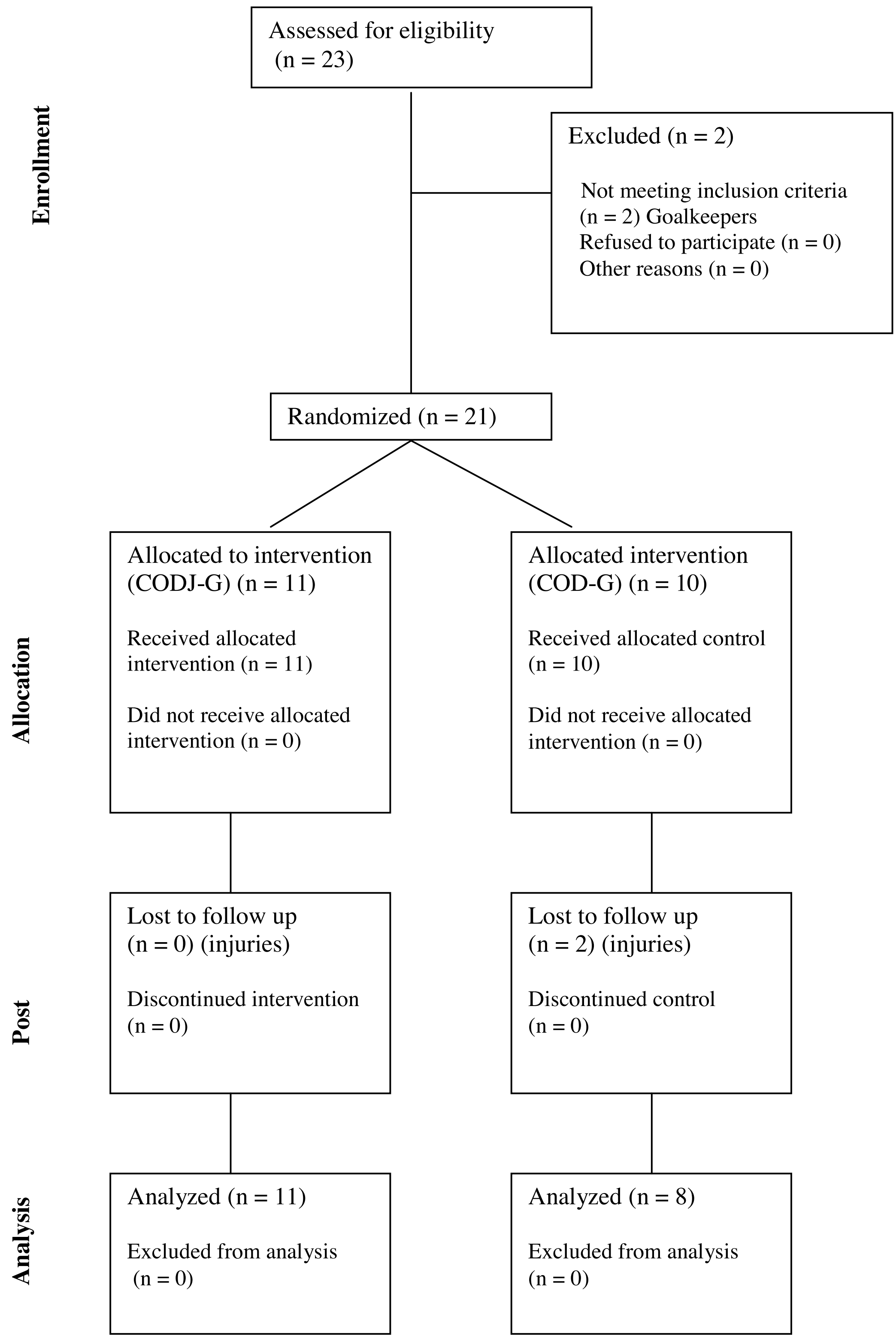
Table 1. Summary of baseline and follow-up data before and after 6 weeks of COD and jump training (CODJ-G, n = 11), and COD training (COD-G, n = 10). Data are presented in mean ± SDs.

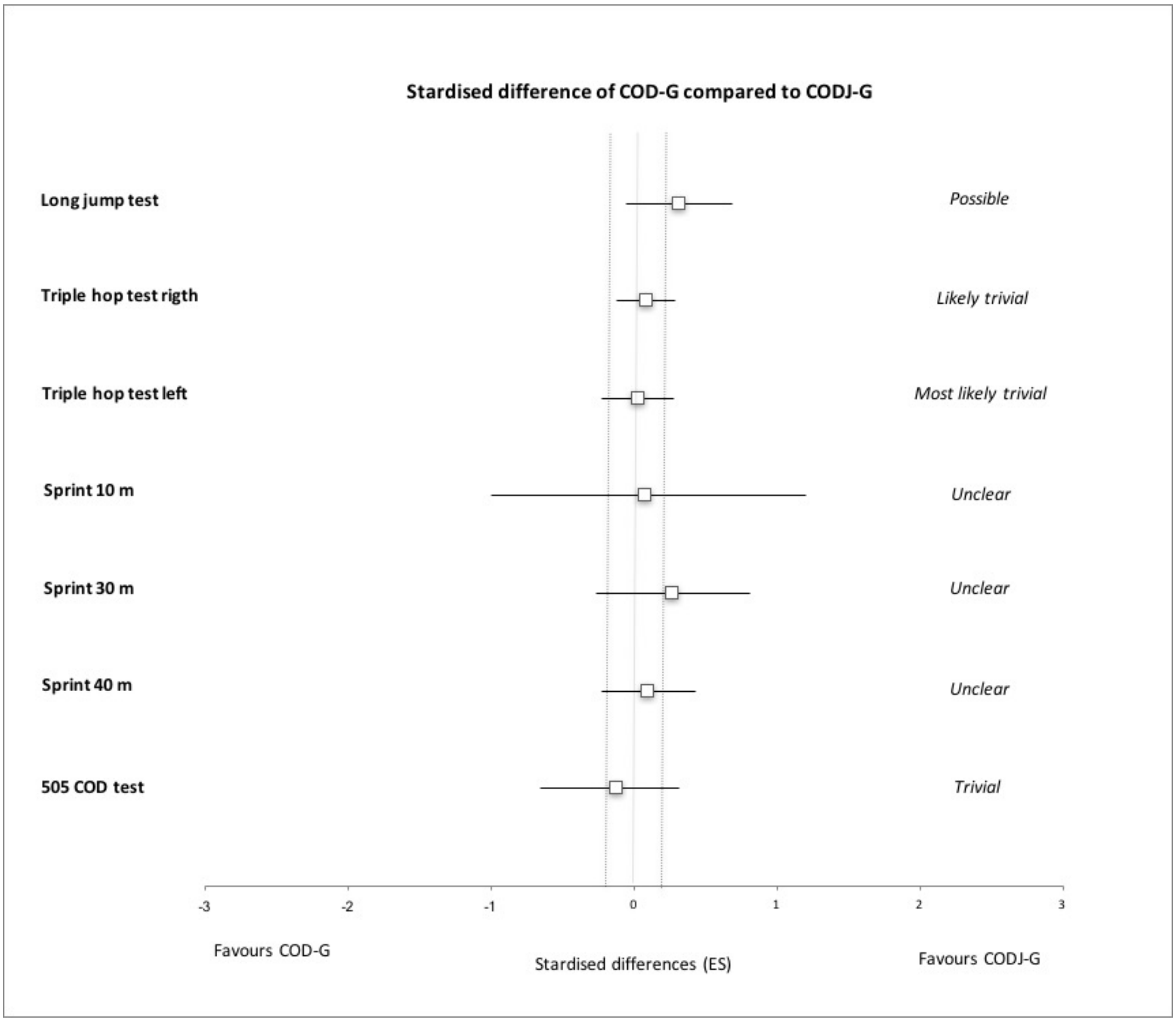
Variable	Baseline Mean ± SDs	Follow-up Mean ± SDs	Delta difference (90% CI)	Standardized difference (90% CI)	Chances of effect better/trivial/worse	Qualitative assessment
CODJ-G						
Long jump (cm)	2.35 ± 0.14	2.40 ± 0.14	0.05 (-0.06; 0.10)	0.36 (-0.05; 0.77)	75/23/2	Possible
Triple hop right (m)	6.82 ± 0.39	6.93 ± 0.52	0.10 (-0.03; 0.25)	0.25 (-0.08; 0.58)	61/37/2	Possible
Triple hop left (m)	6.94 ± 0.46	7.06 ± 0.52	0.11 (-0.05; 0.26)	0.24 (-0.11; 0.59)	58/39/3	Possible
Sprint 10 m (s)	1.82 ± 0.08	1.77 ± 0.09	-0.04 (-0.07; -0.02)	-0.51 (-0.84; -0.18)	94/6/0	Likely
Sprint 30 m (s)	4.29 ± 0.16	4.24 ± 0.14	-0.05 (-0.11; 0.02)	-0.29 (-0.72; 0.14)	64/33/3	Possible
Sprint 40 m (s)	5.48 ± 0.18	5.40 ± 0.24	-0.07 (-0.15; -0.01)	-0.37 (-0.73; -0.01)	79/20/1	Likely
505 COD test (s)	4.72 ± 0.13	4.73 ± 0.12	0.01 (-0.07; 0.08)	0.02 (-0.54; 0.58)	29/47/24	Unclear
COD-G						
Long jump (cm)	2.28 ± 0.14	2.32 ± 0.14	0.04 (-0.11; 0.90)	0.26 (-0.07; 0.60)	63/36/1	Possible
Triple hop right (m)	6.94 ± 0.44	6.96 ± 0.49	0.02 (-0.11; 0.16)	0.03 (-0.12; 0.18)	4/95/1	Very likely trivial

Triple hop left (m)	6.96 ± 0.46	7.04 ± 0.38	0.08 (-0.03; 0.18)	0.19 (-0.09; 0.47)	48/50/2	Trivial
Sprint 10 m (s)	1.86 ± 0.08	1.84 ± 0.09	-0.02 (-0.06; 0.01)	-0.22 (-0.52; 0.08)	55/44/1	Possible
Sprint 30 m (s)	4.38 ± 0.14	4.35 ± 0.17	-0.03 (-0.07; 0.01)	-0.18 (-0.42; 0.05)	44/55/1	Possible trivial
Sprint 40 m (s)	5.60 ± 0.18	5.56 ± 0.24	-0.04 (-0.08; 0.02)	-0.15 (-0.37; 0.07)	34/64/2	Possible trivial
505 COD test (s)	4.79 ± 0.13	4.79 ± 0.12	0 (-0.05; 0.06)	0 (-0.41; 0.5)	0/100/0	Very likely trivial

SDs = Standard deviations; CI = Confidence intervals; m = meters; s = seconds, COD = Change of directions.

Figure 1. CONSORT diagram showing the flow of participants through each stage of a randomized trial.




Stardised difference of COD-G compared to CODJ-G
Long jump test
Possible
Triple hop test rigth
Likely trivial
Triple hop test left
Most likely trivial
Sprint 10 m
Unclear
Sprint 30 m
Unclear
Sprint 40 m
Unclear
505 COD test
Trivial
-3
-2
-1
0
1
2
3
Favours COD-G
Stardised differences (ES)
Favours CODJ-G