Effects of Plyometric and Directional Training on Speed and Jump Performance in Elite Youth Soccer Players

Marco Beato,[1] Mattia Bianchi,[2] Giuseppe Coratella,[3] Michele Merlini,[4] and Barry Drust[5]

[1]*Department of Science and Technology, University of Suffolk, Ipswich, United Kingdom;* [2]*Department of Sports Science, Team Ticino AC, Tenero, Switzerland;* [3]*Department of Biomedical Sciences for Health, University of Milan, Milan, Italy;* [4]*School of Sport and Exercise Sciences, University of Kent, Chatham Maritime, United Kingdom; and* [5]*Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, United Kingdom*

Abstract

Beato, M, Bianchi, M, Coratella, G, Merlini, M, and Drust, B. Effects of plyometric and directional training on speed and jump performance in elite youth soccer players. *J Strength Cond Res* 32(2): 289–296, 2018—Soccer players perform approximately 1,350 activities (every 4–6 seconds), such as accelerations/decelerations and changes of direction (CODs) 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 with 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 ± *SD*; age 17 ± 0.8 years, mass 70.1 ± 6.4 kg, and height 177.4 ± 6.2 cm). Players were randomized into 2 different groups: CODJ-G ($n = 11$) and COD-G ($n = 10$), training frequency of 2 times a week more than 6 weeks. Sprint 10, 30, and 40 m, long jump, triple hop jump, and 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) and 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 with COD-G after the training protocol. This study offers important implications for designing COD and jumps training in elite soccer.

Key Words football, sprint, jumps

Address correspondence to Dr. Marco Beato, M.Beato@uos.ac.uk.

32(2)/289–296

Journal of Strength and Conditioning Research

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 1,350 activities (every 4–6 seconds), such as accelerations/decelerations, changes of direction (CODs) 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). Stretch-shortening cycle 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 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 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 preseason compared with in-season), and players' level (e.g., amateurs report larger adaptation after 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, whereas 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

Experimental Approach to the Problem

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 COD 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), whereas 2 participants of COD-G dropped out because of 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 randomize the sample in 2 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 program. This approach is largely used in clinical trials when an existing treatment that has already been demonstrated to have efficacy exists. Under these circumstances, 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.

Subjects

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, 21 participants were included in the current study (mean ± *SD*; age 17 ± 0.8 years, mass 70.1 ± 6.4 kg, height 177.4 ± 6.2 cm, and 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 (United Kingdom), approved this study. All procedures were conducted according to the Declaration of Helsinki for human studies. No economic incentives were provided.

Procedures

The duration of this study was 8 weeks. Training protocol, as well as the baseline tests and posttraining assessments, was performed between 2 international U18 soccer tournaments. Squad participation of both international tournaments 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 was 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 used to

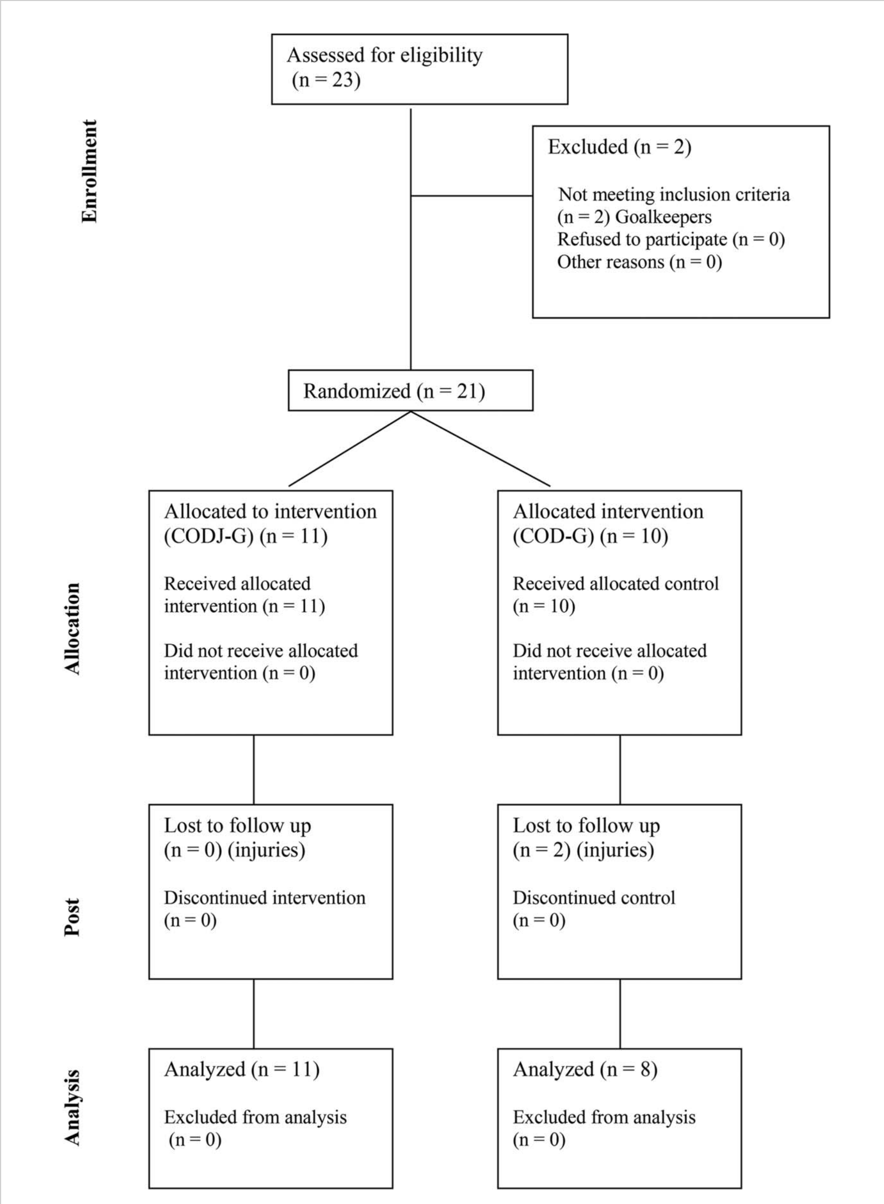

Figure 1. CONSORT diagram showing the flow of participants through each stage of a randomized trial.

evaluate improvement of horizontal nonrebounding 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 before 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. Change of direction ability refers (in this protocol) to a movement where no immediate reaction to a stimulus is required, so the direction change is preplanned, whereas agility requires external and perceived stimuli before any direction change (3,15,29). Plyometric training consisted of 4 × 5-drop jumps from 60-cm high followed by a subsequent jump over an obstacle (15-cm height) and 4 × 5-jumps over obstacles of 15-cm height. Authors manipulated the 2 training protocols a priori, where COD-G performed a specific training that only involved COD (twice a week), whereas 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-minute standardized warm-up composed by aerobic running, dynamic stretching, and 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 sessions a week as team practices and an official match every Saturday, whereas 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).

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, $n = 10$).*†

Variable	Baseline	Follow-up	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 to 0.10)	0.36 (−0.05 to 0.77)	75/23/2	Possible
Triple hop right (m)	6.82 ± 0.39	6.93 ± 0.52	0.10 (−0.03 to 0.25)	0.25 (−0.08 to 0.58)	61/37/2	Possible
Triple hop left (m)	6.94 ± 0.46	7.06 ± 0.52	0.11 (−0.05 to 0.26)	0.24 (−0.11 to 0.59)	58/39/3	Possible
Sprint 10 m (s)	1.82 ± 0.08	1.77 ± 0.09	−0.04 (−0.07 to −0.02)	−0.51 (−0.84 to −0.18)	94/6/0	Likely
Sprint 30 m (s)	4.29 ± 0.16	4.24 ± 0.14	−0.05 (−0.11 to 0.02)	−0.29 (−0.72 to 0.14)	64/33/3	Possible
Sprint 40 m (s)	5.48 ± 0.18	5.40 ± 0.24	−0.07 (−0.15 to −0.01)	−0.37 (−0.73 to −0.01)	79/20/1	Likely
505 COD test (s)	4.72 ± 0.13	4.73 ± 0.12	0.01 (−0.07 to 0.08)	0.02 (−0.54 to 0.58)	29/47/24	Unclear
COD-G						
Long jump (cm)	2.28 ± 0.14	2.32 ± 0.14	0.04 (−0.11 to 0.90)	0.26 (−0.07 to 0.60)	63/36/1	Possible
Triple hop right (m)	6.94 ± 0.44	6.96 ± 0.49	0.02 (−0.11 to 0.16)	0.03 (−0.12 to 0.18)	4/95/1	Very likely trivial
Triple hop left (m)	6.96 ± 0.46	7.04 ± 0.38	0.08 (−0.03 to 0.18)	0.19 (−0.09 to 0.47)	48/50/2	Trivial
Sprint 10 m (s)	1.86 ± 0.08	1.84 ± 0.09	−0.02 (−0.06 to 0.01)	−0.22 (−0.52 to 0.08)	55/44/1	Possible
Sprint 30 m (s)	4.38 ± 0.14	4.35 ± 0.17	−0.03 (−0.07 to 0.01)	−0.18 (−0.42 to 0.05)	44/55/1	Possible trivial
Sprint 40 m (s)	5.60 ± 0.18	5.56 ± 0.24	−0.04 (−0.08 to 0.02)	−0.15 (−0.37 to 0.07)	34/64/2	Possible trivial
505 COD test (s)	4.79 ± 0.13	4.79 ± 0.12	0 (−0.05 to 0.06)	0 (−0.41 to 0.5)	0/100/0	Very likely trivial

*CI = confidence interval; COD = change of direction.
†Data are presented in mean ± *SD*.

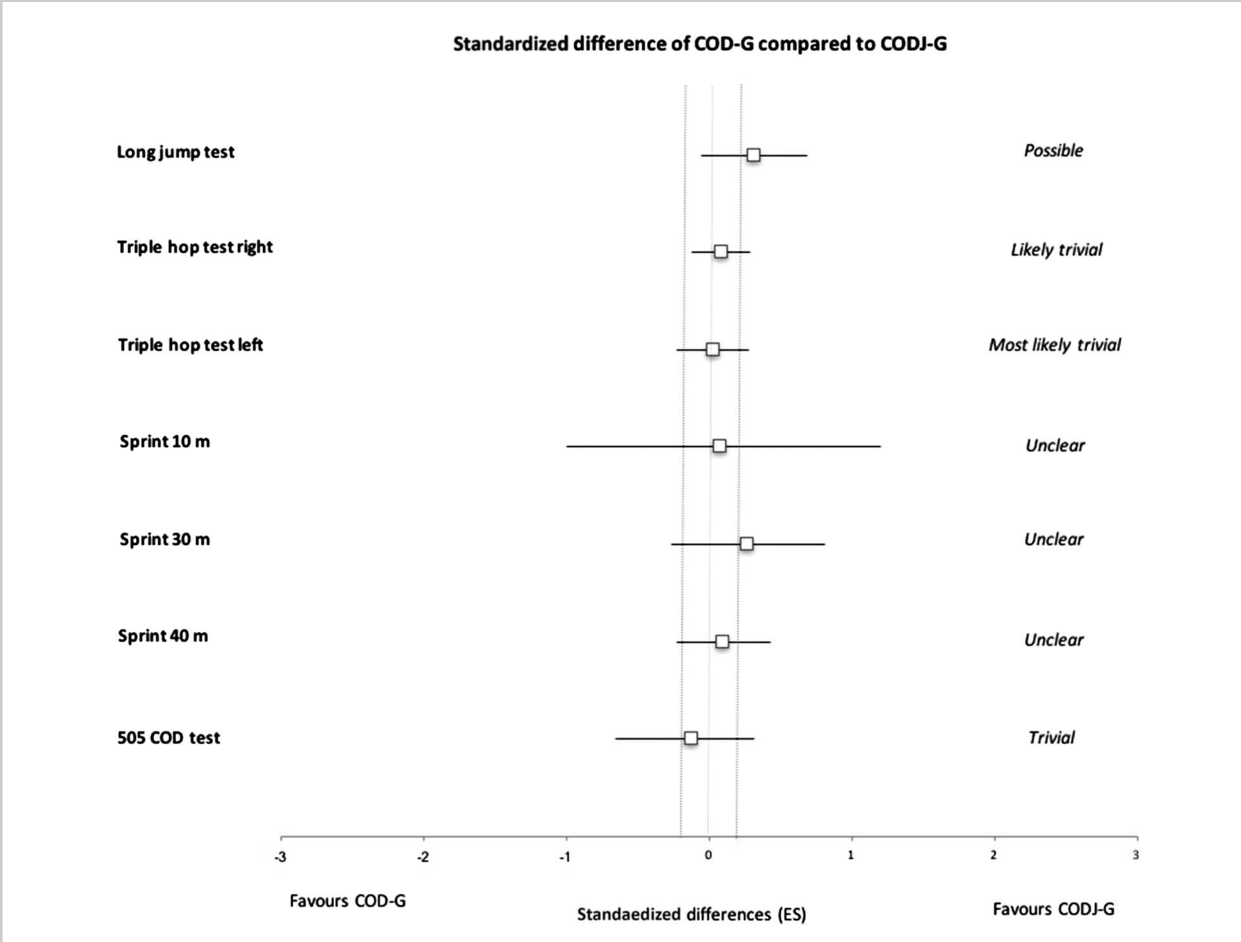

Figure 2. Standardized difference of COD-G compared with CODJ-G.

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 used to evaluate improvement of horizontal nonrebounding 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 on 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 used to evaluate improvement in the COD 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., Milan, Italy). Skinfolds were measured in 7 different sites: triceps, subscapular, midaxillary, chest, suprailiac, abdomen, and anterior thigh. Body weight and height were recorded by Stadiometer (Seca, Italy). The measures were obtained 3 times using the average value for the analysis.

Statistical Analyses

Shapiro-Wilk test was used for checking the normality (assumption). Data were presented as mean ± *SD*. Outcomes were expressed as value, with 90% confidence interval. Analysis of covariance, using baseline values as covariate, was used to detect possible between-groups differences after training (12). Threshold values for benefit or harmful effect were 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, and 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; >1–5%, very unlikely; >5–25%, unlikely; >25–75%, possible; >75–95%, likely; >95–99%, 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 and its advantages have been previously explained (4). Statistical analyses were performed by SPSS software version 20 for Windows 7 (Chicago, IL, USA).

Results

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

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 Table 1.

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

Discussion

The aim of this study was to examine the effect of a short-term COD and combined CODJ 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 2 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, intermuscular coordination, stretch reflex excitability, and changes in leg muscle activation strategies (17). Eccentric-emphasized exercise can elicit acute responses, which differ from concentric-only exercise, and 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, and 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, reaccelerations, and constant adjustments of steps and body posture (20,23). Therefore, appropriate plyometric training, sprint, and multidirectional 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, this 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 these 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, whereas 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 preseason, with a subsequently stabilization of such fitness variables in-season (18). Consequently, higher benefits are expected (and they were reported) in trials performed during the preseason compared with 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 posttraining 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 2 groups. Therefore, this study showed a slightly better effect of combined CODJ training versus COD. However, this study cannot state with absolute 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). This 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 2 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, although 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).

Acknowledgments

The authors thank the management and players of the team who participated in the current investigation.

References

1. Asadi, A, Arazi, H, Young, WB, and Sáez de Villarreal, E. The effects of plyometric training on change-of-direction ability: A meta-analysis. *Int J Sports Physiol Perform* 11: 563–573, 2016.
2. Beato, M, Bertinato, L, and Schena, F. High volume training with small-sided games affects technical demands in football: A descriptive study. *Sport Sci Health* 10: 219–223, 2014.
3. Born, DP, Zinner, C, Düking, P, and Sperlich, B. Multi-directional sprint training improves change-of-direction speed and reactive agility in young highly trained soccer players. *J Sports Sci Med* 15: 314–319, 2016.
4. Buchheit, M. The numbers will love you back in return-I promise. *Int J Sports Physiol Perform* 11: 551–554, 2016.

5. Caldwell, BP and Peters, DM. Seasonal variation in physiological fitness of a semiprofessional soccer team. *J Strength Cond Res* 23: 1370–1377, 2009.
6. Christopher, J, Beato, M, and Hulton, AT. Manipulation of exercise to rest ratio within set duration on physical and technical outcomes during small-sided games in elite youth soccer players. *Hum Mov Sci* 48: 1–6, 2016.
7. Coratella, G, Beato, M, and Schena, F. The specificity of the Loughborough Intermittent Shuttle Test for recreational soccer players is independent of their intermittent running ability. *Res Sport Med* 24: 363–374, 2016.
8. Coratella, G, Bellin, G, Beato, M, and Schena, F. Fatigue affects peak joint torque angle in hamstrings but not in quadriceps. *J Sports Sci* 33: 1276–1282, 2015.
9. Douglas, J, Pearson, S, Ross, A, and McGuigan, M. Eccentric exercise: Physiological characteristics and acute responses. *Sport Med* 47: 663–675, 2017.
10. Hamilton, RT, Shultz, SJ, Schmitz, RJ, and Perrin, DH. Triple-hop distance as a valid predictor of lower limb strength and power. *J Athl Train* 43: 144–151, 2008.
11. Hammami, M, Negra, Y, Shephard, RJ, and Chelly, MS. The effect of standard strength vs. contrast strength training on the development of sprint, agility, repeated change of direction, and jump in junior male soccer players. *J Strength Cond Res* 31: 901–912, 2017.
12. Hopkins, WG, Marshall, SW, Batterham, AM, and Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc* 41: 3–13, 2009.
13. Impellizzeri, FM, Rampinini, E, Castagna, C, Bishop, D, Bravo, DF, Tibaudi, A, and Wisloff, U. Validity of a repeated-sprint test for football. *Int J Sport Med* 29: 899–905, 2008.
14. Jarvis, MM, Graham-Smith, P, and Comfort, P. A methodological approach to quantifying plyometric intensity. *J Strength Cond Res* 30: 2522–2532, 2016.
15. Keiner, M, Sander, A, Wirth, K, and Schmidtbleicher, D. Long-term strength training effects on change-of-direction sprint performance. *J Strength Cond Res* 28: 223–231, 2014.
16. Lesaffre, E. Superiority, equivalence, and non-inferiority trials. *Bull NYU Hosp Jt Dis* 66: 150–154, 2008.
17. Markovic, G and Mikulic, P. Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports Med* 40: 859–895, 2010.
18. McMillan, K, Helgerud, J, Grant, SJ, Newell, J, Wilson, J, Macdonald, R, and Hoff, J. Lactate threshold responses to a season of professional British youth soccer. *Br J Sports Med* 39: 432–436, 2005.
19. Moher, D, Schulz, KF, and Altman, DG; CONSORT GROUP (Consolidated Standards of Reporting Trials). The CONSORT statement: Revised recommendations for improving the quality of reports of parallel-group randomized trials. *Ann Intern Med* 134: 657–662, 2001.
20. Mohr, M, Krustrup, P, and Bangsbo, J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 21: 519–528, 2003.
21. Mohr, M, Krustrup, P, and Bangsbo, J. Fatigue in soccer: A brief review. *J Sports Sci* 23: 593–599, 2005.
22. Rampinini, E, Coutts, AJ, Castagna, C, Sassi, R, and Impellizzeri, FM. Variation in top level soccer match performance. *Int J Sports Med* 28: 1018–1024, 2007.
23. Di Salvo, V, Gregson, W, Atkinson, G, Tordoff, P, and Drust, B. Analysis of high intensity activity in Premier League soccer. *Int J Sports Med* 30: 205–212, 2009.
24. Slimani, M, Chamari, K, Miarka, B, Del Vecchio, FB, and Chéour, F. Effects of plyometric training on physical fitness in team sport athletes: A systematic review. *J Hum Kinet* 53: 231–247, 2016.
25. Stewart, PF, Turner, AN, and Miller, SC. Reliability, factorial validity, and interrelationships of five commonly used change of direction speed tests. *Scand J Med Sci Sports* 24: 500–506, 2014.
26. Taylor, JM, Macpherson, TW, Mclaren, SJ, Spears, I, and Weston, M. Two weeks of repeated-sprint training in soccer: To turn or not to turn? *Int J Sports Physiol Perform* 11: 998–1004, 2016.
27. Thorpe, RT, Strudwick, AJ, Buchheit, M, Atkinson, G, Drust, B, and Gregson, W. Monitoring fatigue during the in-season competitive phase in elite soccer players. *Int J Sports Physiol Perform* 10: 958–964, 2015.
28. Wang, Y-C and Zhang, N. Effects of plyometric training on soccer players. *Exp Ther Med* 12: 550–554, 2016.
29. Wong, DP, Chan, GS, and Smith, AW. Repeated-sprint and change-of-direction abilities in physically active individuals and soccer players: Training and testing implications. *J Strength Cond Res* 26: 2324–2330, 2012.
30. Yanci, J, Los Arcos, A, Camara, J, Castillo, D, García, A, and Castagna, C. Effects of horizontal plyometric training volume on soccer players' performance. *Res Sports Med* 24: 308–319, 2016.
31. Zamparo, P, Bolomini, F, Nardello, F, and Beato, M. Energetics (and kinematics) of short shuttle runs. *Eur J Appl Physiol* 115: 1985–1994, 2015.
32. Zamparo, P, Zadro, I, Lazzer, S, Beato, M, and Sepulcri, L. Energetics of shuttle runs: The effects of distance and change of direction. *Int J Sports Physiol Perform* 9: 1033–1039, 2014.