The effects of repeated sprint training with vs. without change of direction on measures of physical fitness in youth male soccer players

Running title: Effects of repeated sprint training with or without change of direction on physical fitness in youth athletes

Yassine Negra[1], Senda Sammoud[1], Rodrigo Ramirez-Campillo[2,3], Raja Bouguezzi[1], Jason Moran[4], Helmi Chaabene[5,6]

[1]*Research Unit (UR17JS01) «Sport Performance, Health & Society», Higher Institute of Sport and Physical Education of Ksar Saïd, University of "La Manouba", Tunisia, 2037*
[2]*Department of Physical* Activity Sciences. Universidad de Los Lagos. Santiago, Chile.
[3]*Exercise and Rehabilitation Sciences Laboratory. School of Physical Therapy. Faculty of Rehabilitation Sciences. Universidad Andres Bello. Santiago. Chile.*
[4]*School of Sport, Rehabilitation and Exercise Sciences, University of Essex, Colchester, Essex, United Kingdom*
[5]*Department of Sports and Health Sciences, Faculty of Human Sciences, University of Potsdam, Potsdam 14469, Germany*
[6]*High Institute of Sports and Physical Education, Kef, University of Jendouba, Tunisia, 8189*

Corresponding author:

Yassine Negra Ph.D
Research Unit (UR17JS01) «Sport Performance, Health & Society», Higher Institute of Sport and Physical Education of Ksar Saïd, University of "La Manouba", Tunisia, 2037
Email: yassinenegra@hotmail.fr

Abstract

BACKGROUND: Fitness characteristics such as linear sprinting, repeated sprint ability, and change of direction (CoD) are important for male youth soccer players to maximize training safety and physical performance. We aimed to compare the effects of a 9-week repeated sprint training (RST) program, with and without change of direction (CoD) movements, on repeated sprint ability (RSA total time [RSA_{total}], RSA best time [RSA_{best}]), CoD speed (505 CoD test), linear sprint speed (10-m and 20-m linear sprint), and aerobic endurance (AE; Yo-Yo intermittent endurance test level 1) in male youth soccer players. **METHODS:** During the in-season period, 20 soccer players were randomly assigned to a RST with CoD (RST_{CoD}) group (n = 10, age = 15.4±0.4 years) or a repeated linear sprint training group (n = 10, age = 15.6±0.3 years). Both training groups completed approximately two 15 minutes RST sessions per week, with the only difference between training programmes being the inclusion of one CoD movement during sprint repetitions for the RST_{CoD} group. **RESULTS:** The two-way ANOVA with repeated measures revealed a significant, moderate effect of time for RSA_{best} and RSA_{total} (effect size [d] = 0.69 and 0.67, respectively). Likewise, significant, moderate-to-large effects of time were found for CoD (d=0.83), 10-m and 20-m sprint (d=0.68 and 0.67, respectively), and AE (d=0.66). No significant group × time interactions were observed for any measure of physical fitness (d=0.00 to 0.16). **CONCLUSIONS:** RST with and without CoD movements is equally effective in improving RSA total and best time, CoD speed, linear sprint speed, and AE in youth male soccer players.

Keywords: team sports, athletic performance, human physical conditioning, exercise program, football.

Introduction

The sport of soccer is characterized by high levels of running speed and its many derivatives (i.e., linear sprinting, change of direction [CoD] speed, repeated sprint ability [RSA]) [1]. Additionally, a high level of aerobic endurance (AE) is essential to preserve the quality of high-intensity actions across the duration of a match (e.g., CoD speed, RSA) [1]. During soccer matches, players can cover 10–13 km [1], with both sprinting and high-intensity running accounting for up to 11% and 12% of this distance, respectively [2]. Further to this, Bangsbo et al.[3] observed between 1,200 and 1,400 CoD rapid actions by players during a game whilst Bradley et al. [4] reported that one of the primary performance determinants is the ability to repeat high-speed actions (e.g., RSA). Indeed, RSA outcomes (i.e., RSA total time, RSA best time) effectively discriminate between professional and amateur soccer players[5]. Therefore, physical fitness qualities such as CoD speed, RSA, and AE should be systematically developed to help players cope with the competitive demands of modern soccer [6].

Repeated sprint training (RST) is a popular method of training [7]. It consists of several sprints interspersed with brief periods of recovery. Earlier studies showed that RST is effective for developing a variety of different fitness components including linear sprint speed [8,9], CoD speed [8,9], RSA [10], and AE (i.e., Yo-Yo intermittent recovery test level 1 total distance)[9]. RST can be implemented using either sprints with CoDs or linear sprinting[11]. The incorporation of CoDs into a training programme can be an important physiological and mechanical stimulus for high performance[12,13]. Indeed, players accustomed to executing CoD and short shuttle runs can reduce energy demand (i.e., improved economy) during such specific actions [13]. Accordingly, the inclusion of these movements into an RST program can lead to greater development of physical fitness measures associated with neuromuscular factors such as jump, sprint, and repeated sprint performance[5].

In contrast to the points discussed above, Taylor et al. [14] examined the effects of two weeks of RST, both with and without CoDs, on measures of physical fitness in semi-professional male soccer players aged 24 years. These authors revealed no additional benefit of RST with CoDs on measures of physical fitness, a result replicated by Beato et al. [15] who reported no additional benefit of eight weeks of RST with CoDs on measures of physical fitness (e.g., RSA, CoD speed) in an elite male youth population. Similarly, two weeks of RST with or without

CoDs were not effective in improving measures of physical fitness in amateur male soccer players aged 21 years [16]. Of note, the above-detailed studies were characterized by some methodological shortcomings, such as the very short duration of training (i.e., 2 weeks) [14,16], which could undermine the relevance of their findings. Accordingly, it is conceivable that longer interventions, with adequate training frequency, would induce a greater effect on RST with CoD[5,18].

Given the above-presented evidence, our study aimed to compare the effects of two weekly sessions of RST, with and without CoD, on RSA, linear sprint speed, CoD speed, and AE in youth male soccer players over a nine-week period. Our working[16,18] hypothesis was that RST with CoD would induce larger improvements on measures of physical fitness compared with linear repeated sprint training (LRST) in male youth soccer players.

METHODS

Experimental approach to the problem

A parallel two-group repeated measures experimental design was adopted to compare the effectiveness of RST both with and without CoDs on measures of RSA, linear sprint speed, CoD speed, and AE in youth male soccer players. The two training programs were conducted during the in-season period of the year 2021 (February-March). No familiarization sessions were conducted as all players were well acquainted with the physical fitness tests from their routine physical preparation program. Athletes were assessed before and after nine weeks of training. On the first day of testing, anthropometric measurements (i.e., body-mass and height), 10- and 20-m sprint speed, as well as RSA tests were carried out. On the second day, and following 48h of rest, the CoD speed (505 CoD test) and AE (Yo-Yo Intermittent endurance test level 1 [Yo-Yo IET]) tests were conducted.

All tests were scheduled at least 48 hours after the last executed training session or soccer match and were conducted at the same time of day (7:30–9:30 AM) under the same environmental conditions (29–33° C, no wind).

Participants

Figure 1 displays a CONSORT diagram of the levels of reporting and participant flow.

Figure 1 near here

We conducted an *a priori* sample size calculation for the best time in a single trial during the repeated sprint test (RSA_{best}) in the RST with CoDs group (RST_{CoD}). We set α at 0.05 and the statistical power at 0.80. The estimated effect size of Cohen's d = 0.65 is based on a similar study [16]. Therefore, the required number of participants in each group was determined to be nine. To account for potential participant attrition, twenty youth players from a regional soccer team were randomly assigned to RST_{CoD} group (n = 10, age = 15.4 ± 0.4 years, body mass = 60.8 ± 3.8 kg, height = 1.7 ± 0.1 m, and maturity offset = 1.5±0.5 years from peak height velocity [YPHV]) or a repeated linear sprint training (RLST) group (n = 10, age = 15.6 ± 0.3 years, body mass = 60.0 ± 6.5 kg, height = 1.7±0.1 m, and maturity offset = 1.8±0.4 YPHV) (Table 1). The assigned groups were determined by a chance process (a random number generator on a computer) and could not be predicted. This procedure was established according to the "CONSORT" statement, which can be found at http://www.consort-statement.org. In addition, the same investigator, who was blinded to group allocation, conducted all measurements. The participants had 7.0 ± 1.4 years of systematic soccer competition and training, involving five training sessions (80-90 min each) per week and a competitive game on weekends. Athletes who missed more than 20% of the total training sessions and/or more than two consecutive sessions were excluded from the study [19]. Besides chronological age, biological maturity was estimated using the maturity offset method. The maturity offset was calculated by predicting age at peak-height-velocity using the predictive equations established by Moore et al.[20].

Table 1 near here

All players met the following inclusion and exclusion criteria: (i) continuous soccer training over the past three months with no serious (i.e., no more than one session missed due to) musculoskeletal injuries sustained, (ii) absence of potential medical problems that could compromise participation or performance in the study, (iii) any lower-extremity surgery in the two years before the study. All procedures were approved by the Institutional Review Committee for the ethical use of human subjects at ****blind to reviewers***.* Written informed parental consent and participant assent were obtained before the start of the study. All youth athletes and their parents/legal representatives were informed about the experimental protocol and its potential risks and benefits before the commencement of the research project. Participants were permitted to withdraw from the study at any time and without having to provide a reason for doing so.

Soccer Training Program

Over the 9-week intervention period, regular training included five 80-90 minutes sessions per week. Both intervention groups conducted three soccer-specific training sessions per week in addition to two RST sessions. Therefore, the overall exposure time to training was identical between the two experimental groups (details in table 2). Soccer training included fast footwork drills, technical skills and moves (easy/difficult), position games (small/big), and tactical games with various strategic objectives.

Table 2 near here

Repeated sprint training program

After a standardized warm-up, the soccer players completed two ~20-minute RST sessions (details in Table 3). The two weekly sessions were performed on an artificial grass soccer pitch with 48 hours of recovery given between sessions (i.e., Tuesday, and Thursday) [10]. Players were instructed to exert maximal effort across all repetitions and to cover the prescribed running distance as fast as possible. Both groups covered the same distance (i.e., 420-m) per session. Recovery periods of twenty seconds and four minutes were allowed between sprints and sets, respectively. After the RST session, the players completed the remainder of their regular soccer training. Therefore, no additional training load was applied.

Table 3 near here

Linear sprint speed

Twenty-meter linear sprint performance was assessed at 10-, and 20 m intervals using an electronic timing system (Microgate SRL, Bolzano, Italy). Participants started in a standing start 0.3 m behind the first infrared photoelectric gate, which was placed 0.75 m above the ground to ensure captured trunk movement and avoided false signals through limb motion. In total, three single-beam photoelectric gates were used. The between-trial recovery time was three minutes. The best performance out of two trials was used for further analysis. The intra-class correlation coefficients (ICCs) for test-retest reliability were 0.94, and 0.97 for 10-m and 20-m, respectively.

505 change of direction speed

The 505 CoD speed test was administered using the protocol as previously outlined by Sammoud et al. [21] using an electronic timing system (Microgate, Bolzano, Italy). Players assumed a standing position 10-m from the start line, ran as quickly as possible through the start/finish line, pivoted 180° at the 15-m line indicated by a cone marker, and returned as fast as possible through the start/finish line. To ensure proper execution of the test, a researcher was positioned at the turning line and if the participant changed direction before reaching the turning point, or turned off the incorrect foot, the trial was disregarded and reattempted after the recovery period. A between-trial rest period of three minutes was provided. The best performance out of two trials was used for further analysis. The ICC for test-retest trials was 0.93.

Repeated sprint ability

The RSA test was conducted using a photocell system (Microgate, Bolzano, Italy). Immediately after a warm-up, participants completed a preliminary single shuttle-sprint test (20+20 m with 180° CoD). The first trial provided the criterion score for the actual shuttle-sprint test [22]. Participants then rested for five minutes before starting this test. During the first sprint, participants had to achieve at least 97.5% of their criterion score, otherwise, they rested for five minutes and then restarted the test [22,23]. We used such an approach to determine if participants adopted a coping strategy for performance. Of note, all participants attained their criterion score during the first sprint. All performed six 20-m shuttle-sprints with 180º turns, separated by 25-s of passive recovery[22,23]. Three seconds prior to the commencement of each sprint, players were asked to adopt the ready position until the next start signal. From the starting line, they sprinted for 20-m, touched the second line with one foot, and returned to the starting line as quickly as possible. Participants were instructed to complete all sprints as fast as possible. TheRSA_{best} and total time (RSA_{total}) were determined.

Aerobic endurance

Aerobic endurance was assessed using the YoYo intermittent endurance test (level 1). The test was performed as described by Bangsbo et al.[3]. Briefly, it consisted of repeated 2 x 20 m shuttle runs with a 180° turn with these runs executed at a progressively increasing speed indicated by audio beeps. Between each running bout, the players had a 5-s of active rest taken in the form of a 2 x 2.5 m walk. Termination of the test occurred when a participant failed to reach the finish line for a second time. The total distance of completed shuttles was recorded as the test result. The test was conducted outdoors on artificial turf. The reliability of this test was examined elsewhere [3].

Statistical Analyses

Data were tested and confirmed for normal distribution using the Shapiro-Wilk test. Baseline between-group differences were computed with independent t-tests. To establish the effect of the interventions on the dependent variables, a two (group: RST_{CoD} and RLST) × two (time: pre, post) ANOVA with repeated measures was computed. When group × time interactions reached the level of significance (i.e., significant F value), group-specific repeated measure ANOVAs (time: pre, post) were used to determine within-group pre-to-post performance changes. Additionally, effect sizes were determined by converting partial eta-squared from the ANOVA output to Cohen's d [24]. Cohen's d was classified as small ($0.00 \le d \le 0.49$), medium ($0.50 \le d \le 0.79$), and large ($d \ge 0.80$). Test-retest reliability was assessed using the intraclass correlation coefficient. Data were presented as group means values and standard deviation. The level of significance was set a priori at $p \le 0.05$. Data analyses were conducted using SPSS 24.0 program for Windows (SPSS, Inc, Chicago, IL, USA).

RESULTS

All subjects (n=20) received the treatment conditions as allocated. The adherence rate to training was 95% for both groups. None of the subjects reported any training- or test-related injuries. No significant between-group baseline differences were observed for any descriptive variable (Table 1) or physical fitness (Table 4) measures. The main effects of group, time, and group × time interactions are displayed in Table 3.

Table 4 near here

Repeated sprint ability

A main effect of time was noted for RSA_{best} and RSA_{total} (d=0.69 [medium], and 0.67 [medium], p=0.04, and 0.05, respectively) with no significant group × time interactions (Table 4).

505-CoD speed test

A significant main effect of time was found for the 505 CoD speed test (d=0.83 [large], p=0.01) with no significant group × time interaction.

Linear sprint speed

A significant main effect of time was noted for 10-m (d=0.68 [medium]) and 20-m (d=0.67 [medium]) sprint speed performance (both p=0.04). However, no significant group× time interactions were detected for either sprint speed intervals.

Aerobic endurance

Results indicated a significant main effect of time for AE (d=0.66 [medium], p=0.05). However, the group × time interaction did not reach the assigned level of statistical significance.

Discussion

This study examined the effects of a 9-week RST program, with and without CoD movements, on measures of physical fitness in male youth soccer players. Contrary to our hypothesis, our main findings revealed that both training interventions induced similar improvements in RSA_{best}, RSA_{tot}, CoD speed, linear sprint speed, and AE in youth male soccer players.

RSA is a key fitness component in team sports as short maximal sprints, interspersed with brief recovery periods, are frequent actions during match play[5]. Relatedly, RST has been recommended to concurrently improve fundamental soccer movements such as sprints and CoD actions[14,18] that are repeatedly performed in a soccer match. Our findings confirm the positive effects of RST on RSA in soccer players, with medium-sized improvements in RSA_{best} (ES=0.69) and RSA_{tot} (ES=0.67) after RST_{CoD} and RLST, respectively. These findings agree with those recently reported by Beato et al.[16]. These authors revealed moderate improvements (ES= 0.65) in RSA_{best} after two weeks of RST_{CoD} in amateur soccer players aged 21±2.4 years. Similarly, Chtara et al.[8] revealed significant large improvements in RSA best (1.7%) and RSA mean time (1.8%) performance after six weeks of an RST program in elite male youth soccer players. Also, Ferrari et al. [25] revealed a significant improvement (2.1%) in RSA mean time following a 7-week program of RST in youth soccer players aged 17 years. Furthermore, in a meta-analytical study, Taylor et al. [18] reported moderate (ES=0.62) enhancements in RSA following RST. The observed training-related improvements in RSA outcomes appear to be mainly caused by a series of metabolic adaptations, such as increases in muscular enzymatic activity, phosphocreatine and glycogen stores, and improved lactate buffering capacity [27,28]. However, neuromuscular adaptations may also be related to RSA improvements, particularly RSA_{best} [28, 29].

CoD speed is a key determinant of high performance in soccer[29]. Our results showed large CoD speed improvements (ES=0.84), regardless of the training modality adopted, with similar findings also being reported by Beato et al.[15]. More specifically, these authors observed moderate (ES=0.62) improvements in CoD speed performance (505 CoD speed test) after eight weeks of RST_{CoD} in high-level soccer players. Similarly, Chtara et al.[8] revealed a significant large improvement (3.8%) in 20-m Zig-Zag CoD performance after six weeks of an RST program in elite young male soccer players. CoD speed enhancements appear to be associated with improvements in kinetic factors (e.g., horizontal force and impulse), as well as improvements in CoD technique (e.g., kinematic factors such as step length and step frequency) [30].

In terms of linear sprint speed, both groups in our study achieved medium-sized improvements across the measured sprint distances (ES=0.67 to 068). Taylor et al. [14] also observed large beneficial effects for 10-, and 20-m sprint performance after six RST sessions, with and without CoD, over two weeks in semi-professional male soccer players. Similarly, Rey et al.[31] demonstrated significant improvements in 20-m sprint time performance after six weeks of both one (ES=0.531), and two (ES=0.321) sessions of RST per week in male youth soccer players. In the same context, Chtara et al.[8] revealed a large improvement in 10- (4.20%), and 30-m (2.44%) sprint performance after six weeks of an RST program in elite young male soccer players. In contrast, Beato et al.[15] did not find significant improvements in 10-m sprint speed after eight weeks of RST, with and without CoD (ES=-0.13, and-0.36, respectively), in elite-level soccer players (aged between 18–21). The discrepancies between our results and those reported by Beato et al. [15] could be explained by the differential in total training load in the two studies (9 weeks vs. 2 weeks) or possibly the participants' level of training experience and playing status (e.g., amateur vs. elite). In support of this point, a recent meta-analysis by Moran et al.[32] revealed larger increases in sprint speed following eight weeks of sprint training with training conducted over a shorter period of time found to be substantially less effective. According to Lieberman et al.[33], improvements in sprint speed could be caused by changes in the patterns of muscular activity. In fact, well-trained athletes adopt muscle activation patterns that are energetically and biomechanically advantageous for a given task, the repetition of which can lead to improvements in movement efficiency via neural pathways and reduced co-contractions [18]. In addition, sprint-training methods, such as RST, may also increase the activity of muscle groups through enhanced temporal sequencing and fast-twitch muscle fiber recruitment [33]. Further, it is possible that sprint training causes beneficial increases in muscle metabolites (e.g., phosphocreatine and glycogen) and enzymatic activity[34]. Furthermore, sprint speed performance enhancements could also be attributed to neuromuscular adaptations (e.g., increased muscle power) obtained by the repetition of CoD actions and accelerations, as well as the higher total sprint distance covered during the protocol [32].

A high level of AE enables soccer players to effectively cope with the physical demands of a soccer match [35]. Our results revealed significant, medium (ES=0.66) improvements in AE after the RST_{CoD} and RLST programs. These findings corroborate those reported by Taylor et al. [14] who revealed moderate-to-large improvements in AE after six RST sessions, with and without CoD, over two weeks in semi-professional soccer players. Likewise, our results were in line with those reported by Taylor et al.[18] following RST in team sports players (ES=-0.61). Similarly, Marcello laia et al. [9] showed a significant improvement (11.4%) in the distance covered during the Yo-Yo Intermittent Recovery Test (Level 2) after a 9-week RLST program in young male soccer players. Beato et al. [15] also reported a moderate positive effect (ES=0.65) on AE after 8 weeks of RST_{CoD} in high-level soccer players with the same authors demonstrating a small positive effect (ES=0.44) of eight weeks of RSLT on AE. It is worth noting that the observed improvements in AE following both RST programs might have occurred independently of direct measures of AE such as maximal oxygen uptake or lactate threshold [18,36]. More specifically, earlier studies[17,37] reported that the physiology of RST is associated with limitations of phosphocreatine resynthesis, aerobic and anaerobic glycolysis, and metabolite accumulation (e.g., superoxide radicals, ammonia), which cause a decrement in performance (alterations of the homeostasis). Such acute physiological responses could explain the soccer-related aerobic benefits obtained after nine weeks of RST.

Overall, the similar effect observed following the two training interventions in our study could mainly be attributed to the lack of neuromuscular and metabolic differences induced by the two training programs. In this way, the programs may have been too similar in structure to induce differentiated adaptations in the participants. Whilst the RST_{CoD} protocol required high braking and propulsive forces, which could increase metabolic and neuromuscular demands, the biomechanical aspects associated with the RLST, such as longer stride length, better use of the stretch-shortening cycle and higher running speed, may have placed similar demands on the neuromuscular system. This explanation is supported by the very strong relationship reported between the two forms of sprints[38].

Limitations

This study does have some limitations. First, we were unable to include an active control group. Second, the study lacks direct physiological and/or biomechanical measures that may help explain the underpinning mechanisms behind the observed improvements in functional performance. Finally, although players were instructed to exert maximal effort across all repetitions and to cover the running distance as fast as possible, we were unable to assess the metabolic cost, perceived effort, or equivalent markers of potential training intensity during the RST_{CoD} and RLST programs.

Conclusions

RST, both with and without CoD, is equally effective in improving RSA, CoD speed, linear sprint speed, and AE in youth male soccer players. Soccer coaches and strength and conditioning specialists can use RST, both with and without CoD movements, to enhance measures of physical fitness in male youth soccer players.

ACKNOWLEDGMENTS

No sources of funding were used to assist in the preparation of this manuscript. The authors declare that they have no conflicts of interest. The authors express their gratitude to the coaches and participants for their active participation in this study.

References

References

1. Stolen T, Chamari K, Castagna C, Wisloff U. Physiology of soccer: an update. Sports Med 2005;35(6):501-536.
2. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. J Sports Sci 2003; 21(7):519-528.
3. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test : a useful tool for evaluation of physical performance in intermittent sports. Sports Med. 2008;38(1):37-51.
4. Bradley PS, Di Mascio M, Peart D, Olsen P, Sheldon B. High-intensity activity profiles of elite soccer players at different performance levels. J Strength Cond Res 2010;24(9):2343-2351.
5. Bishop D, Girard O, Mendez-Villanueva A. Repeated-sprint ability - part II: recommendations for training. Sports Med 2011;41(9):741-756.
6. Reilly T, Gilbourne D. Science and football: a review of applied research in the football codes. J Ssports Sci 2003;21(9):693-705.
7. Macphearson TW, Weston M. The effect of low-volume sprint interval training on the development and subsequent maintenance of aerobic fitness in soccer players. Int J Sports Physiol Perform 2015;10(3):332-338.
8. Chtara M, Rouissi M, Haddad M, Chtara H, Chaalali A, Owen A, Chamari K. Specific physical trainability in elite young soccer players: efficiency over 6 weeks' in-season training. Biol Sport 2017; 34(2):137-148.
9. Marcello laia F, Fiorenza M, Larghi L, Albrti G, Millet GP, Girard O. Short- or long-rest intervals during repeated-sprint training in soccer? Plos one 2017; 12(2): e0171462.
10. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle. Part II: anaerobic energy, neuromuscular load and practical applications. Sports Med 2013;43(10):927-954.
11. Taylor JM, Macpherson TW, Spears IR, Weston M. Repeated Sprints: An Independent Not Dependent Variable. Int J Sports Physiol Perform 2016; 11(7):693-696.
12. Nedrehagen ES, Saeterbakken AH. The Effects of in-Season Repeated Sprint Training Compared to Regular Soccer Training. J hum Kinet 2015;22 (49) :237-244.

13. Zamparo P, Bolomini F, Nardello F, Beato M. Energetics (and kinematics) of short shuttle runs. Eur J Appl Physiol 2015;115(9):1985-1994.
14. Taylor JM, Macpherson TW, McLaren SJ, Spears I, Weston M. Two weeks of repeated-sprint training in soccer: To turn or not to turn? Int J Sports Physiol Perform 2016;11(8):998-1004.
15. Beato M, Bianchi M, Coratella G, Merlini M, Drust B. A Single Session of Straight Line and Change-of-Direction Sprinting per Week Does Not Lead to Different Fitness Improvements in Elite Young Soccer Players. J Strength Cond Res 2019.
16. Beato M, Coratella G, Bianchi M, Costa E, Merlini M. Short-Term Repeated-Sprint Training (Straight Sprint Vs. Changes of Direction) in Soccer Players. J human Kinet 2019; 70:183-190.
17. Girard O, Mendez-Villanueva A, Bishop D. Repeated-sprint ability - part I: factors contributing to fatigue. Sports Med 2011; 41(8):673-694.
18. Taylor J, Macpherson T, Spears I, Weston M. The effects of repeated-sprint training on field-based fitness measures: a meta-analysis of controlled and non-controlled trials. Sports Med 2015;45(6):881-891.
19. Chaabene H, Negra Y. The Effect of Plyometric Training Volume on Athletic Performance in Prepubertal Male Soccer Players. Int J Sports Physiol Perfor2017;12(9):1205-1211.
20. Moore SA, McKay HA, Macdonald H, et al. Enhancing a Somatic Maturity Prediction Model. Med Sci Sports and Exerc 2015;47(8):1755-1764.
21. Sammoud S, Bouguezzi R, Negra Y, Chaabene H. The Reliability and Sensitivity of Change of Direction Deficit and Its Association with Linear Sprint Speed in Prepubertal Male Soccer Players. J funct Morphol kinesiol 2021, 8; 6(2).
22. Negra Y, Chaabene H, Fernandez-Fernandez J, et al. Short-Term Plyometric Jump Training Improves Repeated-Sprint Ability in Prepuberal Male Soccer Players. J Strength Cond Res 2020;34(11):3241-3249.
23. Padulo J, Tabben M, Ardigo LP, et al. Repeated sprint ability related to recovery time in young soccer players. Res Sports Med 2015;23(4):412-423.
24. Cohen J. Statistical power analysis for the behaviors science.(2nd). New Jersey: Laurence Erlbaum Associates, Publishers, Hillsdale. 1988.
25. Ferrari Bravo D, Impellizzeri FM, Rampinini E, Castagna C, Bishop D, Wisloff U. Sprint vs. interval training in football. Int J Sports Med 2008;29(8):668-674.
26. Gibala MJ, Little JP, van Essen M, et al. Short-term sprint interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance. J Physiol 2006, 15; 575(Pt 3):901-911.
27. Ross A, Leveritt M. Long-term metabolic and skeletal muscle adaptations to short-sprint training: implications for sprint training and tapering. Sports Med 2001;31(15):1063-1082.
28. Ramirez-Campillo R, Gentil P, Negra Y, Grgic J, Girard O. Effects of Plyometric Jump Training on Repeated Sprint Ability in Athletes: A Systematic Review and Meta-Analysis. Sports Med. Apr 28 2021.
29. Mirkov DM, Kukolj M, Ugarkovic D, Koprivica VJ, Jaric S. Development of anthropometric and physical performance profiles of young elite male soccer players: a longitudinal study. J Strength Cond Res 2010;24(10):2677-2682.
30. Lockie RG, Schultz AB, Callaghan SJ, Jeffriess MD, Berry SP. Reliability and Validity of a New Test of Change-of-Direction Speed for Field-Based Sports: the Change-of-Direction and Acceleration Test (CODAT). J Sports Sci Med 2013;12(1):88-96.
31. Rey E, Padron-Cabo A, Costa PB, Lago-Fuentes. Effects of different repeated sprint-training frequencies in youth soccer players. Biol Sport 2019; 36(3):257-264.
32. Moran J, Sandercock G, Rumpf MC, Parry DA. Variation in Responses to Sprint Training in Male Youth Athletes: A Meta-analysis. Int J Sports Med 2017;38(1):1-11.
33. Lieberman DE, Raichlen DA, Pontzer H, Bramble DM, Cutright-Smith E. The human gluteus maximus and its role in running. J Exper Biol 2006;209(Pt 11):2143-2155.
34. Ross A, Leveritt M, Riek S. Neural influences on sprint running: training adaptations and acute responses. Sports Med 2001;31(6):409-425.
35. Rodas G, Ventura JL, Cadefau JA, Cusso R, Parra J. A short training programme for the rapid improvement of both aerobic and anaerobic metabolism. Eur J Appl Physiol 2000;82(5-6):480-486.
36. Denadai BS, de Aguiar RA, de Lima LC, Greco CC, Caputo F. Explosive Training and Heavy Weight Training are Effective for Improving Running Economy in Endurance Athletes: A Systematic Review and Meta-Analysis. Sports Med 2017; 47(3):545-554.

37 Jimenez-Reyes P, Pareja-Blanco F, Cuadrado-Penafiel V, Morcillo JA, Parraga JA, Gonzalez-Badillo JJ. Mechanical, Metabolic and Perceptual Response during Sprint Training. Int J Sports Med 2016;37(10):807-812.

38. Pavillon T, Tourny C, Ben Aabderrahman A, et al. Sprint and jump performances in highly trained young soccer players of different chronological age: Effects of linear VS. CHANGE-OF-DIRECTION sprint training. J Exerc Sci Fit 2021;19(2):81-90.

Conflicts of interest: The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions:

Author A, B and author C have given substantial contributions to the conception or the design of the manuscript, author A and author B to acquisition, analysis and interpretation of the data. All authors have participated to drafting the manuscript, author D, and E revised it critically. All authors read and approved the final version of the manuscript.

Figure1. The diagram (The CONSORT: Consolidated Standards of Reporting Trials) includes detailed information on the interventions received.

Table 1: Anthropometric characteristics of participants

	RST_{CoD} group (n= 10)	**RLST group (n= 10)**
Age (years)	15.4±0.4	15.6±0.3
Height (m)	1.7±0.1	1.7±0.1
Body mass (kg)	60.8±3.9	60.0±6.1
MO (years)	1.5+0.5	1.8±0.4

Notes: Data are presented as means and standard deviations; RST_{CoD}= repeated sprint training with change of direction; RLST= repeated linear sprint training; MO: maturity offset, as years from peak height velocity.

Table 2: Training characteristics during the nine-week intervention period.

	RST_{CoD} group (n=10)	RLST group (n=10)
Number of training sessions	45	45
Number of matches	08	08
Number of RST sessions	18	18

RST_{CoD}= repeated sprint training with change of direction; RLST= repeated linear sprint training.

Table3: Characteristics of the two repeated sprint training programs

Week	RST_{CoD} group	RLST group
	Sets × reps × distance (m) (per session)	Sets×reps×distance (m) (per session)
1	3 × 7 × (20 :10m+10m)*	3 × 7 × 20
2	3 × 7 × (20 :10m+10m)	3 × 7 × 20
3	3 × 7 × (20 :10m+10m)	3 × 7 × 20
4	2 × 7 × (20 :10m+10m)	2 × 7 × 20
5	4 × 7 × (20 :10m+10m)	4 × 7 × 20
6	4 × 7 × (20 :10m+10m)	4 × 7 × 20
7	4 × 7 × (20 :10m+10m)	4 × 7 × 20
8	3 × 7 × (20 :10m+10m)	3 × 7 × 20
9	3 × 7 × (20 :10m+10m)	3 × 7 × 20

RST_{CoD}= repeated sprint training with change of direction; RLST= repeated linear sprint training

Table 4: Physical fitness outcomes from pre-training to post-training

	RST_{CoD} group (n=10)		RLST group (n=10)		ANOVA outcomes		
					Group p value (d)	Time p value (d)	Group×Time p value (d)
	Pretest	Posttest	Pretest	Posttest			
10 m sprint (s)	1.85±0.14	1.76±0.11	1.90±0.14	1.82±0.11	0.19 (0.44)	0.04 (0.68)	0.79 (0.08)
20 m sprint (s)	3.28±0.25	3.14±0.22	3.37±0.27	3.20±0.16	0.33 (0.32)	0.04 (0.67)	0.88 (0.06)
505 CoD test (s)	2.48±0.20	2.33±0.15	2.47±0.15	2.36±0.15	0.88 (0.06)	0.01 (0.83)	0.61 (0.16)
RSA_{best} (s)	7.84±0.55	7.51±0.54	7.70±0.41	7.41±0.31	0.42 (0.27)	0.04 (0.69)	0.922 (0.00)
RSA_{total} (s)	48.87±3.60	46.70±3.38	47.64±2.94	45.83±2.34	0.29 (0.35)	0.05 (0.67)	0.85 (0.06)
Yo-Yo intermittent recovery test level 1 (m)	860.00±453.82	1076.00±404.62	1104.00±447.89	1404.00±313.52	0.03 (0.73)	0.05 (0.66)	0.74 (0.10)

Notes: Data are presented as means and standard deviations. RSA: repeated sprint ability; CoD: change of direction; RSA_{total}: RSA total time; RSA_{best}= RSA best time; d= Cohen's d; RST_{CoD}: repeated sprint training with change of direction; RLST: repeated linear sprint training.