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Abstract

Effective prescription is especially important in elite soccer players, who have a very limited time to dedicate to specific physical development as a consequence of factors such as congested match schedules and travel. The aim of this study was to compare the effectiveness of one repeated-sprint training (RST) session per week over an 8 week period on physical performance. A second aim was to compare the effect of RST involving straight sprints (RST-SS) or changes of direction (RST-CODs). This study used a randomized pre-post parallel group trial design. The elite soccer players were randomly assigned to either a RST-SS (10 players) or RST-CODs (10 players). RST-SS was 3 sets of 7 x 30 m sprints with 20 s and 4 min recovery between sprints and sets, respectively. RST-CODs was 3 sets of 7 x 20 + 20 m (one COD of 180º) shuttle sprints with 20 s and 4 min recovery between sprints and sets, respectively. The physical tests selected were: Long jump, RSA best, RSA mean, 505 agility test, Yo-Yo Recovery Level 1, 10 m, 30 m, and 40 m sprints. RST-SS reported *unclear* variations in Long jump, Sprint 30 m, Sprint 40 m, RSA best, and RSA mean, while RST-CODs showed *unclear* and *trivial* variations in Sprint 10 m, Sprint 30 m, Sprint 40 m, RSA best, and RSA mean. The between-group analysis did not report any statistical difference. In conclusion, a single session of RST-SS and RST-CODs do not improve soccer specific fitness indicators in elite youth players during the season.

Keywords: football, team sports, performance, training, changes of direction, sprint

INTRODUCTION

Soccer is a game where physical fitness, technical ability and tactical skills play a fundamental role in the success of the match (4,11,30). From a physiological point of view, this sport is characterized by an intermittent-activity profile with metabolic contributions from both the aerobic and anaerobic systems (34). Players cover distances of 10–13 km during official matches, of which around 1200 meters are considered high intensity running distance. These physical outputs are performed in approximately 1350 activities, such as sprints, accelerations/decelerations, and changes of directions (CODs) (32). Many of these high-intensity actions are interspersed with short rest periods throughout a soccer match (6,9,38). In such conditions, temporary fatigue, which can be defined as a performance reduction after a period of intense exercise (32), may occur as a consequence of specific metabolic responses associated with anaerobic and aerobic metabolism such as decrement in ATP, phosphocreatine, and muscle pH (15,32,37). The ability to repeatedly produce near maximal or maximal activities of short duration with brief recovery periods is named repeated sprint abilities (RSA) (15,20).

Repeated-sprint training (RST) is considered an effective strategy to concurrently improve a range of fitness measures related to team-sports performance (13,20,38,39). Previous publications support the validity of this methodology partly through the association between RSA and physical performance during soccer games (5,20). It is relatively well known that RST effectiveness may depend on several variables of training prescription such as the frequency, volume, and duration of the exercise, as well as, the specific nature of the activities used within the repeated-sprint methodology (*i.e.* exercises selected in the protocol) (5,8). Fitness improvements may be mainly associated with the specific adaptations associated with this type of training such as a reduction in the lactate accumulated at the end of exercise, an increase in glycolytic enzymes and/or improvements in the players' movement efficiency (*e.g.* learning effect and neuromuscular factors) during CODs (*e.g.* 180º) (17,43,46). From a practical perspective, such studies are particularly interesting as the insights may provide guidance for the application of training by coaches and sport scientists (5).

Effective prescription is especially important because both elite youth and professional athletes within soccer have a very limited time dedicated to specific physical development as a consequence of factors such as congested match schedules, travel and the need for the development of other training types (*i.e.* tactical and technical skills training) (28). Much of the available literature has typically prescribed two or three RST sessions per week reporting physiological improvements (*e.g.* oxygen uptake [VO_{2max}]) and sport specific adaptations (*e.g.* RSA best sprint and mean sprint) with such prescriptions (38). However, the findings in literature are not unequivocal (5,15), as well as such training frequencies (2-3 times a week) are limited in their application to elite players in season (1,5). Therefore, research evaluating the effectiveness of low training frequency protocols have a great importance in the applied elite environment. This has critical importance since little information is currently available on the effects of small regular doses (*e.g.* once a week) of RST in soccer.

RST can be implemented using different types of movement patterns, more specifically either straight sprints or actions that include a CODs (39). It has been reported that the presence of CODs can be an important physiological and mechanical stimulus in training (13,44). Indeed, Hader et al., 2016 reported that RST involving CODs may increase activation (due to the braking activity) of the lower limb muscles such as vastus lateralis and bicep femoris compared to RST-SS (18). Moreover, athletes who are accustomed to performing CODs and short shuttle runs become more economical during such specific actions (44,46). The combination of short shuttle runs and CODs would seem to result in higher metabolic demands (*e.g.* lactate accumulation and oxygen uptake) than straight sprinting since the cost of locomotion is larger during such activities (33). The inclusion of specific COD exercises in a training program (*e.g.* RST) may therefore elicit greater developments in sport specific fitness attributes through increased neuromuscular factors (*e.g.* sprint and RSA) (1,5). The only study that has attempted to analyze the difference between two RST protocols (using a short-term training program, 2 weeks) reported no additional benefits on performance if CODs were included (39). Therefore, further research would seem to be warranted in this area since the training prescription here is both short in duration and not ecologically valid for elite clubs.

The management of exercise variables have important implications within the training programs developed for team-sports athletes. Considering the limited evidence about such topic in RST, this study could offer important indications to practitioners to increase the efficiency of RST in soccer training strategies. The aims of this study were therefore to evaluate the effect of 8 weeks (one session per week) of RST on jumps, sprint, agility, RSA, and sport specific aerobic performance, in a sample of elite young soccer players during the official season (within analysis). Secondly, to compare two RST protocols involving straight sprint and CODs that are largely used in soccer (between analysis).

METHODS

Experimental approach to the problem

The current study was designed to examine the effect of 8 weeks of RST (a single session per week) proposed involving straight sprint and CODs protocol on jumps, sprint, agility, RSA, and sport specific aerobic performance, in a sample of elite young soccer players.

This study used a randomized pre-post parallel group trial design. The randomization was performed according to a computer-generated sequence. The participants were then assigned to either an RST group using straight sprint (RST-SS = 10 players) or an RST group using CODs (RST-COD = 10 players). Eighteen participants completed the study, while one participant per group dropped out due to contact injuries during official games (injuries not associated with the RST protocols). CONSORT participant flow was reported (31). Twenty participants (including the drop outs) were considered in the final statistical analysis (intention to treat analysis). During this study, every player performed a minimum of 4 training sessions per week and were available to take part in the match.

*****Please report figure 1 here. CONSORT participant flow*****

The RST modalities utilized in the current protocol were previously published in the literature (39), though the training duration is different (8 weeks in the current study). Training protocols, as well as the baseline tests and post-training assessments, were performed before the beginning of the second part of the official season.

*****Please table 1 here. An in-season weekly program for an elite youth soccer team*****

In this study, the design selected did not involve a control group. Authors considered the utilization of a control group, in such circumstances, as an unethical because it could have decreased the players' performance and impacted the clubs' success in the wider fixture program. This ethical issue in elite and professional players has been previously reported (38). A more comprehensive explanation of this decision is reported in the following publication

(1). This approach is largely used in clinical trials when an existing treatment that has already been demonstrated to have efficacy exists (26).

Subjects

Twenty-three young soccer players (elite level, Switzerland) were considered during the enrolment process. Only outfield players were included (three goalkeepers were excluded), therefore, twenty participants were included in the current study (mean ± SD; age 19 ± 0.9 years, weight 71.0 ± 6.9 kg, height 176.9 ± 6.4 cm). All participants were informed about the potential risks and benefits of the study and signed an informed consent. The Ethics Committee of the University of Suffolk (UK) approved this study. All procedures were conducted according to the Declaration of Helsinki for human studies.

Experimental procedure

Players were accustomed to the following test battery because it was required by the Switzerland soccer Federation, therefore additional familiarization was not required. The participants replicated the same tests 3 times, with a recovery of 3 min among the trials and the best scores in every test were considered for the data analysis. During the first session, a long jump test was used to evaluate improvement of horizontal non-rebounding ability (players' isolated explosive strength abilities of the leg muscles) (1). In the current study, the interclass coefficient correlation (ICC) of such test was 0.91. In the same session, Sprint 10, 30 and 40 m were performed to evaluate improvements in linear sprint ability (ICC in this study were 0.87, 0.89, 0.88, respectively). For this purpose, infrared timing gates (Microgate, Bolzano, Italy) were placed at the start and end of each of the mentioned distances. After an adequate passive recovery from the previous sprinting test, the 505 COD test was utilized to evaluate improvements in agility (36). On the "Go" command, the participants 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 specificity of this test has previously been demonstrated in soccer (36). The 505 COD test is a highly reliable assessment with a coefficient of variation of 2.8% (36). In the second section, the repeated-sprint test used the following protocol: 6 sprints of 20 + 20 m (with one COD of 180º) interspersed with a recovery time of 20 seconds (20). Repeated-sprint peak (best sprint) and average values (6 sprints) were used for analysis (20). In the third testing section, a Yo-Yo Recovery Level 1 test was used to evaluate soccer specific aerobic fitness variations after the RST protocol (25).

Training

Training was designed a priori considering the period of the season and the sample characteristic (elite players). The decision to develop a low training frequency protocol (once session a week) was chosen to not only to satisfy the professional duties (based on the competitive calendar) of the club (ecological protocol) but to fulfil the aims of the research.

RST-SS was 3 sets of 7 x 30 m sprints with 20 s and 4 min recovery between sprints and set, respectively. RST-CODs was 3 sets of 7 x 20 + 20 m (one COD of 180º) shuttle sprints with 20 s and 4 min recovery between sprints and set, respectively. This protocol was previously utilized to compare RST-SS vs. RST-CODs (2,39). The training volume was maintained constant during the 8 weeks of the protocol. Internal training load was evaluated by ratings of perceived exertions (RPE-10) after all the training sessions to evaluate possible differences in training load (21,41). The average RPE reported for RST-CODs and RST-SS was 6.4 ± 0.7 and 6.1 ± 0.8, respectively (RPE differences were not significant, $p = 0.095$). The average session-RPE per week for RST-CODs and RST-SS was 2517 AU and 2452 AU, respectively. Session-RPE was not significantly different between RST-CODs and RST-SS ($p = 0.377$).

Statistical analysis

Data were presented as mean ± standard deviation (SD). Intention to treat analysis was adopted (every player was considered for the final analysis) (3). Shapiro-Wilk test was used for checking the normality (assumption). Robust estimates of 90% confidence interval (CI) and heteroscedasticity were calculated using bootstrapping technique (randomly 1000 bootstrap samples). Analysis of covariance (ANCOVA), using baseline values as covariate, was employed to detect possible between-groups differences (19). When significant F-values were found, post hoc analysis was performed (Bonferroni). Statistical significance was set at $p < 0.05$. Threshold values for benefit or harmful effect were evaluated based on the smallest worthwhile change (0.2 multiplied by the between-subjects SD). 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 (19). Data were analyzed (within and between interaction) for practical significance using magnitude-based inferences (MBI) in association with p-level as recommended by the Journal. Results has been mainly interpreted based on traditional statistics considering the limitations recently reported for MBI (35). Statistical analyses were performed by SPSS software version 20 for Windows 7 (Chicago, USA).

RESULTS

A compliance of 92% and 93% for RST-CODs and RST-SS, respectively, was reported at the end of this study. Data analyzed (within interaction) found an improvement in Sprint 10 m (*possible*, but not significant, $p = 0.11$), 505 COD test (*very likely*, $p = 0.02$) Yo-Yo recovery level 1 (*likely*, $p = 0.045$) in RST-SS group, while an improvement in Long jump (*possible*, but not significant, $p = 0.09$), 505 COD test (*very likely*, $p < 0.001$) and Yo-Yo recovery level 1 (*very likely*, $p < 0.001$) in RST-CODs group. Within-group variations for both RST-CODs and RST-SS are reported in Table 2. Between-group analysis did not report any statistical difference ($p > 0.05$) in Long jump, 10 m sprint, 30 m sprint, 40 m sprint, RSA best, RSA mean, 505 agility, and Yo-Yo recovery level 1. Between-group variations for both RST-CODs and RST-SS are reported in figure 2.

*****Table 2 here, please*****

*****Figure 2 here, please*****

DISCUSSION

The aims of this study were to evaluate the effect of 8 weeks, a single session per week, of RST on jumps, sprint, agility, RSA, and sport specific aerobic performance, in a sample of elite young soccer players during the official season. Secondly, to compare the effectiveness of two RST protocols involving straight sprint and CODs (between analysis). To the authors' knowledge, this is the first study that compares the effectiveness of RST-SS vs. RST-CODs protocols in ecological conditions (38). After 8 weeks of RST, few meaningful within-group differences were found, though improvements for the RST-SS group reported in Sprint 10 m, 505 COD test and Yo-Yo recovery level 1. RST-SS reported unclear variations in Long jump, Sprint 30 m, Sprint 40 m, RSA best, and RSA mean. RST-CODs group showed moderate positive effects for 505 COD test and Yo-Yo recovery level 1, and unclear and trivial variations in Sprint 10 m, Sprint 30 m, Sprint 40 m, RSA best, and RSA mean. No group differences were found between RST-SS and RST-CODs after 8 weeks of training (trivial and unclear differences, see Figure 2). These findings could have important practical applications as our design represents an ecologically valid approach to RST in youth elite and professional players during the season (1,28). The data in general shows that a single training session per week, independently of the training activity proposed (*i.e.* RST-SS and RST-CODs), does not represent a sufficient stimulus for the development of relevant fitness attributes (with the exception of 505 COD test and Yo-Yo recovery level 1) in youth elite soccer players in season. Moreover, no differences in effectiveness were found between RST-SS and RST-CODs, when such protocols are performed once a week.

A meta-analysis reported an effect of RST on Jump performance (ES = 0.33, *small*), Sprint 10 m (ES = -0.42, *small*), Sprint 20 m (ES = -0.42, *moderate*), and RSA (ES = -0.62, *moderate*) in non-controlled trials (38). Born et al. has also demonstrated improvements in Vertical jump test (ES = 0.12, *trivial*) and Sprint 20 m (ES = -0.28, *small*), after a RST in highly-trained male soccer players (7). The current study did not however show any effective improvements in RSA performance (*i.e.* RSA best and RSA mean), Sprint 30 m, and Sprint 40 m time in either group. Several considerations related with the current literature could support the findings of this study. Firstly, these results could be justified considering the difficulty to improve neuromuscular and physiological factors during the season when the main goals of the training process are mainly oriented to optimize the players' soccer performance in the official matches (1). This consideration is associated with the knowledge that soccer players' fitness indicators improve mainly during the pre-season (30), while throughout the season they still stable or decrease (10,16,22). It is well known that a dose-response relationship exists between RST training volume (frequency) and the outcomes of the training programs (5,17). Therefore, the trivial and unclear variations reported on RSA in this study could be associated with the training frequency proposed and with the consequent low training volume performed, which could have negatively affected the potential benefits of both RST protocols (7,38). Previous studies recommend medium to long-term (*e.g.* 8-12 weeks) training protocol using a training frequency of twice to three times a week in order to have positive adaptations (1,12,29), and this research supports such evidence. The little effectiveness of the RST could also be explained considering the elite sample enrolled, which could have been accustomed to perform sprints and short shuttle running training (41,42). Therefore, the findings of the current research underline the difficulties to improve sport specific physical parameters in elite athletes in season.

In the current study, the Yo-Yo recovery level 1 did however improve after the training period in both RSS training groups. The RST protocols here also seemed to lead to moderate improvements in 505 COD test (40). These findings are well supported in the available literature (7,15,38). The physiology of RST is associated with limitations of phosphocreatine re-synthesis, aerobic and anaerobic glycolysis, and metabolite accumulation (*e.g.* superoxide radicals, H^+, ammonia), which causes a decrement in performance (alterations of the homeostasis) (17,24). Such acute physiological responses could explain the soccer-related aerobic benefits obtained after 8 weeks of RST. While, the changes in COD ability may be associated with improvements in kinetic factors (*e.g.* horizontal force and impulse), as well as with improvements in COD technique (*e.g.* kinematic factors such as step length and step frequency) (27). However, the findings in literature are not univocal, for instance, Ferrari-Bravo et al. did not find improvements in leg power and speed following a RST protocol (15).

This study has compared a RST-CODs vs. RST-SS protocol. Previous evidence has suggested that specific actions such as CODs might offer higher acute physiological responses and that these may subsequently impact the chronic adaptations that may be associated with a training program (43,44,46). CODs are characterized by a deceleration-turn-acceleration dynamic that requires high levels of "mechanical" and "metabolic" load (18). Even if the exact biomechanical and physiological demands of each components of such movements remain unknown, it has been reported that HR, lactate and VO_2 are higher during shuttle running involving 180º than during straight and shuttle running involving CODs of 90º and 45º (46). In this study, only RST-COD showed a *possible* effect (*small*) in Long Jump performance across the training period with RST-SS not reporting any improvement. Long jump performance is an indicator of explosive strength and this small difference in improvements between the protocols may be explained by the expected higher mechanical demands that are associated with the COD's included in the RST-COD. More specifically this mechanism may relate to the high eccentric and concentric forces included in the COD actions in the RST-COD (18,45). On a more general level the current study failed to report any systematic significant differences in training outcomes between the two RST protocols. The current findings (though different from what reported in the literature) (43,44,46) could be explained again by the low training dose used in this design, the participants included in the sample, as well as the period of the season (1). Future studies are necessary to confirm such evidence.

The main limitation of this study is associated with its design (*i.e.* it is not a randomized controlled trial). Previous evidence reported that a control group or at least a "control period" of equal duration without administration is needed (14). Authors considered the inclusion of a control group, but in such circumstances, it was considered unethical as it could have decreased the players' performance in the wider fixture program (1). Secondly, authors consider the low training volume and frequency proposed in this study as a limitation but it was designed in agreement with the club staff to satisfy the professional duties (based on the competitive calendar) of the players. Lastly, even if the training program was ecological, there was, however, no volume progression and protocols were different for total distance covered, exercise duration, and work: rest ratio, which need to be considered a limitation. Authors selected these protocols because they were previously used with success to compare RST SS vs. COD (2,39).

In conclusion, RST protocols involving specific power-type activities and CODs might replicate the biomechanical and physiological demands of a soccer match (23,45). However, in this study, very few improvements in fitness attributes relevant to soccer have been found after 8 weeks of RST intervention, and no differences have been found between the two different RST protocols. Therefore, the protocol proposed does not seem a sufficient stimulus for elite soccer players in season with the exception of COD test and Yo-Yo recovery level 1. A higher training volume should be considering in RST since a one session per week protocol has not been sufficient to offer sport specific fitness improvements in elite soccer players. Further research is needed to clarify and verify the results reported in the current study.

PRACTICAL APPLICATIONS

This study offers several practical applications for strength and conditioning training in soccer. Both protocols reported very few improvements after 8 weeks of training without reporting meaningful between differences. Therefore, coaches should not propose a low RST volume (once per week) in order to improve the fitness level of their players (with exception for COD test and Yo-Yo recovery level 1, which should be considered by coaches). However, this training volume, even if does not seem sufficient to improve soccer players fitness level, may be useful to maintain such fitness level in season. These findings should be considered important, firstly, because practitioners may better prepare their athletes in season, and secondly, because this study has reported few fitness variations following RST protocols. It has been recently shown that a high ratio of positive to negative outcomes published in scientific journals exists. This practice may create a false perception of effectiveness for some training programs. Future research is needed to confirm such evidence and to clarify the dose-response of RST in soccer.

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