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Title: Two-weeks of repeated-sprint training in soccer: To turn or not to turn?

Submission type: Original Investigation

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Running title: Repeated-sprint training in soccer

Abstract word count: 252

Text only word count: 3883

Number of tables: 3

Number of figures: 0
Abstract

Purpose: To compare the effects of two repeated-sprint training programs on fitness in soccer.

Methods: Fifteen semi-professional soccer players (age 24 ± 4 y; body mass 77 ± 8 kg) completed 6 repeated-sprint training sessions over a two week period. Players were assigned to a straight-line (STR) (n = 8; 3–4 sets of 7 × 30-m) or change of direction (CoD) (n = 7; 3–4 sets of 7 × 20-m) repeated-sprint training group. Performance measures included 5, 10 and 20-m sprints, countermovement jump, Illinois agility and Yo-Yo intermittent recovery level 1 (YYIRTL1) performance. Internal (heart rate) and external (GPS-derived measures) training loads were monitored throughout. Data were analysed using magnitude-based inferences.

Results: Internal and external loads were higher in STR than CoD with large differences in maximum velocity (28.7%; ±90% confidence limits 3.3%), moderate differences in mean heart rates (7.0%; ±1.4%) and PlayerLoad™ (17.6%; ±8.6%), and small differences in peak heart rates (3.0%; ±1.6%). Large improvements in 5-m (STR: 9.6%; ±7.0% and CoD: 9.4%; ±3.3%), 10-m (STR: 6.6%; ±4.6% and CoD: 6.7%; ±2.2%) and 20-m (STR: 3.6; ±4.0% and CoD: 4.0; ±1.7%) sprints were observed. Large and moderate improvements in YYIRTL1 performance were observed following STR (24.0%; ±9.3%) and CoD (31.0%; ±7.5%), respectively. Between-group differences in outcome measures were unclear. Conclusions: Two weeks of repeated-sprint training stimulates improvements in acceleration, speed and high-intensity running performance in soccer players. Despite STR inducing higher internal and external training loads, training adaptations were unclear between training modes, indicating a need for further research.

Key words: training load, HIT, soccer training, shuttle sprinting
Introduction

The multi-directional, intermittent nature of soccer match-play necessitates players to possess a range of fitness components.\textsuperscript{1} Repeated-sprint training - a series of short sprints (3-7 s in duration) interspersed by a short recovery period (≤60 s)\textsuperscript{2} - is a mode of training that elicits simultaneous improvements in speed, power, repeated-sprint ability and high-intensity running performance in, all of which are key to soccer performance.\textsuperscript{1,3} As such, repeated-sprint training appears to be an appropriate training method for the development of fitness in soccer players.

Time-efficient fitness sessions (e.g. rapid fitness gains in a short period of time) appeal to coaches when programming a soccer player’s fitness schedule, as they enable coaches to maximize the use of limited available training time, particularly at times of fixture congestion or toward the latter part of the season.\textsuperscript{4-6} Repeated-sprint training is classified as a form of interval training toward the highest end of the intensity spectrum\textsuperscript{2} and similar types of interval training, such as sprint intervals, elicit clear fitness improvements after only two weeks (6 sessions).\textsuperscript{5} However, due to a lack of research in this area, the potential modifying effect of repeated-sprint intervention duration remains unexplored.\textsuperscript{3} As such, establishing the effectiveness of a similar short duration repeated-sprint training program on aerobic, anaerobic and neuromuscular fitness is timely.

While repeated-sprint training is effective in developing a variety of fitness components\textsuperscript{3}, there are key programming considerations that require further investigation; specifically the type and volume of repeated-sprints required to induce desired training adaptations in soccer. Including a change of direction in repeated-sprint training is a prominent issue, given the greater training specificity this imposes\textsuperscript{7}, and research suggests that including a change of direction incurs a greater systemic physiological load.\textsuperscript{7-9} Furthermore, including or increasing the frequency of directional changes in a repeated-sprint program can elicit greater enhancements in components of fitness that have more dependence on neuromuscular factors such as explosive leg-power and agility.\textsuperscript{7, 10} It is of note that higher maximal velocities are reached in straight-line repeated-sprinting in comparison to change of direction repeated-sprinting (specifically shuttle sprinting)\textsuperscript{8} and this might have implications with regards to adaptations in speed qualities of players. Despite this, no research has compared the training adaptations induced by straight-line (STR) or change of direction (CoD) repeated-sprint training.

While performance measures are used to quantify the effectiveness of a training intervention, quantification of the process by which training adaptations are attained is essential to allow practitioners to understand the relationship between the training stimuli imposed and the adaptations achieved.\textsuperscript{11, 12} Although the acute responses to repeated-sprint training have been investigated,\textsuperscript{8, 9, 13} there is a paucity of research investigating the external (i.e., running speed and body load) and internal (i.e., heart rate) responses to such a program. This is noteworthy given the proposed higher systemic load in change of direction sprints\textsuperscript{9} which might result in differential adaptations.

Our study, therefore, aimed to examine the effectiveness of two short duration repeated-sprint programs (straight-line and change of direction) on the fitness of semi-professional soccer players, while also providing a detailed quantification and examination of the training dose.

Methods

Design and Participants

A controlled before and after design was used to compare the effects of the repeated-sprint training programs on acceleration, speed, explosive leg-power, agility and high-intensity
running performance. The study design was adapted from Gibala et al.\textsuperscript{14} and Macpherson and Weston\textsuperscript{9}, with 6 sessions of repeated-sprint training over a two-week training period carried out during the competitive season. Ethics approval from the Teesside University Institutional Review Board and informed consent were obtained before commencement of the study.

Fifteen male soccer players classified as semi-professional,\textsuperscript{15} were recruited (age; 24.1 ± 4.1 y; stature 178.9 ± 5.5 cm; body mass; 76.5 ± 7.6 kg). Before the intervention participants engaged in soccer training twice per week (a time equivalent of ~4 hours per week) and competed at least once per week. Any players suffering from any musculo-skeletal injury at the time of the intervention period were excluded. Fitness testing was conducted to establish baseline performance, against which post-training performance was compared. Following baseline testing, participants were assigned to a condition for the intervention period, with the minimization approach used to balance both training groups at baseline on fitness and anthropometry.\textsuperscript{16}

Training Intervention

Participants were required to complete their allocated training program three times per week. Typically, team training consisted of aerobic/anaerobic conditioning followed by technical and tactical training. The repeated-sprint training programs were included as total replacement of training and competition during the intervention. The team did not have any scheduled fixtures during this period. The groups consisted of 8 players in the straight-line repeated-sprint group (STR: age 24 ± 4 y; stature 180 ± 5 cm; body mass 78 ± 7 kg) and 7 players in the repeated-sprint change of direction group (CoD: age 25 ± 8 y; stature 178 ± 6 cm; body mass 75 ± 8 kg). The training protocols for each group are displayed in Table 1. Sprint durations were selected on the recommendations of Hader et al.\textsuperscript{7} and Buchheit and Laursen\textsuperscript{17} in addition to pilot work that was conducted to ensure sprint duration was closely matched between groups. Repeated-sprint training sessions were separated by a minimum of 48 hours to ensure adequate recovery, with all being completed on an outdoor soccer pitch and standardised warm-up procedures were performed before the training sessions.

Training Load

Monitoring of internal and external training load is crucial to understanding the training process\textsuperscript{12} and therefore both were measured throughout the study. Internal load was monitored using heart rate sensors (Polar Heart rate monitor, Polar RS400, Polar, Kempele, Finland) and presented as percentage points of maximal heart rate, which was obtained through the Yo-Yo intermittent recovery level 1 test. External loads, including maximal running velocity and PlayerLoad\textsuperscript{TM}, were monitored using microsensors (10 Hz global positioning system and 100 Hz piezoelectric accelerometer [Kionix: KXP94]: MinimaxX\textsuperscript{TM} S4, Catapult Innovations, Melbourne, Australia).

Fitness Testing

Field-based fitness tests were used to assess performance. To assess acceleration and speed, participants performed two 20-m sprints, with the fastest sprint time used in the analyses. Light sensitive timing gates (Smart speed, Fusion Sport, Melbourne, Australia) were placed at 0, 5, 10 and 20 m, respectively. All sprint times were recorded to the nearest 0.01 s. Sprints were completed from a standing start, 0.5 m behind a starting line. Explosive leg-power was assessed using countermovement jump height, and was measured using an optical photocell measurement system\textsuperscript{18} (OptoJump Next, Microgate, Italy). The best of two trials, recorded to the nearest 0.1 cm was retained for analysis. Players were instructed to keep their hands on their hips throughout the movement. Agility was assessed using the Illinois agility test,\textsuperscript{19} which
is valid and reliable for agility assessment. Light sensitive timing gates were used to record test performance (to the nearest 0.01 s) and the best of two trials was used for analysis. The players completed this test from a standing start 0.5 m behind the starting line and were instructed to complete the course in the quickest possible time. The Yo-Yo intermittent recovery level 1 test (YYIRTL1) was used to assess high-intensity running performance, due to the strong relationship with match running performance in soccer (r = 0.71). Players were given one warning if they did not meet the required running speed, before being withdrawn on the second time of doing so.

All participants were familiar with the testing protocols, having completed all of the tests previously. Testing was completed in an air-conditioned indoor sports hall at the same time of day in an attempt to minimise any possible influence of circadian rhythm or environmental conditions on test performance. Post-testing was carried out 72 hours following the final training session. Participants were asked to prepare for each of the testing sessions in the same way, refraining from strenuous activity in the 48 hours before testing, whilst maintaining a consistent diet.

**Statistical Analysis**

Data are presented as mean ± standard deviation. Training load data were analysed using a mixed linear model (SPSS v.22, Armonk, NY: IBM Corp) with random intercepts to estimate within-player variability. The effects of repeated-sprint training on our selected measures of fitness were analysed using customised spreadsheets. Within-group changes were analysed using a post-only crossover spreadsheet, while between-group changes were analysed using a pre-post parallel-groups spreadsheet. This pre-post parallel group spreadsheet also calculates individual differences in response to an intervention, which are often highly variable. All outcome measures were log transformed and then back transformed to obtain percent differences, with the uncertainty of estimates expressed as 90% confidence limits (CL). Standardised thresholds for small, moderate, and large changes (0.2, 0.6 and 1.2, respectively) derived from between-subject standard deviations of the baseline measures were used to assess the magnitude of all effects. Inferences were subsequently based upon the disposition of the confidence interval for the mean difference to these standardized thresholds and calculated as per the magnitude-based inference approach. Differences in sprint, jump and agility performance were evaluated mechanistically (classified as unclear when the CL overlapped both substantially positive and negative thresholds by >5%), while YYIRTL1 performance was evaluated clinically (i.e. unclear when the CL indicates a benefit: harm ratio of ≤66). Clear inferences were qualified using the following scale: 25-75%, possibly; 75-95%, likely; 95-99.5%, very likely; >99.5%, most likely.

**Results**

**Training Load Quantification**

Mean total set times of 161.2 ± 5.5 s and 158.3 ± 7.1 s were recorded for the STR and CoD repeated-sprint groups, respectively. Training load data for both groups, along with between-group comparisons are displayed in Table 2. All training load measures were higher in the STR group with the magnitude of effects ranging from small to large. The within and between-player variability in peak heart rate (%HR\(_{\text{max}}\)) was 7.5 (±90% confidence limits 0.6) and 3.3 (±1.4) percentage points, respectively, while the variability in mean heart rates (%HR\(_{\text{mean}}\)) was 6.5 (±0.4) and 3.0 (±1.3) percentage points. Maximal training velocity had a within- and between-player variability of 3.5 (±0.3) and 5.1 (±1.8) %, while the variability in player load was 6.3 (±0.5) and 12.0 (±4.2) %, respectively.
Outcome measures

Within- and between-group analyses on the percentage change in all outcome measures are displayed in Table 3. The STR and CoD training programs had large beneficial effects on 5, 10 and 20-m sprint speed in both groups and moderate to large beneficial effects on YYIRTL1 performance. The effects of STR and CoD repeated-sprint training programs on countermovement jump and Illinois agility performance were unclear, as were all between-group comparisons. The standard deviation of the individual responses (within-subject variation) were greater in the STR for 10-m sprint (2.2%; ±90% confidence limits 3.7%), 20-m sprint (2.3%; ±2.5%), Illinois agility performance (1.9%; ±3.3) and countermovement jump (3.2%; ±7.1%) performance, and greater in CoD for 5-m sprint (6.1%; ±8.1%) and YYIRTL1 (5.2%; ±8.0%) performance.

Discussion

Repeated-sprint training - a popular mode of training in team sports - has recently been reported to induce simultaneous improvements in speed, power, repeated-sprint ability and high-intensity running performance. While these fitness components are central to physical performance in soccer, given the high-intensity intermittent nature of the sport, further work examining the intricacies of the dose-response relationship of repeated-sprint training is needed. As such, our aim was to investigate the effectiveness of short-term repeated-sprint training (two weeks), while also comparing two disparate modes of repeated-sprint training; straight-line versus change of direction. We report for the first time that two weeks of repeated-sprint training is sufficient to elicit substantial gains in sprint speed and high-intensity running performance. The differences in these training adaptations were unclear between STR and CoD, despite STR repeated-sprints inducing higher external and internal training loads.

The improvements in 5-m sprint performance observed for both groups demonstrate that repeated-sprint training had a large beneficial effect on the acceleration phase of sprinting. Furthermore, we observed large beneficial effects in both the STR and CoD groups for 10- and 20-m sprint performance. These effects were greater than the small and moderate pooled effects reported in a recent meta-analysis investigating the effects of repeated-sprint training in team sports athletes, despite similarities between the training protocols used. The reasons behind these differences are not yet known, although it is possible that the players in our study were less accustomed to the structured repeated-sprint training stimulus imposed than those in the previous studies. Repeated-sprint training has been suggested to elicit greater metabolic adaptations in individuals who are not well trained anaerobically, permitting greater scope for improvement in anaerobic fitness. Before the intervention period the general structure of the team’s training sessions consisted of a period of aerobic/anaerobic conditioning (mainly longer duration intervals or small-sided games) followed by technical and tactical work, with sprint-based interval training used only sporadically throughout the season, indicating that development of anaerobic fitness was not a priority. However, given that we did not monitor training before the intervention we are unable to quantify the prior training load. The moderate to large improvements we observed in high-intensity intermittent running performance (YYIRTL1) were similar to those reported following repeated-sprint training in team sports players. Taken together, these findings provide further support for the multi-component benefit of repeated-sprint training in team sports players. Our findings also suggest that the beneficial effects of repeated-sprint training occur in the early part of a repeated-sprint program given that our intervention period was shorter than many previous studies, yet our effects were similar if not greater than previously reported. The findings also indicate that the overall dose of sprint-training required to achieve benefits might be lower than previously used as in this study the players completed only six sessions in comparison to the eight or more sessions.
completed in other studies.\textsuperscript{26, 27} It must, however, be noted that our program was more intensive than many of these studies; three sessions per week were administered compared to one or two sessions per week in previous work.\textsuperscript{25-28}

The improvements in acceleration, speed and high-intensity running performance following repeated-sprint training are important given that sprinting is proposed to occur in close proximity to key moments in soccer competition\textsuperscript{29}, while improved performance on the YYIRTL\textsubscript{1} has been demonstrated to reflect an increase in very high-intensity running distance in soccer match-play.\textsuperscript{21, 22} These improvements are a likely consequence of both metabolic and neuromuscular adaptations that occur following this mode of training.\textsuperscript{5} Engaging in sprint-interval training stimulates increases in mitochondrial enzyme activity, resulting in increased phosphocreatine and muscle glycogen stores, while reducing glycogen utilization and lactate accumulation - all of which facilitate improvement in high-intensity running performance.\textsuperscript{13}

Additionally, short sprint training might facilitate morphological adaptations such as changes in muscle fibre type and contractile properties resulting in improvements in explosive anaerobic performance.\textsuperscript{30} Furthermore, neural adaptations are proposed to be one of the key adaptations leading to improved performance in power activities such as sprinting\textsuperscript{30} and it has been suggested that a series of neural adaptations occur following a period of repeated-sprint training.\textsuperscript{31} Adaptations, such as increased muscle fibre recruitment, firing frequency and motor unit synchronization are suggested to occur early on within strength/power training programs, and this might provide some explanation for the rapid improvements observed.\textsuperscript{31} However, due to the disparity in the protocols investigating this, further research seems necessary to fully elucidate the neural adaptations to repeated-sprint training.

We observed no changes in countermovement jump and agility performance in our study, which is noteworthy given that neuromuscular factors largely determine an individuals’ ability to change direction rapidly and efficiently. Our findings contrast with the findings of Attene et al.\textsuperscript{10} who reported significant improvements in countermovement jump height and agility performance with the inclusion of two changes of direction compared to one, after 4-weeks of repeated-sprint training. This improvement was attributed to increased braking and acceleration forces with more directional changes.\textsuperscript{10} It is possible that the short duration of our training intervention was insufficient to stimulate these adaptations; however, more research focussing on the time-course of adaptations to repeated-sprint training seems necessary. It is also possible that the design of our course with 180-degree turns was such that participants might have turned on their favoured side, thus promoting unilateral adaptations which might not be manifested in bilateral activities such as vertical jumping. Increasing the frequency and controlling the direction of turns potentially imposes a higher load and greater symmetry of load which might in turn lead to enhanced adaptations in these symmetrical power related activities.

Considering the maximal velocities and heart rates recorded for both groups, the repeated-sprint training provided a high-intensity training stimulus. Furthermore, our estimates of within- and between-player variability in training dose demonstrate a relatively consistent training load across the duration of the 2-week training program. The higher training loads of the STR group, contrast with much of the existing data suggesting that shuttle sprinting (i.e. 180 degree change of direction) incurs a higher systemic load.\textsuperscript{8, 9} It is possible that our findings differ with these studies due to the time-matched protocols we used. For example, Buchheit et al.\textsuperscript{8} used repeated-sprints consisting of $6 \times 25$-m sprints (either straight-line or shuttle sprints) on a 25 s cycle to compare the responses of these repeated-sprint training modes, recording mean sprint times of 4.09 s and 5.30 s, respectively. Ashton and Twist\textsuperscript{9} suggested a higher systemic load is incurred when shuttle and straight-line sprinting are completed at the same
speed; given that maximal velocity was higher in the STR group in our study, it is likely that their findings do not apply in this instance. Our findings are, however, in agreement with Buchheit et al.\textsuperscript{13} who also used time-matched protocols to compare the acute responses of straight line repeated-sprinting and repeated-sprint protocols including 45, 90 and 135 degree changes of direction – although it should be noted that they did not investigate the acute responses to a 180 degree change of direction in repeated-sprinting. Regardless of the higher physiological and mechanical load when completing straight-line sprints, the effects of these differences on performance adaptations were unclear. It is possible that the sprint or the intervention durations were insufficient to elicit clear differences in the training adaptations.

It is suggested that repeated-sprint training should be considered using a cost-benefit approach\textsuperscript{17} due to the injury risks associated with maximal sprint training. Within our study one player was forced to cease participation following two repeated-sprint training sessions due to injury, highlighting this issue, although it is speculative to assume this was caused by the repeated-sprint training alone. Optimal integration of repeated-sprint training within a concurrent training program would also appear to require further research given that the majority of the existing research has focussed on the inclusion of repeated-sprint training in isolation. Considerable variation in work: rest, sprint distance, the presence of a change of direction in addition to wide variations in training frequency and program duration typically characterize the research in this area. Although our study provides some clarification regarding the inclusion of a change of direction and the rapid benefits of repeated-sprint training following a two week program, further research is welcomed.

Though our findings show clear beneficial effects of the two weeks of repeated-sprint training, our work has several limitations. Firstly, our study was carried out in total replacement of team training within the competitive season and we acknowledge that this might not be feasible or appropriate in many scenarios, such as periods during the season where it is essential to place greater emphasis on tactical and technical preparation. Nonetheless, our data provide evidence of the rapid fitness improvements that can be achieved via repeated-sprinting. Secondly, we were unable to assess the effects of the training interventions on match running performance. Given the difficulties in accurate assessment of physical performance, we chose to use reliable and valid performance measures such as YYIRTL\textsuperscript{1} performance.\textsuperscript{21, 22} Thirdly, we chose not to assess repeated-sprint ability within this study. Given the similarities between the training and any potential testing protocols (and the lack thereof of a gold standard testing procedure), we felt that this was not an appropriate way of assessing the effects of repeated-sprint training.\textsuperscript{25} Furthermore, given the range of repeated-sprint testing procedures, many of which include a change of direction, choosing either a straight-line repeated-sprint test or a test including a change of direction would likely have favoured one of the training conditions,\textsuperscript{32} whilst the applicability of repeated-sprint testing in soccer has also been questioned in recent times.\textsuperscript{33}Fourthly, the data presented on maximal velocity and player load should be interpreted with some caution given the reliability and validity issues of GPS when monitoring short sprinting.\textsuperscript{34} Although we did not use differential ratings of perceived exertion (dRPE) to monitor training load, this would have provided greater insight into the training stresses placed on the players both centrally and peripherally. However we felt there was insufficient time to familiarize the participants with the Borg CentiMax scale commonly used to assess dRPE\textsuperscript{35}, given that this intervention was carried out in-season. Finally, we acknowledge our relatively small sample size, which was a consequence of the intervention being carried out in-season, making it logistically difficult to recruit more participants from a similar population. However, the fact that the intervention was carried out in-season increases the ecological validity of the study.
Practical Applications

Given the importance of anaerobic and aerobic fitness in soccer\(^1,\,4\), training modes that can simultaneously stimulate adaptations in these areas are highly sought after. Furthermore, time-efficient training methods such as the protocol used in this study (only \(\sim 105-140\) s of maximal work per-session) might also be very appealing to practitioners, permitting more time to be spent on tactical and technical training given that a number of fitness components are addressed simultaneously.\(^36\) In a recent meta-analysis we demonstrated the beneficial effects of repeated-sprint training on a variety of fitness components in training programs 4-12 weeks in duration.\(^3\) This study develops these findings by demonstrating that as little as two weeks of repeated-sprint training stimulates improvements in acceleration, speed and high-intensity running performance. Our findings have important practical applications within the training process for soccer, particularly at times where rapid development of fitness is required or during times when training time is limited, i.e. in periods of fixture congestion\(^5\), and would seem applicable for use in soccer at all competitive standards. Though our results demonstrate higher internal and external training loads in straight-line compared to change of direction repeated-sprint training, the training adaptations between the training modes were unclear statistically, meaning further work is necessary. Future research should also focus on determining whether a longer duration intervention period elicits clear differences between straight-line and change of direction repeated-sprint training given the differences in training load that we observed. Although we have further demonstrated that repeated-sprint training is effective in the rapid development of soccer specific fitness, as proposed by Buchheit\(^32\), the most appropriate way to integrate repeated-sprint training into the overall training program of team-sports players’ still requires attention.

In conclusion, substantial improvements in acceleration, speed and high-intensity running performance following only two weeks of repeated-sprint training demonstrate the usefulness of this mode of training in soccer. While it appears that straight-line repeated-sprint training elicits a greater training load, we observed no clear differences in the training adaptations between change of direction and straight-line repeated-sprint training following a two-week training programme. There is a need for further research investigating how manipulating programming and within-session variables affects the training responses/adaptations to repeated-sprint training.
References


