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Influence of Fatigue on Change of Direction Performance in Soccer Players

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ABSTRACT

International Journal of Exercise Science 13(1): 656-666, 2020. We investigated the acute fatiguing effects of sprint interval training (SIT) on change of direction performance in male and female soccer players. A T-test was performed once before (PRE) and twice following (POST 1 and POST 2) the completion of four sets of 4 s cycle ergometer sprints protocol. The sprint intervals were separated by 25 s active recovery. POST 1 was performed approximately 25 s following the final cycle sprint and POST 2 began two minutes after completing POST 1. Repeated measures ANOVA and Bonferroni post hoc tests were used to determine any significant differences in the time to complete the T-tests. The average power output drop measured during cycle SIT was 30.7 ± 9%. Time to complete the T-test significantly differed among the three tests (PRE: 10.46 ± .17 s; POST 1: 11.67 ± .33 s; POST 2: 10.96 ± .19 s; $F(2, 54) = 6.174$, $p = .003$). Post hoc test revealed an increase in time from PRE to POST 1 ($p = .002$) but no difference between PRE and POST 2 ($p = .473$). Nine participants (48%) were unable to complete POST 1 without errors; however, ten (52%) participants recovered enough to perform POST 1 without error. These results show that acute fatigue from SIT impairs change of direction performance, but performance can be recovered within a few minutes of rest. Coaches can combine fatigue inducing drills and change of direction training into same sessions with the right rest interval between the training modes.

KEY WORDS: Performance, coaching, conditioning, speed training, team sport.

INTRODUCTION

Change of direction is an explosive total body movement relying on the ability to change speed and direction rapidly (12, 14, 15). It is a planned movement, that compared to agility does not depend on stimuli (26, 29). Therefore, in order to maximize training efficiency for change of direction performance and agility, the two should be trained independently (12, 29).

Change of direction is often viewed as a determinant to overall sport performance (24, 26) and occurs repeatedly during field sports. Fatigue following these high metabolic and neuromuscular demands will alter performance negatively (23). The many physical components required in playing soccer makes conditioning of soccer players challenging (14). High intensity interval training (HIIT) is a beneficial way to physically prepare the athletes by mimicking the energy demands required during a soccer game (12, 14). Furthermore, the time efficiency of HIIT allows a coach to work on multiple physical components of soccer performance in the same session. This is especially important during in-season, when training time is limited and athletes experience a high training volume. HIIT has previously shown improvements in multiple components related to optimizing soccer performance (11, 28).

Bogdanis et al. (2) found that the main cause of fatigue during HIIT is reduction in the energy-providing substrate, phosphocreatine (PCr). As energy provided by PCr decreases, energy provided through glycolysis increases. However, the energy turnover rate is slower during glycolysis compared to the PCr system, which results in reduced power output and will affect high intensity performance negatively (2, 3, 19).

Since the average sprint in soccer lasts about 2-4 s (28), short duration of high intensity interval training, also referred to as sprint interval training (SIT), is feasible for soccer players. By inducing fatigue through SIT, soccer athletes can be put under game like situations, causing both the physiological and psychological stress needed to further develop change of direction skills (12, 25). However, high levels of fatigue will impair the implementation of proper technique. Therefore, it will negatively affect skill performances, such as change of direction technique, landing mechanics, basketball shooting, and kicking velocity (6, 30). Poor mechanics will increase the injury risk during activities like change of direction, that have high explosive neuromuscular demands, and affect performance both during practice and in competition (4, 9, 12, 13). Fatigue induced training through SIT should therefore be implemented with caution when technical proficiency is the goal (12).

To ensure optimal benefit from skill related practice following SIT whilst maintaining a safe performance, fatigue drop should only be imposed to a certain point (5). Skill-related performance can be maintained without a decline in mechanical performance if fatigue does not exceed 10% of maximal power output (1, 21). With respect to speed, fatigue should not lead to an increase in performance time exceeding 7 - 10% (23). However, controlling for power output drop during conditioning sessions in field settings are problematic.

Little research has been conducted on how to successfully combine SIT with change of direction training, without compromising performance or the remainder of practice. Therefore, the purpose of this study was to investigate the fatiguing effects of cycle SIT on change of direction performance, and if change of direction performance can be fully recovered following a short rest period. We hypothesized that cycle SIT will decrease change of direction performance, however the change of direction performance can be recovered with following at least two minutes of rest.

METHODS

Participants

In order to be eligible for this study, participants were required to have at least three years of competitive soccer experience, competing at college level within the last five years, and no injuries or illnesses that had kept the athlete from competition in the three months prior to testing. Both male and female soccer players were invited to participate in this study during their post-season. None of the athletes were under 18 years old (table 1) and all signed informed consent prior to participating in the study, approved by Barry University Institutional Review Board.

Table 1. Participant demographics mean ± SD

	Participants (*n*)	Age (year)	Height (cm)	Weight (kg)
Males	9	22.0 ± 2.0	180.0 ± 7.8	80.0 ± 11.6
Females	10	20.0 ± 2.0	166.0 ± 4.5	64.5 ± 4.6
Total	19	20.9 ± 2.2	172.6 ± 9.2	71.8 ± 11.6

Protocol

SIT is known to cause fatigue, which may negatively impact neuromuscular skills such as change of direction, yet SIT is a vital component of a strength and conditioning program. We sought to investigate the effects of SIT on change of direction performance and used time to completion of the T-test as our dependent variable. The T-test is an acceptable test for change of direction in soccer players and has shown high reliability (r = .89) in male soccer players (16). Collegiate male and female soccer athletes performed the change of direction test prior to SIT and twice following SIT. SIT was performed on a cycle ergometer and consisted of four sets of 4 s cycle ergometer sprints protocol separated by 25 s of active recovery at self-selected pace.

Based on the average sprint duration seen in soccer games, 2 - 4 s (28), a cycle SIT protocol was developed. Similar protocols have been used to simulate game situations in field hockey (27), a sport that contains movement similar to soccer. The cycle SIT protocol was performed no more than five minutes after completion of the two pretests T-test. The sprint protocol was performed with a resistance corresponding to 7.5% of the participant's body mass. The participant was instructed to accelerate to maximal cycling cadence. Once a plateau in maximal cycling cadence was observed, the weight was applied to the flywheel by the primary investigator. Subject remained seated while attempting to keep cycling cadence as high as possible during the four sets of 4 s cycle ergometer sprints protocol. Between sprints, 25 s active recovery at a self-selected pace with a .5 kg load was performed. At the end of the 25 s recovery, the participants received instructions to accelerated towards maximal cycling cadence to begin the next resisted sprint. This procedure was repeated for all four sprints and time was controlled through Monark Anaerobic Test software version 3.0.1 (Monark Exercise AB, Vansbro, Sweden). Vocal encouragement was given during all sprints for maximal performance. Fatigue during the sprint protocol was expressed as the percentage difference between the highest and lowest average power output achieved during the sprints. The T-test was performed two times following the cycle SIT protocol. Once the final cycle sprint was completed, participant was escorted to the gymnasium to perform the first change of direction test post-fatigue (POST 1) within 25 s. After the completion of the POST 1 change of direction test, the participant was given additional two minutes of rest before performing the final change of direction test, POST 2. Meaning that the total rest time prior to POST 2 following the SIT protocol was about two and a half minutes.

Each participant completed three different sessions. The participant practiced the T-test in the first two sessions to avoid changes in time due to learning effects. Height and weight were gathered in the third session prior to the warm-up. The warm-up was performed on the Wingate cycle ergometer (Monark 874-E, Vansbro, Sweden), with the seat adjusted according to ACSM recommendations (~25-degree knee flexion at maximal leg extension) (20). Five minutes standardized warm-up was performed at 75 revolutions per minute (rpm) with a resistance of .5 kg including three maximal cycle sprints in the last 15 s of the 2nd, 3rd and 4th minutes of the warm-up. After the warm-up, the participant performed 10 minutes dynamic warm-up specific to change of direction performance led by a certified strength and conditioning coach. The warm-up consisted of jogging, high knees, butt kicks, lateral shuffles, backpedaling, and linear and lateral acceleration and deceleration. This routine was followed by dynamic stretches for the anterior and posterior hip and thigh muscles.

The T-test was performed on a wooden floor and included linear forward and backwards running, and lateral shuffling. Four 30 cm high cones were used and positioned as markers for turning points. The participant began the test with both feet behind the start line (A) (either in an athletic or staggered stance) and began the test volitionally by sprinting 9.14 m forward, touching the first cone with the right hand (B), shuffling 4.57 m to the left touching the cone with left hand (C), shuffling right 9.14 m touching the cone with the right hand (D), shuffling left 4.57 m back touching the cone with the left hand (B), and finally backpedaling 9.14 m to the starting point (A).

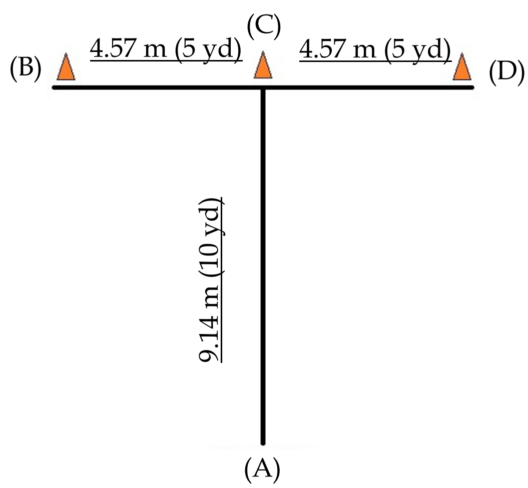

Figure 1. The T-test configuration.

Performance error included crossing the feet, falling, failing to touch the cones, failing to touch the cones with the correct hand, or failing to perform the tests with assigned rest time between T-tests (2 min) or SIT protocol (25 s). No verbal communication or encouragement was given during the T-tests. Prior to the SIT protocol, each participant performed two Tests serving as the baseline, separated by three minutes to ensure sufficient recovery between tests. The best of these tests was used as the baseline (PRE). The tests were followed by the SIT protocol and two additional T-tests (POST 1 and POST 2). Each T-test was recorded with a video camera. Each video was downloaded to a computer for subsequent analysis in Dartfish Prosuite software version 8.0 (Dartfish, Atlanta, GA, USA). The video timestamp was rounded to the nearest .01 of a second and was analyzed using frame-by-frame, 30 frames per seconds. The start point of the T-test was determined as the point at which the second foot lost contact with the ground, behind the start line. The finish point of the T-test was determined as the first contact of a foot with the ground, on or over the finish line.

Further assessment of the change of direction performance included the analysis of the left and right foot ground contact times (GC L and GC R), forward motion time (LIN F), lateral motion time (LAT) and backward motion time (LIN B). GC L was calculated as the time period between initial ground contact of the left foot at point C to toe off of the left foot. GC R was calculated as the time period between initial ground contact of the right foot at point D to toe off of the right foot. LIN F, LAT and LIN B times were analyzed as the duration between toe off of the first and ground contact of the last step in the direction of the movement. Two technicians analyzed all the videos, frame-by-frame as described above. Each technician identified the beginning and the end of the T-test. The technicians compared and contrast their finding and identified the agreeable best test time, which was kept for analysis.

Statistical Analysis

Data were analyzed with PASW statistics version 24.0 (SPSS Inc, Chicago, IL, USA). To test the reliability of the T-test, mean difference in time to complete both PRE tests were tested. Using a dependent student t-test and a Pearson Product Moment, correlation coefficient was calculated. A one-way ANOVA repeated measures was used to test for significant main effects in the time to complete the T-test, power output drop, and running variables between the PRE, POST 1, and POST 2 conditions. Bonferroni post hoc test was applied when a significant difference was observed among the tests. The independent variables were the SIT protocol and time after the SIT protocol. The dependent variables were the T-test completion time, power output drop, ground contact time and running variables time. Data were expressed as mean ± standard deviation (SD) and significance level was set at $p < .05$.

RESULTS

Effect size for the change in T-test time (PRE, POST 1, POST 2) was .487 and power .988 based on $p = .05$. Effect size for power output drop was .87, power 1.00 based on $p = .05$. The T-test reliability was found to be high. Mean time for PRE 1 was 10.63 ± .73 s. and mean time for PRE 2 was 10.4 ± .67 s. There was no significant difference between the means ($p = .085$) and since PRE 1 and PRE 2 showed high correlation ($n = 19$, mean difference .18 ± .2 s, $r = .928$), the test resulting in the best score was used for analyses (PRE). In the cases where one test was performed incorrectly, the other test was used in the final analyses.

Significant main effect was found (F (2, 54) = 6.174, $p = .003$), mean times during the T-test ($n = 19$) was 10.46 ± .74 s for PRE, 11.66 ± 1.47 s for POST 1, and 10.95 ± .81 s for POST 2. Post hoc analysis revealed that there was a significant difference between PRE and POST 1 ($p = .002$), but no significant difference between PRE and POST 2 ($p = .473$). The relative time difference between PRE and POST 1 ($n = 19$) was 11.7% and 4.8% between PRE and

POST 2.

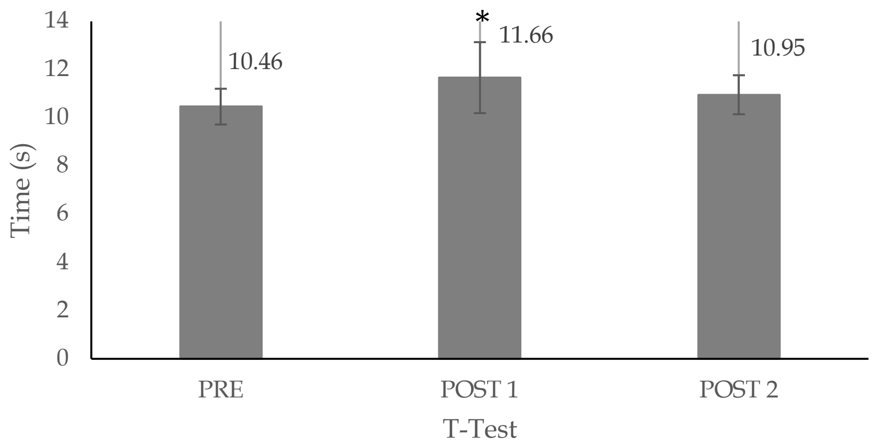

Figure 2. T-test performance time before and after the cycle SIT protocol (n = 19). * Significantly different from "PRE" (p < .05).

Out of the 19 participants, 10 (52%) completed all three tests without performance error. Out of the nine who had an error during POST 1, one participant fell, two participants stumbled, two did not touch all cones, and two crossed their feet. Additionally, two participants failed to complete the test at the right times, one due to technical difficulties with the cameras and the other one due to dizziness following the cycle protocol. A second analysis was made for the 10 out of 19 recruited subjects that performed POST 1 correctly (n = 10). Mean T-test time (n = 10) was PRE = 10.42 ± .75 s, POST 1 = 11.33 ± .89 s and POST 2 = 10.90 ± .70 s. A significant main effect difference was seen (F (2, 27) = 3.369, p = .049) between tests. Post hoc showed that there was a significant difference between PRE and POST 1 (p = .045), but not between PRE and POST 2 (p = .544). The increase in time between the PRE and POST 1 was .91 ± .35 s, which is equal to an 8% increase in time. On the other hand, the remaining subjects (n = 9) who performed the test with errors had a 15% increase in time from PRE to POST 1.

Analysis of running variables for the group (n = 19) showed that there was no significant main effect difference in GC L and GC R between the three T-test times (table 2). There was a significant difference between PRE and POST 1 in LIN F (F (2, 54) = 7, 275, p = .002), LAT (F (2, 54) 6.586, p = .003) and LIN B. (F (2, 54) = 6.008, p = .004) but no significant difference in any of the variables between PRE and POST 2, or POST 1 and POST 2.

Table 2. Analysis of Running variables mean ± SD (n = 19).

	GC L	GC R	LIN F	LAT	LIN B
PRE (s)	.43 ± .07	.44 ± .07	1.77 ± .12	5.95 ± .40	2.58 ± .38
POST 1 (s)	.50 ± .08	.49 ± .15	2.02 ± .26*	6.65 ± .77*	3.01 ± .40*
POST 2 (s)	.47 ± .09	.42 ± .08	1.88 ± .11	6.20 ± .42	2.79 ± .28

Note: * Significantly different from "PRE" (p < .05)

The average power output during the cycle SIT protocol is illustrated in figure 3. The mean power output drop between sprint one and four was 30.20% with the greatest drop (16%)

occurring between sprint one and two. There was a significant main effect between power output drop, (F (3, 72) = 3.869, p = .013). Post hoc showed that there was a significant difference in power output drop between sprint one and four (p = .013).

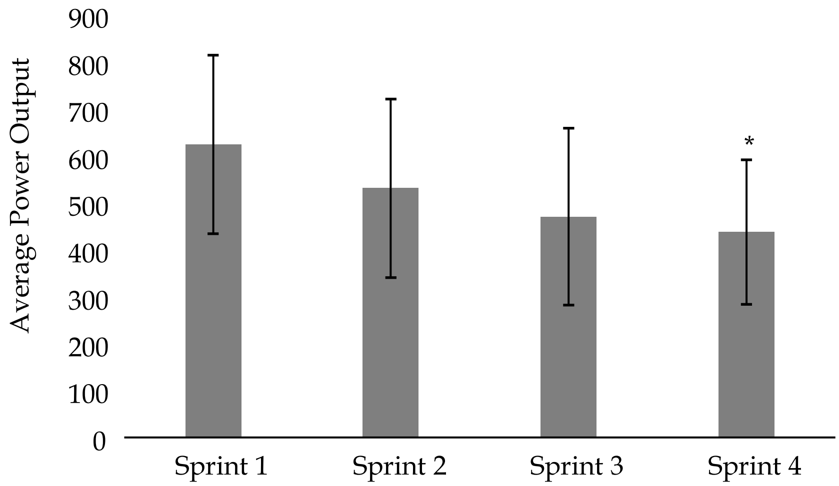

Figure 3. Average power output (W) for each sprint during the cycle SIT protocol. Sprint 1: 624.61 ± 190.32 W, sprint 2: 531.03 ± 190.29 W, sprint 3: 470.71 ± 188.55 W, sprint 4: 437.80 ± 154.08 W. * Significantly different from "Sprint 1" (p < .05).

DISCUSSION

The purpose of this study was to determine if a fatiguing bout of SIT cycling protocol would affect change of direction performance and if performance could be recovered following a short rest period. As we hypothesized, change of direction performance was impaired immediately after the completion of the SIT cycling protocol, more specifically 25 s after. However, performance was recovered within two minutes after the completion of the SIT cycling protocol.

There are multiple models used to explain fatigue. The theory of task-dependency describes how the type of muscular fatigue (central or peripheral fatigue) depends on the characteristics of the activity performed, thus fatigue inducing components during sprinting would be: metabolic demand, increased acidosis, neural components, and pain tolerance (18, 19, 22). However, most research have indicated that peripheral fatigue and the ability to reproduce ATP from PCr were the main causes of fatigue during repeated sprinting (1, 2, 17,19). The initial decrease in PCr starts the accumulation of byproducts from glycolysis (such as hydrogen ions). This may impair mechanical performance and the contractile mechanism (3). Additionally, byproducts accumulation and depletion of ATP substrates occurs simultaneously during heavy and intense exercise, such as SIT. Therefore, it is challenging to differentiate the main contribution to fatigue (2, 3, 19).

Short cycle protocols have previously been used for sport-specific purposes to simulate, assess, and improve repeated sprinting ability (8, 17, 27). A study by Gaitanos et al. (7) found that 10 x 6 s cycle sprints separated by 30 s recovery decreased mean power output by 27% among male participants, corresponding to an anaerobic energy contribution of 35.6%. Our SIT protocol was based on the average sprint duration (2 – 4 s) and repetitions (3 - 7) observed among field sports (27). The similarity between our protocol and the protocol by Gaitanos et al. (7) led us to believe that four sets of 4 s cycle ergometer sprints protocol would be sufficient to cause fatigue and influence change of direction performance. Fatigue was seen through drop in average peak power output, 30.2 ± 9%, during the cycle sprints with no significant difference between genders (males 30.48 ± 7%, females 29.95 ± 11%).

The participants in our study were unable to reproduce change of direction performance following cycling fatigue. Likewise, the participants in the study by Rampinini et al. (21) showed decreased sprinting ability and maximal voluntary contraction due to fatigue following a soccer game. Interestingly, short-passing ability was maintained and may be attributed to the difference in induced peripheral compared to central fatigue.

Change of direction relies on eccentric muscle actions. Therefore, another reason for altered change of direction performance, is the impaired stretch shortening cycle (SSC). Due to the linear relationship between eccentric hamstring strength and the ability to produce power, acceleration movement will be negatively affected when eccentric muscle actions and SSC are impaired (6, 9, 22). Cortes et al. (5) looked at biomechanical alterations in change of direction performance following fatigue among soccer players. The participant performed change of direction tests both with and without sufficient recovery. They found that fatigued athletes achieved less knee flexion and greater hip flexion, which decreased the ability to utilize SSC. Less knee flexion following fatigue in running could be an unconscious attempt to reduce stress on the hamstrings. This will affect speed by decreasing stride length, possibly by a restricted swing-phase, and decreased cadence due to increase in ground contact time (10).

Some of these biomechanical alterations can explain the differences in running time variables seen in our study. However, ground contact time did not show statistically significant difference. Ground contact time has shown to be more affected when performing fatigue induced agility (4). This is likely to be explained by a delay the muscles reaction to a stimulus, called reflex-responds, after fatigue that puts higher demands on the CNS (30).

Ruscello et al. (23) state that to maintain performance and avoid mechanical alterations, changes in performance should not exceed 7-10% of that performed in a non-fatigued state. Their theory applied to our study would mean that an athlete would have been too fatigued, following the SIT protocol, if ones T-test time would have increased by >10%. The group of athletes, not performing any errors, increased their change of direction time by 8%. Since they were able to perform the drill correctly and implement proper mechanics, their change of direction performance can benefit from such fatiguing session.

Anatomical limitations in lateral ankle and knee flexibility makes lateral movements performed under high speed more likely to disrupt stability (24). However, only female participants (n = 3) fell or stumbled. As average power output drop was similar between genders, it is possible that there are other performance differences among genders. Balance is a predictor of change of direction performance in trained adult males, while strength and power are better predictors for women (24). Turner et al. (28) have stated that the higher frequency of knee related injuries among females is correlated to their lower hamstring strength and neuromuscular control compared to males. Women has shown greater decrease in stride length compared to men following fatigue (10). It is therefore possible that peripheral muscular fatigue will have greater effect on change of direction performance among females than males.

Following the two minutes of passive recovery after POST 1, it was evident that agility performance was recovered. The work by Bogdanis et al. (2) has shown that the majority of the PCr restoration occurs in the first few minutes of recovery. After a 30s cycle sprint, untrained people restored majority of their PCr levels within 1.5 min passive recovery (from 15.1 ± 1.0 to 49.7 ± 1.1 of the total resting 77.1 ± 2.4 mmol/kg dry muscle mass), followed by a slower PCr restoration rate. However, since active recovery has shown to be more efficient following short duration SIT (27), and recovery duration may be influenced by the type of athlete, it is possible that our participants recovered PCr at a faster rate. Soccer athletes are well rounded and have great aerobic capacity (28). Aerobically trained athletes have shown to recover PCr levels 40% faster than untrained and anaerobically trained athletes (21). Therefore, the characteristics of the sport need to be taken into consideration when determining recovery duration following SIT. Additionally, since the structure of the study controlled the recovery times between SIT, POST 1 and POST 2, it is possible that the athletes could have shown recovered change of direction performance sooner following SIT, if being allowed to dictate recovery time by themselves. However, based on our result we can conclude that two minutes is sufficient to recover change of direction performance following fatigue-induced SIT cycle protocol in soccer players.

We conclude that change of direction drills can be safely performed following two minutes of fatigue-inducing SIT cycle protocol in soccer players. Based on previous research on SIT, we support the use of repeated sprint interval protocols combined with change of direction training for athletic development. Coaches should be encouraged to implement SIT into their conditioning routines, especially during seasons when practice time is limited, and athletes already experience high volume training. Maintaining change of direction performance throughout the competition and season is important, since research has shown a correlation between change of direction performance and athletic level (26).

Even though cycling is not sport specific, the physiological benefits of cycle sprints are well supported. Enabling incorporation of short cycle sprint protocol as part of strength and conditioning technique could, therefore, be beneficial as a conditioning mode for soccer players. It brings variety to their training routines by putting a different muscular demand on the athletes, assist in producing well-rounded neuromuscular adaptations, and avoid training plateau. To avoid a performance plateau and achieve training goal, it is important for coaches to understand that recovery duration required will vary depending on the athlete, mode of SIT, and change of direction drill. To better define training guidelines, we suggest further research on the topic, examining variations seen with different SIT protocols, on a variety of athletes, in both change of direction performance and sport specific skills. Our findings can assist coaches in implementing fatigue-induced training. Stimulating game-like environment that challenges the athletes while controlling fatigue will improve performance while minimizing the risk of injuries by enabling the use of proper technique.

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