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Original Research

Differences in Physiological Responses Between Two Repeated Sprint Protocols in Female Soccer Players

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ABSTRACT

International Journal of Exercise Science 17(6): 1605-1617, 2024. Soccer is a team sport characterized by repeated high-intensity sprints followed by brief periods of recovery. Repeated sprints with (RCOD) and without (RSA) change-of-direction has therefore been recognized as an important fitness component. The purpose of the present study was to examine the differences in physiological responses between RSA and RCOD, and the relationship with Yo-Yo intermittent recovery test (YYIR1), as an estimate of aerobic capacity, in female soccer players. Thirteen female soccer players (age: 20.8 ± 2.6 years) participated. All players performed an RSA and RCOD test, as well as a YYIR1 test. Total time, fatigue (dec%), lactate ([La]b), rating of perceived exertion (RPE) and heart rate were recorded for each sprint test along with total distance covered in the YYIR1. RSA induced significant higher dec% (8.0 ± 3.0% vs. 5.0 ± 2.4%, p = 0.008, ES = 0.89), [La]b (13.5 ± 3.1mml/L vs. 9.9 ± 3.0mml/L, p = <0.001, ES = 2,25) and RPE (8 vs. 7, p = 0.003, ES = 1.0) compared to RCOD. The heart rate recovery was significantly faster for RCOD compared to RSA (173 ± 11 bpm vs. 178 ± 8 bpm, p = 0.02, ES = 0.89). No significant correlation could be found between aerobic capacity and RSA and RCOD variables. RSA was a more physiological taxing test compared to RCOD when the protocols were matched for sprint duration. This information can help athletes and coaches that are involved in women's soccer to design and adapt training strategies in the future.

KEY WORDS: Repeated sprint ability, repeated change of direction, women, football

INTRODUCTION

Soccer is a team sport characterized by high-intensity work that consists of short sprints followed by brief periods of active or passive recovery (32). Players are therefore required to perform repeated maximal efforts without complete recovery, which during a game could lead to increased fatigue and deterioration in performance (22). Repeated sprint ability (RSA) has therefore been recognized as an important fitness component to train and master for enhanced game-related performance in soccer (2).

The original RSA test is limited to a forward sprint without taking into consideration the deceleration or change of direction movements included in soccer game situations (23). In

accordance, previous research has shown that soccer players perform intermittent high-speed changes of direction movements during games (5). Consequently, repeated sprints with change-of-direction (RCOD) is considered an important fitness component alongside RSA (12,24). Through the identification of RSA and RCOD as an important fitness component in soccer, coaches and researchers regularly implement different repeated sprint tests, with or without change of direction, to evaluate and enhance performance (10,36). Despite the widespread use of RSA and RCOD in sports, the differences in physiological responses between the two tests are not yet well understood.

The ability to quickly change direction requires athletes to perform fast deceleration and re-acceleration, making RCOD a more complex movement than RSA (14). When a test or game contains changes in speed and direction, it impacts the muscular demand and, consequently affects the energy cost compared to straight-line running (13). Previous studies that have compared the physiological differences between RSA and RCOD incorporated the same sprint distance and rest period leading to higher work:rest ratio for RCOD; as the RCOD test required longer work time due to the change of direction movement (13,14,36). Consequently, making a direct comparison of the physiological responses between RSA and RCOD is challenging. Buchheit et al. (9) compared RSA and RCOD when protocols were matched based on sprint duration, and revealed higher physiological responses induced by RSA. However, their study included only males and no data are reported regarding female participants (9). To our knowledge, no study has investigated the physiological responses between RSA and RCOD in women when implementing the same sprint duration and work: rest ratio, highlighting the need for further research.

When looking closer at the energy systems used in these short maximal sprints, the primary sources of energy supply during the first and following sprints are anaerobic metabolism, phosphocreatine (PCr), and glycolysis (17). As the sprints are repeated, the ATP production from anaerobic metabolism progressively decreases and the aerobic metabolism progressively increases and can go from a contribution of 10% in the first sprint up to 40% of the total energy supply during the last sprint (17).

The theory that high aerobic capacity (i.e., maximal oxygen uptake) enhances athletes' ability to perform repeated sprints specific to team sports has resulted in a new field of research in the last two decades. Studies that have examined the aerobic capacity and its relationship to different repeated sprint-tests have found conflicting results. Some previous studies have failed to find a significant correlation between individuals' aerobic capacity and repeated sprint indices (16), whereas other studies successfully found, or partly found, a significant correlation between aerobic capacity and repeated sprints (19,21,28). The discrepancy in the literature may be attributed to the significant variation in the sprint protocols used (16,19,28). In addition to variation in sprint distances and rest periods, it´s common that researchers implement either a straight sprint or sprints with a change of direction movement. Research has yet to examine the possible differences between RSA and RCOD and how they relate to aerobic capacity, as both repeated sprint actions are frequently used in game situations (16).

The existing research that examines the different aspects of repeated sprint activity is mainly limited to the male population (11), although women also participate in sports that require an increased capacity of performing maximal repeated sprints. Men and women differ regarding anthropometrics, physiology, and endocrinology, and generalizing previous research conducted on men to the female population may be difficult and inaccurate (25). Therefore, a better understanding of the differences between RSA and RCOD, and their relationship with aerobic capacity in a female population can provide valuable insights for athletes and coaches involved in women's soccer led to evidence-based training strategies. The purpose of this study was two folded: (a) to examine the differences in physiological responses between two different repeated sprint protocols performed with either straight sprint or changes of direction and (b) to investigate the relationship between indirect measures of aerobic capacity and two different repeated sprint protocols performed with either straight sprint or changes of direction in female soccer players.

METHODS

Participants

A power analysis (effect size ≥ 0.8 and a = 0.05) conducted ahead of recruitment revealed that a total of 23 participants were needed in the present study. We have therefore contacted 2 women´s soccer teams (in total 36 soccer players) and asked them to participate in the study. Thirteen female soccer players (age, 20.8 ± 2.6 years; weight, 63.4 ± 6.2 kg; height, 166 ± 6 cm) participated throughout the whole study protocol. The participants were active female soccer players aged 18-35 years, who regularly took part in soccer activities and with a training experience minimum of five years. The players' weekly training time was between 3 - 10 hours. Participants with injuries that inhibited their ability to perform the tests or had any chronic diseases or prescribed medication that affected their heart rate were excluded. The players were recruited from local soccer clubs in Umeå, Sweden. The research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (27). The study was approved by the Department´s ethical Committee at Umeå and a written informed consent was collected from each participant before testing began.

Protocol

The study was composed of four testing occasions separated by a minimum of 48 hours. On the first occasion the players visited the test lab at Umeå University for anthropometric measurements. On the second and third occasion, all players performed an RSA and RCOD test, one test on each occasion, in a randomized order. On the fourth and last occasion, they performed a Yo-Yo intermittent recovery level 1 test (YYIR1). All test sessions were conducted during pre-season, on a synthetic turf soccer field during the afternoon between 5 pm and 8 pm. Each test occasion included ambient temperature recording, with one team performing all tests indoors at a steady temperature of around 10°C, while the other team conducted their tests outdoors at approximately 4°C. Recommendations were given to the players to avoid participating in any strenuous activity 24 hours prior to testing and consuming any heavy meal within the last 2 hours prior to testing.

RSA and RCOD protocol: The participants performed a 10-minute warmup prior to the testing, including jogging at a self-selected pace and sprint drills (high knees, heel flicks, and jump steps), followed by sprint practice with and without direction changes. Within 5 minutes following the warmup, the main testing began. The repeated sprint ability test (RSA) included a 10 x 20m straight-line sprint while the RCOD test included 10 x 15m sprint with two 100° change of directions every 5m (Fig. 1). Each test was performed on a continue timer, with both RSA and RCOD commencing every 15s resulting in a work: rest ratio approximal of 1:4. The repeated sprint protocols was adapted according to previous research (14,35) with changes in rest, sprint distance and type of sprint in order to match work: rest ratio between protocols, and better reflect the demand of a soccer game (5,11).

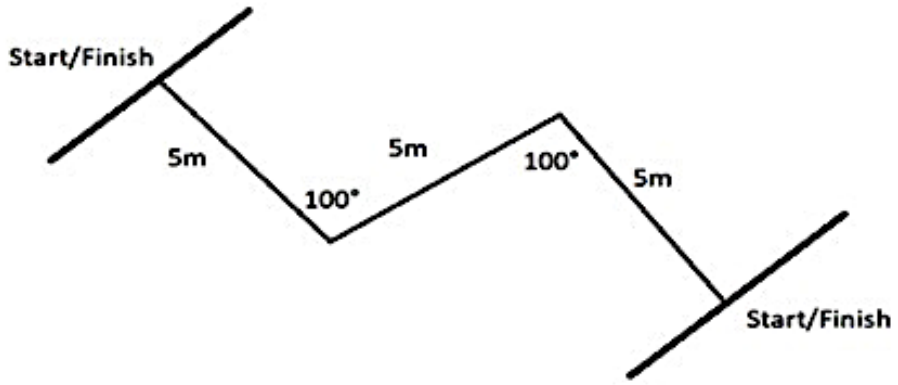

Figure 1. Schematic representation of RCOD.

All sprints began 0,5m behind the starting line with a countdown from the test leader to ensure the right starting time. The athlete sprinted back and forth between two lines, with each subsequent sprint heading to the opposite direction from the previous one, starting from the line where the previous sprint had concluded. All players were instructed to perform each sprint as fast as possible, while the test leader provided high encouragement throughout the sprint test. Sprint times were measured using a single-beamed photocell system (Microgate Witty, USA) placed at the start and finish line at a height parallel to the subject's pelvis. Each sprint time, fastest time (FT), and total time (TT) were recorded during both the RSA and RCOD test. The percentage decrement score (Dec%) was calculated using the following equation (ss): Dec% = (100 x (total sprint time ÷ ideal sprint time)) – 100, where Ideal sprint time (s) is the best time (s) x number of sprints. Dec% is used as the most valid and reliable method of quantifying fatigue in RSA (18).

Physiological responses: A fingertip blood lactate sample (5 µL) was collected three minutes after completion of each repeated-sprint test (34). Blood lactate concentration [La]b was determined using a Lactate Scout analyzer (SensLab, GmbH, Germany) (33) . Heart rate (HR) was continuously monitored (Polar Ignite, Polar Electro, Kempele, Finland) during RSA and RCOD tests, and the area under the curve for the total of 10 sprints (HRauc) and during the 60s recovery (HRRauc) was calculated. Participants' rating of perceived exertion (RPE) was

recorded directly after each repeated sprint-test using the RPE-scale proposed by Foster et al. (15).

YYIR1: YYIR1 consisted of 20-m back and forth shuttle run (40m total) between two cones, the shuttle runs were repeated until the player reached voluntary exhaustion or if she failed to complete the instructed distance for two consecutive rounds. Between each shuttle run, the player had a 10s recovery with 10m of jogging (2 x 5m) back and forth. YYIR1 starts at 10 km/h with a progressive increase in speed throughout the test. Instructions for the execution, including sprint start, turns, and stops for the individual level of speed, were regulated by an audio recorder. The test leader warned if the players fail to complete the required pace. The players performed a 10-minute general warmup, including jogging at a self-selected pace, followed by practice runs of the first four intervals before the actual test. Total distance was recorded as the outcome.

Statistical Analysis

Assumption of normality was assessed for each depended variable with the Shapiro-Wilks test and q-q-plot before further statistical analysis. All variables were normally distributed except for RPE. Significant difference in physiological response for normally distributed variables (Dec%, [La]b, HRauc, HRRauc) between RSA and RCOD was determined using a two-tailed paired T-test. Following criteria for Cohen´s d was used to determine effect size (ES): d >0.2 – 0.5, small ES; d >0.5 – 0.8, moderate ES; d >0.8, large ES (8). Wilcoxon ranking test was used to determine if there was a significant difference in RPE between RSA and RCOD. Pearson's product-moment correlation coefficient was used to examine the relationship between aerobic capacity (YYIR1 results) and RSA and RCOD variables (TT, Dec%). For interpreting the magnitude of the correlation (r) between test measures, following criteria were adopted: ≤ 0.1, trivial; 0.1 - 0.3, small; 0.3 - 0.5, moderate; 0.5 - 0.7, large; 0.7 - 0.9, very large; and > 0.9, almost perfect. All analyses were performed using Jamovi (Version 2.2.5.0). The significance level was set at $\alpha = 0.05$ for all analyses. All data are presented as means ± standard deviations (SD) if not otherwise stated.

RESULTS

Each of the 13 participants successfully completed all three test occasions. There was no significant difference in neither FT between the RSA group (3.42 ± 0.16s) and the RCOD group (3.33 ± 0.27s) ($p = 0.23$) nor in the mean sprint time (RSAmean = 3.72 ± 0.18s vs. RCODmean = 3.52 ± 0.28s, $p = 0.14$). The TT was, on the other hand, significantly ($p = 0.02$) higher for RSA (36.9 ± 1.8s) compared to RCOD (35.0 ± 2.7s). Only 10 players were included in the analysis of HRauc and HRRauc due to technical issues during heart rate monitoring.

Differences in physiological responses between RSA and RCOD: The analysis revealed a significant difference between RSA and RCOD for Dec% (8.0 ± 3.0% vs. 5.0 ± 2.4%, $p = 0.008$, 95% CI = 0.95 – 4.99, ES = 0.89) and [La]b (13.5 ± 3.1mml/L vs. 9.9 ± 3.0mml/L, $p = <0.001$, 95% CI = 2.56 – 4.58, ES = 2.25), whereas RSA presents higher values compared to RCOD (Figure 2).

The players estimated their RPE significantly higher after RSA compared to RCOD with a large ES (ES = 1.0), while their HRauc did not present any significant difference between the two sprint tests (table 1). In contrast, the HRRauc was significantly smaller for RCOD compared to RSA with a large ES (173 ± 11b vs. 178 ± 8b, p = 0.02, 95% CI = 1 – 8, ES = 0.89) (Figure 3).

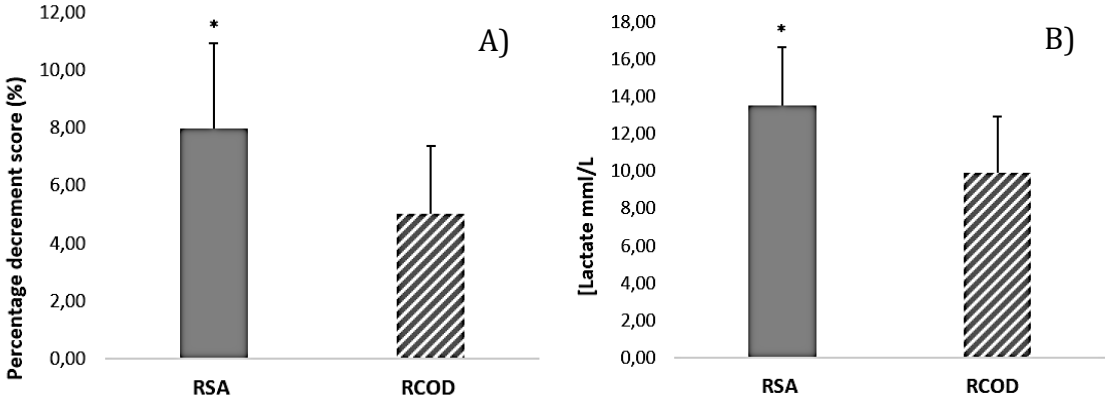

Figure 2. Percentage decrement score (A) and post lactate concentration (B) for RSA and RCOD. Significantly different from RCOD (p <0,05)(*). RSA; repeated sprint ability, RCOD; repeated change of direction.

Table 1. RPE and HRauc for repeated sprint and repeated change of direction.

	Participants: RPE n = 13, HRauc n = 10				
	RSA	RCOD	p-value	95% CI	ES
RPE[1]	8 (0.0)	7 (0.0)	0.003	1.0 – 1.5	1.0
HRauc[2]	453 ± 13 b	445 ± 21 b	0.15	-3 – 18	0.50

RPE = Rating of perceived exertion, HRauc = Heart rate - area under the curve during sprint test. b = Total beats per test. [1] Presented as median (IQR). [2] Presented as mean ± SD.

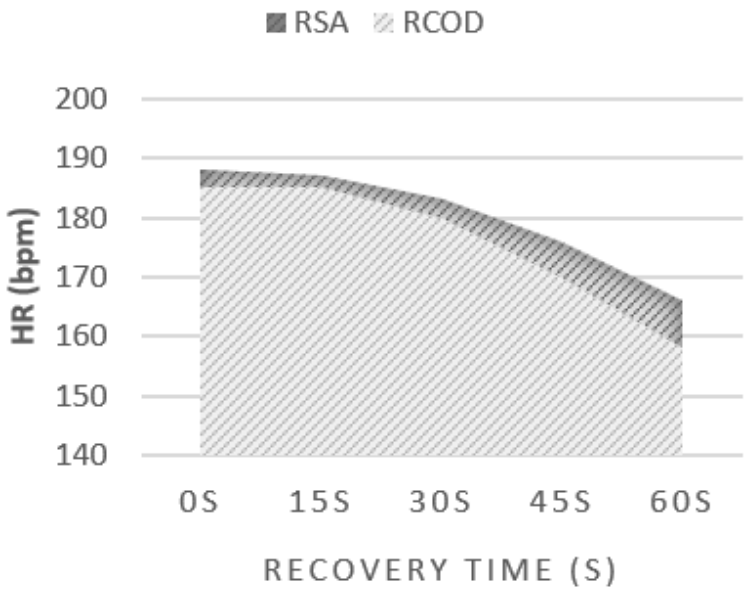

Figure 3. Area under the curve for 60s heart rate recovery for RSA and RCOD.

Relationship between RSA, RCOD and estimated aerobic capacity: There was no significant correlation found between YYIR1 and RSA TT (r = - 0.49, p = 0.09, 95% CI = 0.09 - -0.82) and RSA Dec% (r = - 0.50, p = 0.082, 95% CI = 0.07 - -0.82). Additionally, no significant correlation was found between YYIR1 and the RCOD variables TT (r = - 0.33, p = 0.28, 95% CI = 0.28 - -0.74) and dec% (r = - 0.23, p = 0.45, 95% CI = 0.37 - -0.69). The correlation matrix is presented in figure 4 for TT and figure 5 for dec%.

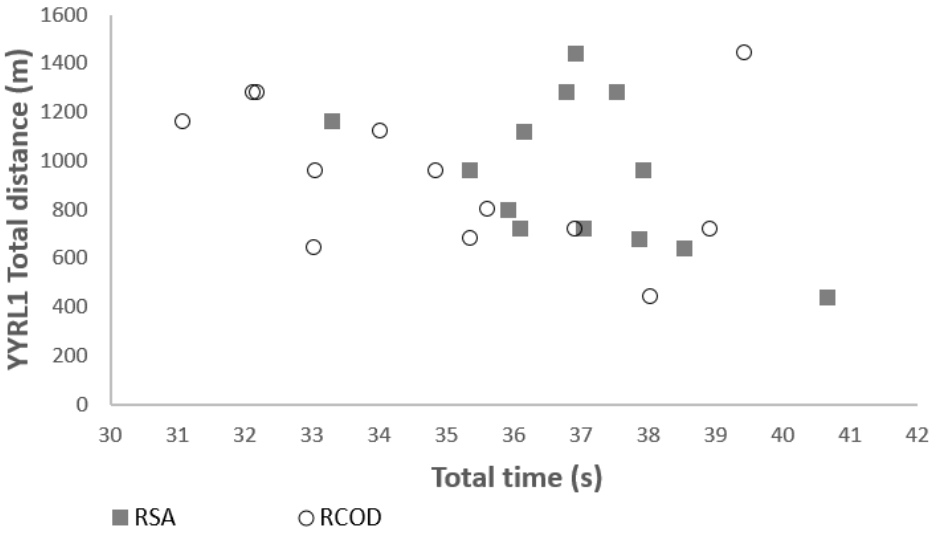

Figure 4. Correlation between RSA and RCOD total sprint time and YYRL1 test result.

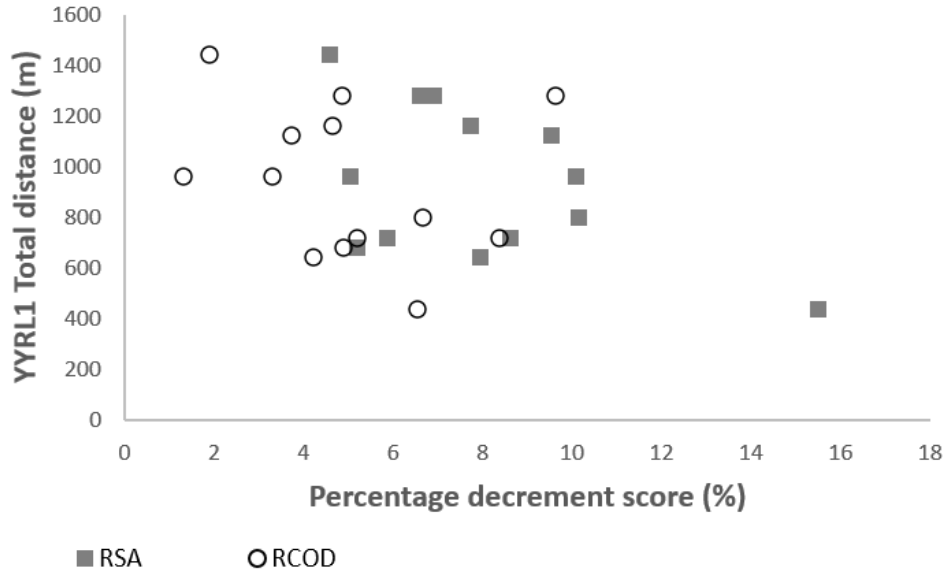

Figure 5. Correlation between RSA and RCOD percentage decrement score and YYRL1 test result.

DISCUSSION

The first purpose of the study aimed to investigate if there is any difference in physiological responses between RSA and RCOD. We observed significantly higher dec%, [La]b, and RPE by the players during the RSA test compared to the RCOD test. Furthermore, the players' heart rate recovery was significantly faster, indicated by a smaller area when calculating auc, during RCOD than RSA, despite no significant difference in heart rate during the two sprint tests.

The present results are in line with previous research showing that RSA induce higher fatigue, peak heart rate, post-lactate, and RPE compared to RCOD in male athletes when the sprint distance was matched for initial sprint time (9). These results as well as the outcomes of the present study could be due to the fact that fatigue development is inversely related to initial power output or speed during repeated sprint work (26). Straight sprints produce maximal muscle activation throughout the entire sprint; the shorter linear distance and change of direction requirement during RCOD results in lower running speed and a fluctuating muscle activation affecting fatigue development (4,20).

The theory that RCOD might require higher muscular demand and be more physically strenuous is due to the deceleration and re-acceleration that must be performed during these tests (28). Buchheit et al. (9) concluded that physiological responses might be angle dependent as they found a clear difference between 45°, 90°, and 135° angles, whereas 90° was the less physiologically and perceptually demanding angle. Conversely, as the angle increased to 135°, the physiological loads also increased, suggesting that the lower running speed is compensated by a higher muscle demand. In the present study, the RCOD test protocol included 100° changes of direction that might have produced lower muscle activation and thereafter lower physiological responses compared to a protocol in which changes of direction would be sharper (<90°) or blunter (>120°). This is supported by Buchheit et al. (8), that found similar or higher physiological responses in repeated shuttle sprints, including 180° change of direction, compared to repeated straight sprints. However, the repeated shuttle sprint protocol by Buchheit et al. (8) had a 30% longer sprint duration compared to their included repeated straight sprint test, along with the same rest period, making it hard to directly compare the effect of the included change of direction.

Even though RSA and RCOD seem to be depending on similar leg muscle qualities such as power (1), performance in RCOD can be related to other performance aspects because of its nature as a more complex movement. Agility, turning technique, and the reactive strength of the players are thought to affect the performance in RCOD (6). Specific movement training is plausible needed to utilize optimal performance and physiological responses in RCOD. This is supported by previous research that has found significant performance improvements in a change of direction test after a specific training period (37). This seems possible as the players participating in this study also expressed difficulties performing the RCOD test due to the changes in direction movements (verbal feedback after testing).

The second purpose of the present study was to investigate the relationship between RSA, RCOD and estimated aerobic capacity. The analysis showed no significant correlation between repeated sprint variables (TT, dec%) and the estimated aerobic capacity (YYIR1) in the female soccer players included in this study, regardless the type of sprint protocol.

Few previous studies have examined this relationship in a female population, and the results are contradictory. Our results are in line with Sanders et al. (30), who were not able to find any significant correlation between aerobic capacity and RSA fatigue in either male or female soccer players. Contrary, Goncalves et al. (19) found a significant negative correlation between fatigue in RSA and aerobic capacity in adult women soccer players. This difference could be due to the different repeated sprint protocols implemented. Goncalves et al. (19) implemented 35m sprints with 10s rest between each repetition, while Sanders et al. (30) used a similar distance (30m) but with a 25s rest. A variability in the number of sprint bouts, sprint distance, and rest period may require different amounts of contribution from aerobic metabolism (35). While our study had a similar rest period as Goncalves et al. (19), the sprint distance was considerably shorter (15-20m shorter), which could explain why our study didn´t find significant correlation. This could also explain why RCOD did not present any correlation with estimated aerobic capacity compared to other studies (28). Compared to the present study's 15m sprint distance, Padulo et al. (28) incorporated a 30m sprint distance and found a significant negative correlation between aerobic capacity and RCOD TT. However, no correlation could be found for fatigue index. A more physiological demanding test protocol may therefore require a higher aerobic contribution resulting in a higher correlation between the tests. Lastly, aerobic capacity is only one aspect of an individual´s aerobic fitness, and is determined by central factors (3) while repeated sprints are influenced by peripheral factors (32) and therefore a stronger association to them has been previously shown (31).

This study has some methodological limitations that should be addressed. The YYIR1 can have an 10-15% inaccuracy when estimating athletes' aerobic capacity (i.e., VO2max) (21,31), and is plausible more effective when evaluating an individual's ability to repeat high intensity exercise with both anaerobic contribution and recovery processes (2). A more accurate method for assessing the relationship between aerobic capacity and repeated sprint test is to assess VO2max through an objective measurement like the maximal incremental test. Further, sprint performance on artificial turf is generally faster compared to natural grass, particularly over longer distances and that might have affected the results. However, previous research has not shown significant differences in fatigue-related performance deterioration between the two surfaces, indicating that the impact of synthetic turf on change of direction speed and coordination may be minimal (29). Another possible limitation is that one of the teams included in the study performed all testing indoors with a constant temperature around 10°C while the other team was tested outside with a temperature around 4°C. As testing conditions can affect athlete´s performance (7), these circumstances should be taken into consideration when interpreting the results.

Last but not least, study's small sample size (13 participants) is a significant concern that affects the generalizability of the findings.

Concluding, repeated straight sprints seem to induce higher physiological stress than a change of direction protocol when protocols were matched based on sprint duration and work: rest ratio. The current findings contribute to additional knowledge about repeated sprint tests for female athletes participating in soccer. The results suggest that the tests cannot be used interchangeably due to their significant differences in physiological responses and that they instead emphasize on different physical qualities. A repeated sprint protocol of 10 x 20m with a 1:4 work:rest ratio can be useful to increase players' systematic physiological load, aligning with the demands of a soccer match. Conversely, a repeated sprint protocol matched for sprint duration and work: rest ratio, while including two 100° changes of direction, can serve as an alternative to reduce the physiological load and focus on the players´ agility and specific strength during directional changes. Enhanced aerobic capacity does not appear to directly correlate with improved RSA and RCOD performance (e.g., TT, dec%) in female soccer players. However, this may vary depending on factors such as number of sprints and sprint distance.

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