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Repeated sprint ability related to recovery time in young soccer players

J. PADULO

University eCampus, Novedrate, Italy and Tunisian Research Laboratory 'Sports Performance Optimization', National Center of Medicine and Science in Sports, Tunis, Tunisia

M. TABBEN

Faculté des Sports, Centre d'Etudes des Transformations des Activités Physiques et Sportives, Université de Rouen, Rouen, France

L.P. ARDIGÒ

School of Exercise and Sport Science, Department of Neurological and Movement Sciences, University of Verona, Verona, Italy

M. IONEL, C. POPA, and C. GEVAT

Faculty of Physical Education and Sport, Universitatea Ovidius Constanța, Constanța, Romania

A.M. ZAGATTO

Department of Physical Education, Faculty of Sciences, Univ Estadual Paulista - UNESP, Bauru, Brazil

A. DELLO IACONO

Science Life, Orde Wingate Institute for Physical Education and Sports, Netanya, Israel

This study aimed to describe the influence of recovery duration during a repeated sprint ability (RSA) test (6 × 40 m) by investigating a number of variables, such as general performance, metabolic demand, and muscular stretch-shortening performance. Seventeen male soccer outfield players (16 ± 0 years, 66 ± 10 kg) performed three field shuttle-running tests with 15, 20, and 25-sec recoveries. In addition to specific shuttle test's variables, blood lactate concentration and vertical jump height were assessed. Resulting measures were highly reliable (intra-class correlation coefficient up to 0.86).

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Address correspondence to: Luca Paolo Ardigo, School of Exercise and Sport Science, Department of Neurological and Movement Sciences, University of Verona, Via Felice Casorati, 43, 37131 Verona, Italy. E-mail: luca.ardigo@univr.it

25-sec recovery improved test performance (–3% total time from 15-sec to 25-sec recovery), vertical jump height (+7% post-test height from 15-sec to 25-sec recovery), and decreased blood lactate accumulation (–33% post-test from 15-sec to 25-sec recovery). Study findings suggest that metabolic acidosis plays a role in worsening performance and fatigue development during the shuttle test. A 25-sec recovery duration maximized performance, containing metabolic-anaerobic power involvement and muscular stretch-shortening performance deterioration during a RSA test.

KEYWORDS interval training, running, recovery, soccer, metabolism

INTRODUCTION

Soccer (association football) is a complex sport requiring the repetition of many different activities such as jogging, sprinting, and jumping (Impellizzeri et al., 2008). Outfield players are often required to repeatedly produce maximal or near-maximal sprints of short duration with brief recovery periods (Bangsbo, Norregaard, & Thorso, 1991). Therefore, the ability to repeat multiple high-speed sprints plays a crucial role in the soccer players' performance. Indeed, repeated sprint ability (RSA) is an important fitness component of the performance of team-sport athletes (Spencer, Bishop, Dawson, & Goodman, 2005). Players with good RSA will likely perform better than athletes who are less able to repeat sprint efforts at a similar intensity (Bishop, Spencer, Duffield, & Lawrence, 2001). It is known that performance and fatigue (Granatelli et al., 2014) during repeated sprints are influenced by the amount, intensity, duration, and distribution of work periods (Gaitanos, Williams, Boobis, & Brooks, 1993). During repeated sprints, the recovery duration represents a key factor. The recovery duration determines the overall mid- and long-term sustainable intensity of exercise and, if sufficient, also prevents fatigue (Balsom, Seger, Sjödin, & Ekblom, 1992).

The influence of recovery duration on performance during repeated sprints has been previously reported for different modalities of recovery (i.e., passive vs. active recovery) (Brown & Glaister, 2014; Castagna et al., 2008; Dupont, Blondel, & Berthoin, 2003), different types of recovery patterns (i.e., changing the recovery-to-exercise time ratio) (Billaut & Basset, 2007), and different durations of recovery periods (from 2–3 to 120 sec) (Balsom et al., 1992; Glaister, Howatson, Pattison, & McInnes, 2008). The results of the above studies are heterogeneous but globally underline the important influence of recovery duration on sprint performance during the RSA tests (meant to indicate players' RSA levels). It has

been shown that the minimum recovery duration for maintaining the initial peak power output during two successive cycle sprints of 8 sec is about 30 sec (Billaut, Giacomoni, & Falgairette, 2003). The RSA of soccer players has been investigated using a wide range of testing protocols, mostly based on recovery periods not exceeding 30 sec (Gabbett, 2010; Impellizzeri et al., 2008; Wragg, Maxwell, & Doust, 2000; Zagatto, Beck, & Gobatto, 2009). The most common test of RSA in soccer is the repeated shuttle sprint ability test, which consists of six repetitions of 40-m shuttle sprints interspersed with 20 sec of passive recovery (Impellizzeri et al., 2008).

The effect of recovery duration on RSA tests has previously been investigated across a range of different methodologies using almost 'unrealistic' (during real gameplay) recovery periods of 30 sec or greater (Balsom et al., 1992), including the Glaister et al. (2008) study in which recovery periods of 35 and 65 sec were compared to each other. This study showed that there is a better performance and fatigue response (i.e., a smaller loss of 'ability to repeatedly produce a high-power output or sprint speed') with a 65-sec recovery period compared to one that is 35 sec. Despite the fact that this study illustrates a considerable influence of recovery duration on various measures during multiple sprints, more precise investigations concerning 'realistic' (during real gameplay) recovery periods may be more accurate and could still be useful for coaches and soccer players. Variables featuring metabolic demand and muscular stretch-shortening performance, which are important for athletes and coaches as performance results, should be investigated. In most instances, during RSA tests in soccer, intermittent recovery periods last around 20 sec (Bishop, Girard, & Mendez-Villanueva, 2011). Therefore, the goal of this study was to examine in ecological conditions the influence of recovery duration on various measures during multiple sprints using recovery periods near to those mostly used during the RSA test protocol in soccer.

METHODS

Participants

Seventeen male soccer outfield players recruited from the Junior Romanian Soccer Team (age: 16 ± 0 years; body mass: 66 ± 10 kg; height: 1.81 ± 0.06 m; BMI: 20.1 ± 2.0 kg·m⁻²) volunteered to participate in this study. The inclusion criteria were soccer high-level ability, about 5 years of training (5 ± 1 years), and about 8 h of training per week in addition to the weekly official match. The participants were used to training with shuttle running and were participating in the national championship during the investigation (mid-season). The players were blinded about the aim of the study. Written consent was obtained from the participants'

parents/guardians after they had been thoroughly informed about the study design, in conformity with the Code of Ethics of the World Medical Association (Declaration of Helsinki). All experimental procedures were approved by the local university human research ethics committee, which followed these ethical standards.

Procedures

Field tests were completed on a certified synthetic turf pitch with players wearing proper soccer shoes. The average weather conditions during the 3 days of the experiment were as follows: calm wind (about $0.8 \text{ m}\cdot\text{s}^{-1}$), a temperature of about 22.8°C when the testing session started at 3:30 pm, and about 23.5°C when it ended at about 6:30 pm. We used a single-group repeated-measures study design in which recovery mode was the independent variable, whereas sprint times, blood lactate concentrations, and jump heights were the dependent variables. Three testing sessions (i.e., a session with 15-sec recovery, a session with 20-sec recovery, and a session with 25-sec recovery) were randomly performed on three different days with 5 days between each testing day. On the first, second, and third testing days, the participants performed the standard RSA test (Padulo et al., 2014). No additional strength, power, or plyometric training was performed during the testing period. No type of training was performed within 48 h before the testing session. Caffeine ingestion was forbidden before tests on the testing days.

RSA Shuttle Test

During each session, the participants were familiarized with the standard RSA test (Padulo et al., 2014), despite the fact that they were already familiar with this kind of test as it was part of their routine assessment. After the familiarization, they rested for 5 minutes. The standard RSA test was administered as warm-up. The RSA test on the first, second, and third days consisted of six maximal 40-m shuttle sprints (20 + 20 m with 180° change of direction [COD]) separated by 15/20/25-sec recovery for each RSA test. For each RSA test, only recovery time changed: 15 sec (RSA15), 20 sec (RSA20), and 25 sec (RSA25). The three RSA tests were randomly administered. The participants started from a line (standing start), sprinted for 20 m, touched or just passed the second line with a foot, and then sprinted back to the starting line as fast as possible. After 15/20/25 sec of passive recovery, the participants repeated the shuttle sprint. The time for each single shuttle sprint was recorded using a photocell gate (Brower Timing System, Salt Lake City, UT, USA; accuracy of 0.01 sec). To avoid undue switch-on of the timing system, players had to position the front

foot immediately before a line set 30 cm from the photocell beam. The photocell beam was positioned at 1 m height and 2 m apart. A few seconds (about 2.5 sec) before the start of each sprint, the participants returned to the start line and waited for the start signal. Each player was verbally encouraged to make his maximal effort during all sprints. To balance the physical exertion of the legs during the COD, the participants were asked to alternate the leg used (i.e., they had to do the first COD with the right leg braking and the next COD with the left leg and so on). For all tests, the fatigue index (FI) was calculated according to Fitzsimons' (Fitzsimons, Dawson, Ward, & Wilkinson, 1993) formula:

$$FI = 100 \times (TT/(BT \times 6)) - 100,$$

where TT corresponds to total time and BT corresponds to best time.

Blood Lactate Concentration Assessment

During each session, the participants attended a blood lactate (BLa) concentration assessment video demonstration, despite the fact that they were already familiar with this kind of evaluation as it was part of their in-season assessment. BLa concentration ($\text{mmol}\cdot\text{L}^{-1}$), as a proxy for metabolic-anaerobic demand, was determined immediately before each RSA test and 3 minutes after the end of the test (RSA15, RSA20, and RSA25) as reported in the literature (Hirvonen, Rehunen, Rusko, & Harkonen, 1987). As commonly done during field tests, a microsample of arterialized blood from the ear lobe was taken and immediately analysed with a validated lactate analyser (Arkay Lactate Pro LT-1710, Kyoto, Japan) (Hirvonen et al., 1987).

Jump Performance

During each session, the participants attended a countermovement jump (CMJ) test video demonstration, despite the fact that they were already familiar with this kind of test as it was part of their routine assessment. To assess the individual level of stretch-shortening performance (Padulo et al., 2013), each soccer player performed a CMJ test 3'30" before and immediately after the end of each RSA test with an OptojumpTM device (Microgate, Bolzano, Italy) used to measure the jump height (cm), as a proxy for a muscular stretch-shortening performance (Bosco, Luhtanen, & Komi, 1983) and consequently for running mechanics. Jump height is related to 200- and 400-m running performances (Dal Pupo et al., 2013). Jump tests were performed according to the protocol described by Bosco et al. (1982).

Statistical Analysis

All data were expressed as mean values, standard deviation, and 95% confidence. The analysis was performed using the statistical software SPSS 15.00 (SPSS Inc. Chicago, IL, USA), using a mixed model for repeated measures analysis of variance (ANOVA) with a compound symmetry working covariance matrix on the following dependent variables: BT, worst time (WT), TT, FI, BLa, and CMJ height (CMJh). The same model was used to analyse the effects of repeated sprints on the time variable in the three test conditions (RSA15, RSA20, and RSA25), while the effect of each sprint on the time among the tests (RSA15, RSA20, and RSA25) was analysed using a one-way repeated measures ANOVA. Significant F-values were followed by multiple comparisons to locate differences. A Fisher's least significant difference (LSD) correction was used to adjust the *P*-value in relation to the number of contrasts that were performed. For testing the repeatability of the measure (first sprint time of each RSA test and CMJh before each RSA test), the intra-class correlation coefficient (ICC) between RSA15, RSA20, and RSA25 was calculated (Atkinson & Nevill, 1998). The significance level was set at *P* < 0.05.

RESULTS

The results are summarized in Table 1. A comparison of RSA15, RSA20, and RSA25 showed highly reliable data, with ICCs of 0.851 and 0.860 for the first sprint time and CMJh, respectively. The analysis of variance showed a

TABLE 1 Results of all variables analysed during repeated sprint ability (RSA) tests with different recovery durations.

Variables	RSA15	RSA20	RSA25	Δ%		
				RSA15/ RSA20	RSA20/ RSA25	RSA15/ RSA25
Best time (BT) (sec)	7.36 (0.10, 0.05)	7.35 (0.16, 0.08)	7.33 (0.13, 0.06)	0.17	0.23	0.41
Worst time (WT) (sec)	7.94 (0.21, 0.10)	7.72 (0.17, 0.08)	7.63 (0.16, 0.08)	2.76*	1.26*	3.68*
Total time (TT) (sec)	46.12 (0.85, 0.40)	45.41 (0.94, 0.45)	44.82 (0.90, 0.43)	1.54	1.29	2.82*
Fatigue index (FI) (%)	4.45 (1.21, 0.58)	3.03 (0.88, 0.42)	1.92 (0.71, 0.91)	32.01*	36.48*	56.81*
Blood lactate (BLa) (mmol L ⁻¹)	14.53 (0.37, 0.18)	12.74 (1.19, 0.57)	8.02 (1.49, 3.81)	14.47*	22.04*	33.33*
CMJ height (cm)	35.63 (0.95, 0.45)	37.47 (2.66, 1.26)	38.28 (3.68, 1.75)	5.14	2.18	7.44*

Notes: Values are mean (standard deviation, 95% confidence) of RSA variables with 15 sec (RSA15), 20 sec (RSA20), and 25 sec (RSA25) of recovery durations. Blood lactate and counter movement jump (CMJ) assessed at the end of the test.

*Significant differences (*P* < 0.05).

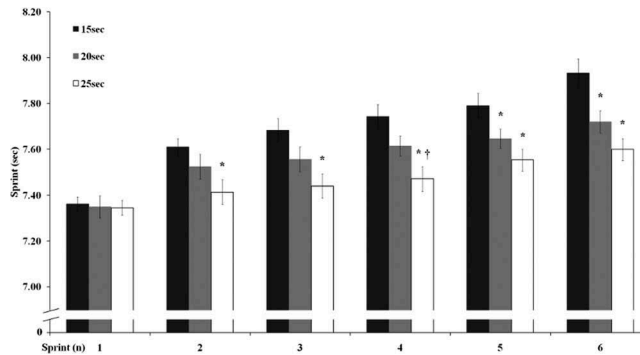


FIGURE 1 Sprint profile ($n = 17$) of the repeated sprint ability tests (mean \pm standard error) with different recovery durations (15/20/25 sec).

Notes: * $P < 0.05$ compared to RSA15.

†Compared to RSA20.

significant main effect on RSA variables with different recovery durations: TT ($F_{(1,15)} = 6.278$, $P = 0.00$), WT ($F_{(1,15)} = 8.858$, $P = 0.00$), FI ($F_{(1,15)} = 21.037$, $P < 0.001$), and post-RSA test BLa ($F_{(1,15)} = 29.972$, $P < 0.001$). In contrast, no significant effect was found for BT ($F_{(1,15)} = 0.158$, $P = 0.85$), pre-RSA test BLa ($F_{(1,15)} = 0.432$, $P = 0.65$), pre-RSA test CMJh ($F_{(1,15)} = 0.250$, $P = 0.78$), and/or post-RSA test CMJh ($F_{(1,15)} = 2.465$, $P = 0.10$). Repeated measures analysis within each RSA sprint (Figure 1) showed a main effect from the second to sixth sprint ($F_{(1,15)} = 5.052$ – 11.059 , $P = 0.01$ – 0.00). First sprint time was the same for all investigated RSAs (about 7.35 sec), because it preceded any different recovery duration (Figure 1).

LSD correction revealed significant effects on WT between RSA15 and RSA20/25 ($P = 0.00$ and $P = 0.00$), TT between RSA15 and RSA25 ($P = 0.00$), and FI between RSA15 and RSA20/RSA25 ($P = 0.00$ and $P < 0.001$) and RSA20 and RSA25 ($P = 0.00$). The FI decreased over increasing recovery duration ($r = 0.678$ with $P < 0.001$; Figure 2). Pre-RSA test BLa was the same for all investigated RSAs (about $2.53 \text{ mmol}\cdot\text{L}^{-1}$). Post-RSA test BLa decreased over the increasing recovery durations (Figure 2). Pre-RSA test CMJh was the same for all investigated RSAs (about 39.16 cm). Post-RSA test CMJh increased over the increasing recovery durations (RSA15 decrease [from pre-RSA test value] = $-8.60 \pm 1.73\%$; RSA20 decrease [from pre-RSA test value] = $-5.74 \pm 1.39\%$; RSA25 decrease [from pre-RSA test value] = $-1.62 \pm 0.68\%$). LSD correction revealed significant effects between RSA15 and RSA25 ($P = 0.04$).

DISCUSSION

The aim of this study was to examine the influence of recovery duration (15, 20, and 25 sec) on both performance and physiological measures of RSA tests

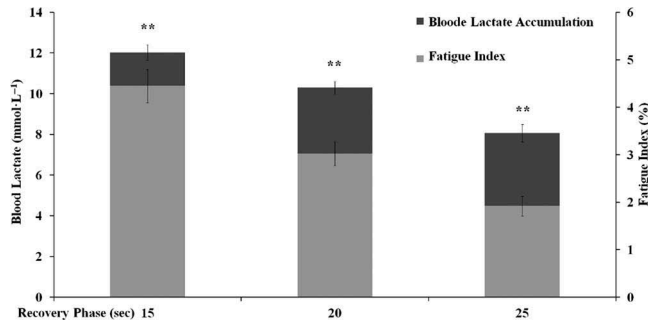


FIGURE 2 Blood lactate accumulation (BLa) pre- to post-test accumulation and fatigue index (FI) (mean \pm standard error bar) with different recovery durations (15/20/25 sec).

Note: $^{**}P < 0.05$ for BLa pre- to post-test accumulation and FI between RSA15 and RSA20/25 and RSA20 and RSA25.

in ecological conditions. Recovery duration had a significant effect on measures of TT and WT and FI and post-RSA test blood lactate concentration (BLa). Between 15 and 25 sec, there was a significant negative effect of the recovery duration on CMJ height, i.e., a proxy for muscular stretch-shortening performance.

The results show that a significant interaction exists between recovery duration and sprint performance (Table 1 and Figure 1). This overall finding supports previous studies reporting that performance and fatigue during repeated sprints are strongly influenced by the recovery duration (Attene et al., 2014; Balsom et al., 1992; Billaut & Basset, 2007; Bishop et al., 2011). During repeated sprints, performance is dependent on the ability to recover from previous work bouts as well (Balsom et al., 1992). The changes in TT, FI, and BLa over sprints displayed different patterns of fatigue between the three recovery durations, which reflected the considerable influence of recovery duration on fatigue development. In fact, the longer the duration of the recovery the better the performance, despite a still high level of BLa. High BLAs are associated with increased hydrogen ion concentrations, which are reported to interfere with the activity of various enzymes involved in the adenosine triphosphate (ATP)-generating processes (Bogdanis, Nevill, Boobis, & Lakomy, 1996). However, the recovery of maximal power output is associated primarily with the re-synthesis of phosphocreatine (PCr) (Bogdanis et al., 1996). Although the availability of PCr may be a limiting factor in performance even before PCr stores are depleted (Sahlin, Tonkonogi, & Soderlund, 1998), it is likely that the 25-sec recovery periods of RSA25 enabled PCr to make a large contribution to ATP re-synthesis throughout each sprint cycle. It has been reported that the re-synthesis of PCr needs 22 sec or longer (Bogdanis et al., 1996; Laurent et al., 1992). Therefore, it is likely that the 15- and 20-sec recovery periods in the current study were not be long

enough to allow PCr to maintain a significant contribution to RSA performance beyond the first sprints.

In the present study, there was a significant difference in BLa after RSA tests over the three recovery durations. Such a finding is supported by the study of Glaister et al. (2008) which, using different repeated-sprint protocols (10 vs. 30 sec of recovery duration), reported a significantly higher post-test BLa in the 10-sec recovery protocol with respect to the 30-sec recovery protocol. The indication that performance during the repeated sprints is regulated predominantly by PCr availability provides the most likely explanation for the significant differences between the three recovery durations in terms of BLa accumulation. Indeed, a higher post-test BLa may be associated with a lower PCr during protocols with lower recovery duration, as accumulation of metabolites in the process of ATP-Cr splitting (i.e., pyruvate, adenosine diphosphate, and adenosine monophosphate) is suggested to be the *stimulus* for anaerobic glycolysis (Crowther, Carey, Kemper, & Conley, 2002). However, previous investigations on the physiological response to RSA have reported an evident inhibition of glycolysis over multiple sprints (Glaister et al., 2008; Laurent et al., 1992). Given that BLa concentration is only a reflection of the dynamic balance between its production and clearance, and only one sample at the third minute after the end of the test may not truly reflect BLa blood level given its normal variability (Glaister et al., 2008), the progressive increase in BLa throughout the three recovery durations supports the need for further investigation into the full extent of glycolytic inhibition during repeated sprints, e.g., by assessing ATP and PCr as well. Another limitation of the study is that there was no comparison to 30-sec (or more) recovery.

CONCLUSIONS

This study contributes to the refining of RSA procedures recovery duration starting from the usual field-chosen durations (about 20 sec) and durations already studied in the literature (from 2–3 to 120 sec). By investigating performance, metabolic-anaerobic demand, and muscular stretch-shortening performance variables in ecological conditions, it was found that the optimal recovery duration is 25 sec in order to practically maximize performance and contain metabolic-anaerobic power involvement and muscular stretch-shortening performance deterioration.

In comparison to shorter recovery duration RSA tests, a 25-sec recovery test is characterized by better overall performance and post-test muscular stretch shortening performance with lower anaerobic demand in young soccer players. When the gameplay pace allows it, the player could try to extend his inter-sprint recovery up to 25 sec to maintain his RSA over the entire match. And, limitedly to feasible gameplay situations, coaches could train and make

use of playing strategies meant to allow small players groups recovering on a rotating basis to maintain their RSA over the entire match.

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DISCLOSURE STATEMENT

The authors declare no conflicts of interest, financial, or otherwise.

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