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The specificity of the Loughborough Intermittent Shuttle Test for recreational soccer players is independent of their intermittent running ability

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ABSTRACT
The aim of the present study was to evaluate whether or not recreational soccer players (SP) and non-soccer players (non-SP) with similar intermittent-running ability had similar physiological responses to a soccer match-simulation protocol. Twenty-two recreational SP and 19 fitness-matched non-SP participated. Yo-Yo level 1 assessed intermittent-running ability, while the Loughborough Intermittent Shuttle Test served as soccer match-simulation protocol. Heart rate (HR), blood lactate concentration [La⁻] and rating of perceived exertion (RPE) were recorded after each bout (1–5, plus an exhaustive task). SP had lower HR after the third, fourth and fifth bout, compared to non-SP. Similarly, SP had lower [La⁻] after the third, fourth and the fifth bout. SP also had lower RPE after the third, fourth and fifth bout. The appropriateness of intermittent-running ability as the main determinant of physical performance in SP was questioned.

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Intermittent recovery test level 1; rating of perceived exertion; shuttle running; repeated-sprint ability; soccer match simulation

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Introduction

Soccer is characterized by an intermittent-activity profile with metabolic contributions from both the aerobic and anaerobic systems. Soccer players (SP) cover distances of 10–13 km during matches and perform approximately 1350 activities, with variations every 4–6 s (Mohr, Krustrup, & Bangsbo, 2005). In addition to technical skills, physical abilities such as intermittent-running and repeated-sprint ability (RSA) are key factors during competition. Indeed, the physical demands of competition have increased in recent years (Bush, Barnes, Archer, Hogg, & Bradley, 2015) particularly in regards to high-intensity activities (Barnes, Archer, Hogg, Bush, & Bradley, 2014). Therefore, it is important for soccer practitioners to identify simple tests than can be used to evaluate physical capabilities that contribute to overall performance (Impellizzeri, Rampinini, & Marcora, 2007). Such tests can be used to monitor training adaptations, identify the current status of a player and for talent identification and selection purposes. Physical capabilities of SP are often difficult to assess in isolation (Paul, Bradley, & Nassis, 2015). Notwithstanding, several testing assessments have been validated for evaluating the

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main soccer physical determinants. Both laboratory-based or field-based procedures can be used for measuring the aerobic characteristics (Manzi, Impellizzeri, & Castagna, 2014), the RSA (Ferrari Bravo et al., 2008) or the intermittent-running ability. Importantly, the latter has been widely proposed as the main SP determinant (Bangsbo, 1994). Therefore, several testing protocols have been created for ensuring accuracy and reliability, such as the Yo-Yo intermittent recovery test (Krustrup et al., 2003), the 30–15 intermittent fitness test (Buchheit, 2008) and Carminatti's test (Teixeira et al., 2014).

The Yo-Yo intermittent recovery test level 1 (IR1) is a generally accepted test of physical fitness in soccer and other team sports. It is reliable (Krustrup et al., 2003) and discriminates between competitive standard and playing position (Mohr & Krustrup, 2014), making the test useful for talent selection purposes. It has been suggested that the IR1 can be used as a comprehensive test to reflect soccer-specific fitness (Ingebrigtsen et al., 2014). Many practitioners and researchers rely on IR1 performance to infer on a player's physical condition, mainly because the test scores are related to match running performance (Krustrup et al., 2003). However, the validity of IR1 as a comprehensive evaluation of specific soccer performance was questioned early in the development of the test (Kindermann & Meyer, 2003). IR1 performance is a compound quality, which depends on multiple physical fitness factors (Mendez-Villanueva & Buchheit, 2013). This is an indication that using a single physical capacity test (e.g. intermittent-running ability measured by IR1) as a proxy for soccer-specific fitness might be misrepresenting the actual demands of matches.

A different approach to the evaluation of soccer-specific fitness is to measure performance, physiological and perceptual responses to match-simulation protocols. Two main protocols have been used in applied research settings: the Loughborough Intermittent Shuttle Test (LIST; Thompson, Nicholas, & Williams, 1999) and the Football-specific Aerobic Field Test (Small, McNaughton, Greig, Lohkamp, & Lovell, 2009). These tests are based on the repetition of alternated types of locomotion (e.g. sprinting, running, walking) for a total duration of 90 min. The LIST has received more attention in recent years, for example to investigate effects of fatigue on muscle imbalance (Coratella, Bellin, Beato, & Schena, 2015), and it was therefore selected for the present investigation. Moreover, the test displays acceptable reliability (Nicholas, Nuttall, & Williams, 2000) and it has been recently modified to improve its reflection of modern football demands (Ali, Foskett, & Gant, 2014). Finally, the LIST had similar responses for muscle damage markers and neuromuscular variables compared to a soccer match (Magalhães et al., 2010).

While LIST is commonly used as a soccer-specific fitness assessment tool, there is limited information about its ecological or discriminant validity (i.e. time to exhaustion and physiological responses). In addition, as the LIST protocol depends on the intermittent-running ability (which can be measured by IR1), a positive relationship between the two should occur. Indeed, two out of the four actions performed in the LIST directly derived from the IR1. It can be expected that, given the predominance of the intermittent-running ability among the soccer-specific physical capacities, increasing such capacity can lead to better physiological responses during a soccer match-simulation protocol, as already shown for soccer matches (Krustrup et al., 2003). On the contrary, similar intermittent-running ability should lead to similar physiological responses. Consequently, even if two different populations but with similar intermittent-running abilities should perform the LIST, similar physiological responses should result. To date, no study has investigated the responses to LIST in two different groups (SP and non-soccer players [non-SP]) with a similar intermittent-running ability. Therefore, the aim of the present study was to investigate whether or not LIST discriminates between recreational SP and non-SP, and whether this would be dependent on intermittent-running ability.

Methods

Experimental approach to the problem

This study was conducted as a parallel two-group design. An a-priori power analysis was performed (two-tail, effect size [ES] = 0.5 [medium], alpha-error = 0.05 and power = 0.80) and it returned a desired sample size of 21 participants per group.

Forty-eight healthy male sport science students were initially recruited for the present study. Participants were involved in two separate testing sessions. The first session comprised an assessment of their intermittent-running ability (IR1). After the IR1 assessment, the intermittent-running ability of both soccer and non-SP was evaluated and compared and the maximal aerobic speed (MAS) was calculated (Bangsbo, Iaia, & Krustrup, 2008). Then, from the initial pool of 26 non-SP, those with a comparable intermittent-running ability to the SP were included in the present investigation. Therefore, as control group, 19 non-SP were finally included in the present study. In the second session, the participants completed the standardized football match-simulation protocol (LIST). During this session, heart rate (HR), rating of perceived exertion (RPE) and blood lactate concentration were assessed. The two testing sessions were separated by 1 week. Participants were instructed to refrain from any form of strenuous physical activity for the entire duration of the study.

Participants

Twenty-two SP (age 20.1 ± 2.4 years, height 1.77 ± 0.09 m, body mass 78.3 ± 2.8 kg), with at least 5 years of soccer experience, and 19 non-SP (age 20.3 ± 1.9 years, height 1.79 ± 0.10 m, weight 79.7 ± 3.7 kg) were recruited for this project. Non-SP were enrolled among different sports: six recreational basketball players, five recreational runners, three recreational futsal players, three recreational triathlon athletes, two recreational tennis players. Participants with cardiovascular or respiratory diseases as well as knee, ankle or hip joint injury were excluded from participation. All participants were previously informed about the benefits and risks associated with the procedures, and they provided a written consent to participate in the project, which was approved by the Ethics Committee of the University of Verona.

Procedures

Yo-Yo IR1

This test comprised 2 × 20-m shuttle runs at increasing speeds, separated by 10 s of active recovery (Krustrup et al., 2003). The participants were required to run on a

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parquet-floor indoor court, guided by an audio signal, until they were unable to maintain the desired speed. The test was ended when participants were no longer able to reach the finish line on the signal for two consecutive occasions. The stage reached and total distance covered (m) were recorded. The VO_2 peak and MAS were calculated according to Bangsbo et al. (2008).

LIST

The LIST protocol was divided in two parts. The first part comprised five bouts in which participants sprinted, walked and ran at 55% and 95% of the MAS on a 20 m shuttle track. Specifically, participants had to

- walk 3 × 20 m
- sprint 1 × 20 m
- recover for 4 s
- run at 55% of MAS 3 × 20 m
- run at 95% of MAS 3 × 20 m.

This pattern was repeated for 15 min and each bout was separated by 3 min of recovery. The second part comprised 20 m shuttle running with alternated running at 55% MAS and 95% of MAS, until exhaustion. Operators encouraged the participants to maintain the audio signal pace while running. The test ended when participants failed to run two consecutive 20 m shuttles in their own pre-established pace. Time to exhaustion was recorded.

Physiological responses

HR was recorded during the protocol using a standard HR monitor (Polar S810, Kempele, Finland) placed around the participants' upper thorax at the level of the xiphoid process. HR was recorded for the entire period of each bout and the exhaustive task. Then, the mean was analysed and inserted into the data analysis (Nicholas et al., 2000).

Blood lactate concentration $[La^-]$ was assessed at baseline, immediately after the end of each bout, and after the exhaustive task. Blood samples were collected using capillary blood from an ear lobe. Then, the blood samples were immediately placed onto a sample strip and inserted into a hand-held lactate analyser (EKF Diagnostic GmbH, Magdeburg, Germany) for single measurements.

RPE was assessed using a 6–20 scale (Borg, 1982). Participants were carefully instructed about the purpose of the scale and accustomed to the procedures. Standard anchoring was performed by asking the participants to associate a previous experience of a light walking exercise to a rating of 7, and a near maximal running bout to a rating of 19. RPE was assessed after the end of each bout and after the exhaustive task.

Statistical analysis

Data analysis was performed using SPSS 16.0 (SPSS, Chicago, IL). The normality of data was investigated using the Shapiro–Wilk's test. The sphericity of data was investigated using the Mauchly's test. The HR, RPE and blood lactate concentration

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between groups were compared using a mixed-design factorial ANOVA. *Post-hoc* analysis using Bonferroni's correction was executed to investigate the effect for group (two groups: SP and non-SP) and time (seven levels in [La^-] and in HR and six levels in RPE). The estimated VO_2 peak, MAS and time to exhaustion between SP and non-SP were compared using a between-groups one-way ANOVA. Data are reported as mean ± SD. *Post-hoc* comparisons are shown as mean difference ± SD with absolute change score (CI95%) and Cohen's standardized ES with 95% confidence limits (CL). ES was classified as follows: ≥0.2 small, ≥0.5 moderate and ≥0.8 large.

Results

IR1 performance

There was no difference in the IR1 performance between SP and non-SP, being 1476 ± 344 and 1406 ± 486 m, respectively. Therefore, MAS was similar between the two groups (13.9 ± 0.8 and 13.8 ± 1.2 km h^{-1} for SP and non-SP, respectively).

LIST time to exhaustion

The time to exhaustion in part B of LIST was longer in SP than in non-SP (313.2 ± 48.2 and 220.1 ± 51.2 s, respectively, $p = 0.002$, ES = 1.97, CL 1.43–2.51).

HR

Main effect for group was found for HR during LIST ($p = 0.039$). Compared to non-SP, SP showed moderately lower HR after bout 3 (−9.0 ± 4.4 b min^{-1}. CI95% −17.8 to −0.1, $p = 0.048$, ES = 0.61, CL 0.01–1.22), after bout 4 (−8.7 ± 3.9 b min^{-1}, CI95% −16.8 to −0.6, $p = 0.035$, ES = 0.65, CL 0.05–1.26) and mostly lower after bout 5 (−11.9 ± 3.8 b min^{-1}, CI95% −19.6 to −4.3, $p = 0.003$, ES = 0.89, CL 0.32–1.46) (Figure 1). Similarly, main effect for time was found ($p < 0.001$). Compared to baseline, *post-hoc* analysis showed HR increments over time after each bout and after the exhaustive task for both SP and non-SP ($p < 0.05$). Finally, A time × group interaction was found ($p = 0.041$).

Blood lactate concentration

Main effect for group was found for [La^-] during LIST ($p = 0.028$). Compared to non-SP, SP had moderately lower [La^-] after bout 3 (−0.8 ± 0.4 mmol L^{-1}, CI95% −1.4 to −0.2, $p = 0.041$, ES = 0.59, CL 0.05–1.13) and after bout 4 (−1.0 ± 0.5 mmol L^{-1}, CI95% −1.6 to −0.4, $p = 0.027$, ES = 0.74, CL 0.19–1.29) and mostly lower after bout 5 (−1.0 ± 0.5 mmol L^{-1}, −1.6 to −0.4, $p = 0.010$, ES = 0.81, CL 0.30–1.32) (Figure 2). Similarly, main effect for time was found ($p < 0.001$). Compared to baseline, *post-hoc* analysis showed greater [La^-] over time after each bout and after the exhaustive task both for SP and non-SP ($p < 0.05$). Finally, time × group interaction was found ($p = 0.031$).

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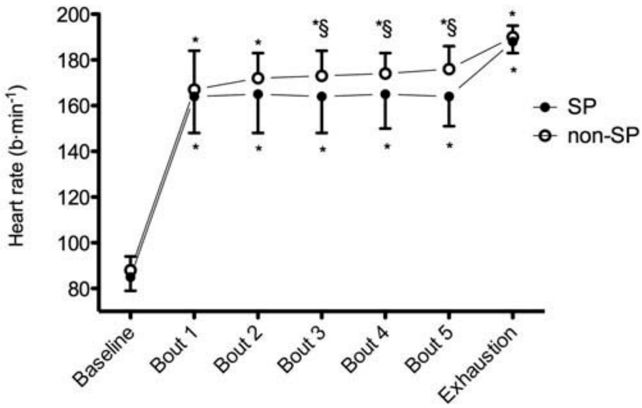

Figure 1. Difference in heart rate between SP and non-SP after each bout and at exhaustion. Data are shown as mean ± SD. *$p < 0.05$ compared to baseline; §$p < 0.05$ compared to SP.

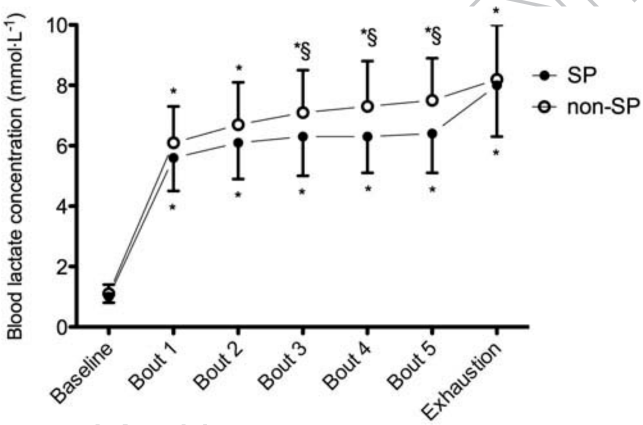

Figure 2. Difference in blood lactate accumulation between SP and non-SP after each bout and at exhaustion. Data are shown as mean ± SD. *$p < 0.05$ compared to baseline; §$p < 0.05$ compared to SP.

RPE

Main effect for group was found for RPE during LIST ($p = 0.004$). Compared to non-SP, SP showed moderately lower RPE after bout 2 (−1.4 ± 0.5 AU, CI95% −2.5 to −0.3, $p = 0.011$, ES = 0.78, CL 0.19–1.37) and after bout 4 (−1.5 ± 0.6 AU, CI95% −2.7 to −0.3, $p = 0.015$, ES = 0.75, CL 0.15–1.34), while the RPE was mostly lower after bout 3 (−1.9 ± 0.6 AU, CI95% −3.0 to −0.7, $p = 0.002$, ES = 0.92, CL 0.36–1.49) and after bout 5 (−1.9 ± 0.6 AU, CI95% −3.0 to −0.6, $p = 0.004$, ES = 0.87, CL 0.30–1.45) (Figure 3). Similarly, main effect for time was found ($p < 0.001$). Compared to exhaustion, *post-hoc* analysis revealed lower values over time after each bout both for SP and non-SP ($p < 0.05$). Finally, time × group interaction was found ($p = 0.018$).

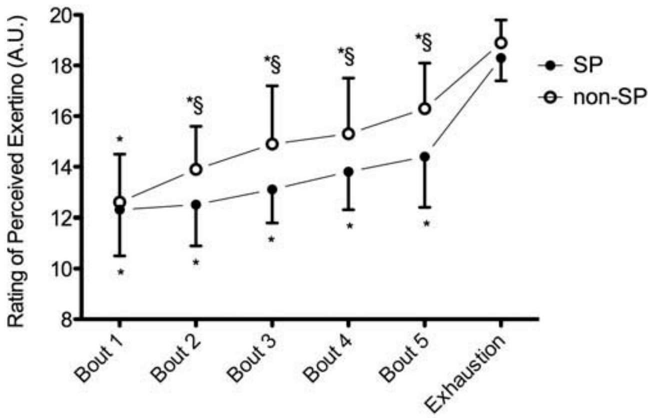

Figure 3. Difference in rating of perceived exertion between SP and non-SP after each bout and at exhaustion. Data are shown as mean ± SD. *$p < 0.05$ compared to baseline; §$p < 0.05$ compared to SP.

Discussion

The present study was designed to investigate whether or not SP and non-SP with similar intermittent-running ability had similar physiological responses to a standardized soccer match simulation. The present results showed lower HR, blood lactate concentration and RPE in SP compared to non-SP during the sub-maximal component of LIST. In addition, SP reached exhaustion later compared to non-SP.

Soccer has previously been defined as an aerobic task with a large component of intermittent exercise (Bangsbo, 1994). Subsequently, practitioners and researchers have focused their attention on the effect of intermittent exercise (or high-intensity interval training) on physiological adaptations and players' performance. Indeed, maintaining exercise intensity close to VO_2 peak is well known to induce both cardiovascular and pulmonary adaptations (Buchheit & Laursen, 2013a). In addition, neuromuscular adaptations such as improvements in muscle fibre recruitment and consequently greater strength development, as well as increases in resistance to fatigue are induced by intermittent exercise (Buchheit & Laursen, 2013b). Importantly, intermittent exercise increased the blood lactate clearance (Ahmaidi et al., 1996). Finally, intermittent exercise training performed both in traditional (e.g. running) and in soccer-specific (e.g. small side games) modalities was equally effective for promoting aerobic fitness and match performance (Impellizzeri et al., 2006). Therefore, it seems that increasing the players' intermittent-running ability can provide useful adaptations for improving the soccer performance. Such a relationship has been previously showed in young (Castagna, Impellizzeri, Cecchini, Rampinini, & Alvarez, 2009) and professional adult SP (Bangsbo & Lindquist, 1992).

Among the field tests measuring the intermittent-running ability, the IR1 is perhaps the most used. It was demonstrated to be valid and reliable (Krustrup et al., 2003), as well as soccer-specific (Castagna, Impellizzeri, Chamari, Carlomagno, & Rampinini, 2006). Indeed, IR1 is able to discriminate between different competitive levels (Bangsbo et al., 2008). In addition, IR1 can be successfully used to monitor training responsiveness in

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elite (Fanchini et al., 2015) or young (Carvalho et al., 2014) SP. Therefore, IR1 can be used for evaluating the players' intermittent-running ability.

The variety of soccer actions cannot be reduced only to a simple intermittent-exercise task. Several studies have investigated soccer match performance by match analysis and they showed that both non-technical and non-tactical tasks such as standing, walking, jogging, running or sprinting have been identified within soccer matches (Sarmento et al., 2014). For example, soccer matches include several brief sprints, interspersed with short recoveries (Padulo et al., 2015). The ability to limit decrements in repeated-sprint performance has been termed RSA (Girard, Mendez-Villanueva, & Bishop, 2011). Even if the amount of sprints performed during the soccer matches depends on the players role, age and playing time (Buchheit, Mendez-villanueva, Simpson, & Bourdon, 2010), RSA has been identified as one of the key factors in soccer match performance (Spencer, Bishop, Dawson, & Goodman, 2005). Several factors contribute to RSA, such as PCr availability, oxidative phosphorylation, anaerobic glycolysis and buffer capacity (Girard et al., 2011). Previous studies have reported positive correlations between RSA and aerobic fitness in SP (Da Silva, Guglielmo, & Bishop, 2010), and RSA was impaired by fatigue irrespective of the players role (Kaplan, 2010). Subsequently, several training protocols have been recommended for improving RSA in SP (Bishop, Girard, & Mendez-Villanueva, 2011). Therefore, the SP involved in the present study may have more efficiently managed the sprint-induced fatigue than non-SP.

LIST is performed on a 20-m shuttle run course, in order to mimic the several changes of direction (COD) in which SP are involved during a match. Although the inclusion of COD into the intermittent exercise did not modify the metabolic response and the RPE, the lower limb muscle activity was affected by COD compared to straight-only intermittent exercise (Hader, Mendez-Villanueva, Ahmaidi, Williams, & Buchheit, 2014). Quadriceps, hamstrings and gastrocnemii activity resulted greater when COD is included into the intermittent exercise, mainly due to the increasing knee stabilization (Besier, Lloyd, & Ackland, 2003). Such increased muscular activity could be related to the twofold (or even more) energy cost of shuttle runs compared to straight run, as recently shown (Buglione & Di Prampero, 2013). In addition, while slightly more than one half of non-SP were confident with COD, the remaining ones were habituated to linear movement patterns. Even if the IR1 does include the COD in its protocol, the duration of the LIST (and soccer match) is greatly longer than IR1. Furthermore, the inclusion of COD in training can help to manage fatigue from both a psychological and metabolic points of view (Hader et al., 2014). Therefore, considering the overall sports' backgrounds of the two selected populations, it is likely that SP can be more conditioned to COD than non-SP.

While no difference in physiological responses was found comparing SP and non-SP at the end of LIST, SP reached exhaustion mostly later than non-SP. In addition, after the third, fourth and fifth bout of LIST (i.e. after 51, 69 and 87 min, respectively), HR, blood lactate concentration and RPE were moderately or mostly lower in SP than non-SP. During the 90+ minutes of a soccer match, players experience several periods of temporary fatigue, particularly in the initial phase of the second period, and at the end of the match (Mohr et al., 2005). The fatigue perceived during a match can derive from both metabolic and psychobiological factors (Paul et al., 2015). The same authors suggested that SP could establish a self-selected pacing, voluntary or subconscious, which insulates them from both

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metabolic and mental fatigue (Paul et al., 2015). It may be speculated that SP better manage the fatiguing process during LIST compared to non-SP.

Considering the pooled data, HR increased from the baseline after each bout until exhaustion in both groups. The present results are in line with previous studies that monitored the HR during LIST both in recreational or semi-professional SP (Magalhães et al., 2010; Nicholas et al., 2000) and in students who were active in other sports (Thompson et al., 1999). $[La^-]$ increased from the baseline after each bout until the exhaustion in both groups, in line with previous studies that measured $[La^-]$ during LIST in recreational SP (Nicholas et al., 2000). However, non-SP resulted in higher $[La^-]$ compared to previous studies. Such a difference could be explained by a greater aerobic fitness level (55 ± 1 vs. 48 ± 4 mL min^{-1} kg^{-1}) of the participants involved in the previous study (Thompson et al., 1999) compared to those enrolled in the present investigation. RPE is a valid and reliable method introduced for monitoring the perception of effort during an exercise session (Borg, 1982). In addition, the RPE recorded during interval and team sport sessions is a useful method for evaluating the intensity of the training load (Foster et al., 2001). The RPE recorded in SP is in line with a previous study in which recreational male SP were recruited (Delextrat, Gregory, & Cohen, 2010). Unfortunately, no suitable comparison regarding non-SP was found. Finally, both SP and non-SP experienced similar RPE immediately after the exhaustive task, possibly meaning that both groups experienced an effort close their maximal when they reached exhaustion (Marcora & Staiano, 2010).

The present study comes with some acknowledged limitations and also interesting perspectives for future research. First, the population recruited for this study comprised recreational SP (more than 5 years of soccer experience). It would be of interest to design similar investigations including semi-professional or professional players. It may be speculated that differences in physiological parameters could be even greater, but this remains to be proved. Similarly, LIST could be useful to discriminate SP among different levels. Second, LIST was used for simulating a soccer match and although LIST has been widely used in literature for this purpose, performing modified versions of LIST, (Ali et al., 2014), or different soccer match-simulations protocols (Small et al., 2009), could have different impacts on the resulting physiological parameters. Finally, we have no data in regards to specific differences in sprinting activities between SP and non-SP. Although each participant maximally performed each sprint, it could have been useful to analyse differences in sprinting performances over the entire duration of the LIST.

In conclusion, lower HR, $[La^-]$ and RPE were found in recreational SP compared to non-SP matched for intermittent-running ability when performing the first part of LIST. In addition, SP performed the exhausting task longer than non-SP. The intermittent-running ability, although important for soccer match performance, could not entirely describe the physical demands in a soccer match simulation. RSA, change of direction and specific-task fatigue management should be taken into account for more accurately describing the physiological profile of the recreational SP.

Practical applications

The IR1 has been largely used for measuring the intermittent-running ability of SP. However, the present study questioned the suitability of intermittent-running ability as the main physical ability in recreational SP. Although the IR1 is easy to prescribe, it

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should not be considered as a comprehensive test for such specific population. Therefore, in order to have a more comprehensive evaluation, it is recommended that intermittent-running ability should be assessed in conjunction with other specific tests, for example RSA and COD agility tests.

On the other hand, the present investigation suggests that soccer-specific, training-induced adaptations can be highlighted in recreational SP by performing a match simulation. Therefore, LIST can be successfully used for both cross-sectional and longitudinal task-specific physiological evaluations in recreational SP.

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