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Energy cost and energy sources of an elite female soccer player to Repeated Sprint Ability Test: a case study

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Abstract

Intense physical efforts performed at maximal or near-maximal speeds and the ability to recover among sprint are important characteristics of soccer player. Considering that women's soccer is a markedly growing sport, the aim of the study was to analyse the performance (total time –TT-; fatigue index percentage -IF%) and physiological (aerobic and anaerobic) responses to Repeated Sprint Ability Test (RSA, 7x30 m sprints with 25 s of active recovery among sprints) in an elite female player (age: 30 yrs; BMI: 20.3 kg/m^2). A repeated measure MANOVA over the 7 sprints time series was applied ($p< 0.05$). Results showed that TT was 58.71 s (Ideal Time: 56.98 s) with IF% of 3.0%. Energy contributions were given for 80.3% by aerobic, 19.2% by anaerobic lactid, and 0.5% by anaerobic alactid sources. Considering that 1) we have different kinetics in heart rate (HR) and maximum oxygen uptake with oxygen uptake that reach the peak when HR is still rising, and 2) the energy consumption during intermittent exercises requires different metabolism as a result of physiological stimuli proposed, the present findings substantiate the need to choose specific and adequate training methods for female soccer players that aim at increasing their RSA performances.

Key words: GEDAE-LaB, Energy cost, Aerobic and Anaerobic contribution

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1. Introduction

Soccer is a multifactorial sport that requires many physical (jogging, running, jumps, sprint, and direction and speed changes) and sport-specific activities (tackles, dribbling, passing, and shooting the ball) during a match [1]. Intense physical efforts performed at maximal or near-maximal speeds and the ability to recover among sprint are important characteristics of soccer player [1, 2]. Studies of Mohr et al. [3, 4] showed better values of top-level soccer players in fast-paced running and sprinting than their lower-level counterparts.

The Repeated Sprint Ability (RSA) is the ability to repeatedly produce maximal or near maximal sprint efforts (≤10 s) with brief (≤60 s) recovery intervals (rest or low/moderate activity) and it is considered an important indicator in talent identification [5-7]. It is related to both neuromuscular and metabolic factors [5, 8-9]. Some researchers have redefined it as “repeated acceleration ability”: 1) as metabolically taxing accelerations do not always reach fixed sprinting thresholds [10, 11], but are more likely to hit an individualized sprinting threshold; 2) player’s aerobic capacity may not contribute to RSA as much as other physiological factors [12, 13].

In the last years, women's soccer is a rapidly and markedly growing sport (+34% from 2000) [14]. Lohmander et al. [15] declared that women's soccer was the second largest sport in Sweden with 20% of all soccer players registered were women. A recent UEFA report about Women's football across the national associations [16] showed: 1) increase of registered female players (from 1.270 million in 2016 to 1.365 million in 2017; +7.5% in one year), 2) 6 countries (England, France, Germany, Netherlands, Norway, Sweden) with more than 100000 players, 3) more than doubled of Professional and Semi-Professional soccer players in four years (from 1.680 in 2013 to 3.572 in 2017), 4) increase of qualified coaches (from 17.553 in 2016 to 19.474 in 2017), qualified match officials (from 7.505 in 2013 to 12.785 in 2017), and women’s youth teams (from 21.285 in 2013 to 35.183 in 2017).

For these reasons, the sports science community has increased its attention to this sector with studies that have investigated on the physical characteristics and performance responses of female match play to translate these data into specific training protocols [17, 18] but there still exists a large disparity in the volume of studies involving male and female players. The aim of the present case study was to analyse the performance and physiological responses to Repeated Sprint Ability test (RSAt) in an elite female player.

2. Materials and methods

2.1 Experimental Approach to the Problem

The female soccer player engaged in an experimental session organized in the first week of April 2017 during the competition period. Assessments (anthropometric and physiology evaluations) were performed in the same testing session, with 15-minutes rest among them, on the first training day after a soccer match (at least 48 h of recovery, between 16:00 PM and 18:00 PM) by experienced investigator. The participant did not undergone any other strenuous activity and training 24 h before the test.

To evaluate RSA performance, this study used a protocol of Bangsbo et al. [19] and, to reduce the weather conditions' influence (temperature: 18 °C; humidity: 70%), it was performed on an artificial turf [20], approved for national level competitions, with the participant who wore sports shoes. Before the test, a standard 15-minute warm-up of jogging at 40-60% of maximal heart rate (HR_{max}) and strolling locomotion was performed.

Energy cost and energy source of a RSAt was evaluated using a portable metabolimeter (K5, Cosmed, Rome, Italy) while energetic profile during RSAt estimated by free software GEDAE-LaB [21] which use the mathematical functions presented in previous studies [22, 23].

Percentages of individual HR_{max} have been used as markers of exercise effort and grouped in five intensity categories (maximal effort: >95% HR_{max}, high-intensity: 86–95% HR_{max}, low-intensity: 76–85% HR_{max}, active recovery: 65–75% HR_{max}, passive recovery: ≤65% HR_{max}.) to indicate the physical load imposed [24].

2.2 Subject

A female soccer player (Age: 30 yrs; Weight: 60 kg; Height: 1.72 m; BMI: 20.3 kg/m^2; Body Fat: 14%; Soccer Experience: 24 yrs) was recruited from the female club of Italian Soccer Federation (Roma CF; League "B"), with training volume of at least 3 days with the duration of 2 h per training session and a match per week, and volunteered to participate in this study. Participant was fit and healthy at the moment of data collection, and reported no recent injuries. Considering that the exercise intensity in the RSAt protocols was extremely high, the reasons for using this female soccer player as the "case study" were 1) her soccer training begun with male soccer players (from 6 to 14 yrs), and 2) she played at high level categories ("A","B", and "C") from 15 years old. Her experiences as elite female soccer player makes her worthy of study that could be useful to increase the knowledge about the target of training to follow.

Written informed consent was received from the player after verbal and written explanation of the experimental design and potential risks of the study. She was free to withdraw from the study without any penalty for upcoming reason(s). All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Player agreed to provide her maximum will effort to perform at her best during the field test considered in this study.

2.3 Testing Procedures

2.3.1 Anthropometrics

Anthropometric measures were taken by experienced anthropometrist. Anthropometric values (weight and height) were measured with participants wearing only light clothes and barefoot using an digital scale (± 0.1 kg) and a fixed stadiometer (± 0.1 cm) instrument (Seca 702, Seca GmbH & Co. KG, Hamburg, Germany). Body mass index (BMI) was used to assess weight relative to height and calculated by dividing body mass in kilograms by height in squared meters (kg/m^2).

Body adiposity was estimated by the measurement of skinfold thickness to the nearest 0.1 mm using a Harpenden caliper (Rosscraft, Surrey, British Columbia, Canada). Four skinfold measurements (triceps, abdomen, anterior suprailiac, thigh) were taken in triplicate on the right side of the body and the average value was taken for calculation. To estimate the percent body fat (%BF) we used the following skinfold equations [25]:

$$D=1.096095-0.0006952*X+0.0000011*(X)^{2}\text{\^{}}2-0.0000714*Age$$

$$\%BF = C_1-C_2/D$$

where X is sum of skinfolds (mm) measured and C_1 and C_2 are constant values for young adult female (5.05 and 4.62, respectively).

2.3.2 Repeated sprint ability test

In the present study, we used the repeated sprint ability test [19] which requested 7x30 m sprints (25 s active recovery among sprints) with a change of direction to the best of their abilities, decelerating as quickly as possible after the finishing line. The recovery consisted to cove a distance of 40 m (including deceleration phase) of jogging to return to the starting line for a new start (Fig.1). Intraclass correlation coefficients, power and effect size for repeated sprint test were 0.94, 0.99 and 0.84, respectively.

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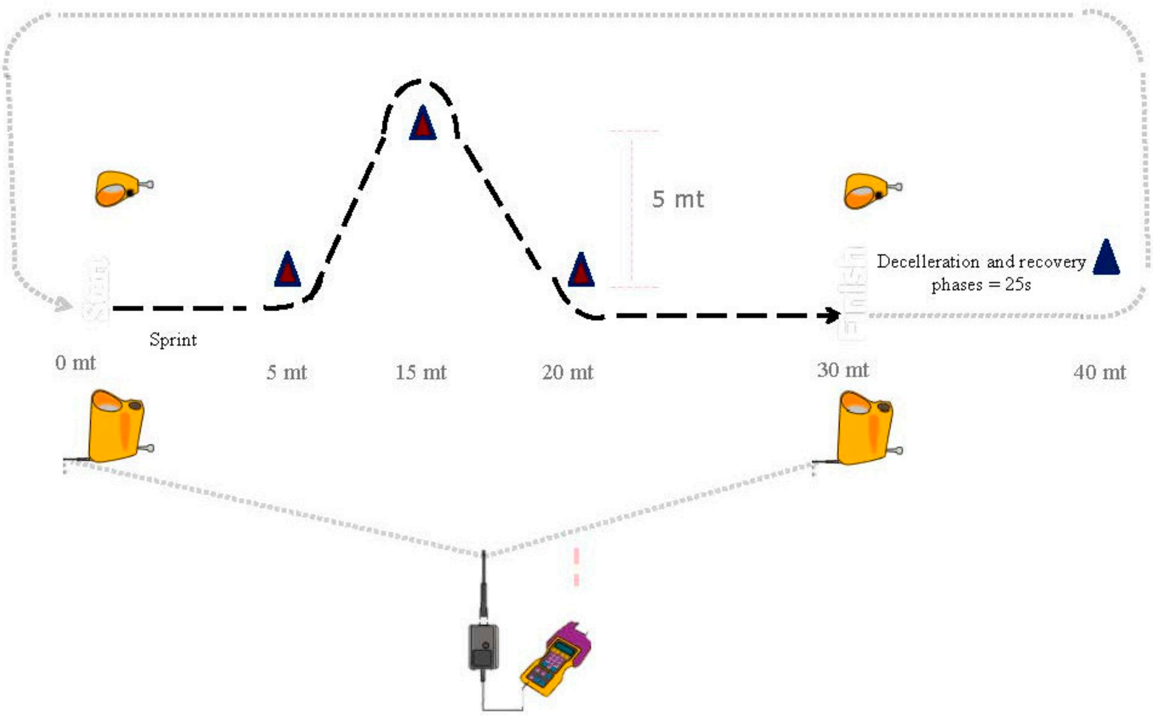

Figure 1. Repated Sprint Ability text.

To evaluate RSA performance, we used a dual infrared reflex photoelectric cell system (Polifemo, Microgate, Udine, Italy). According to literature [26, 9], for the RSAt validation, the first sprint time had to be not slower than 5% of the individual's best 30 m performance previously assessed. In this study, the sum of sprinting scores was considered as global RSA performance (total time, TT) [26, 9], while the fatigue index percentage (IF%) was calculated as follow [26]:

fatigue index (IF%) = [(total sprint time/lowest sprint time*7)*100] - 100)

During the test, HR (Sport Tester, Polar Electro, Kempele, Finland), blood lactate [La] (Accusport Lactate Analyser, Roche, Basel, Switzerland), oxygen uptake (VO_2), carbon dioxide production (VCO_2), and ventilation were measured (K5, Cosmed, Rome, Italy), and expiratory rate ratio was calculated. The K5 data showed intraclass reliability coefficients >0.99 (unpublished data). The flow meter and the gas analyzer was calibrated with a 3 L syringe (Hans Rudolph, Inc., Dallas, TX, USA), and with known gas mixtures (O_2: 16.0% and 20.9%; CO_2: 5.0% and 0.03%), respectively. The K5 metabolimeter was placed on the back to minimize interference during the performance, in particular during the changes of direction. HR and Ventilatory gases were collected

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from 5 minutes before to 6 minutes after the end of the test. HR values recorded every 5 seconds while Ventilatory gases recorded breath by breath.

[La] was measured by using finger blood samples before, immediately, and at 3, 6, and 9 minutes after the end of the test with a 0.999 intraclass reliability [27]. An alcohol swab was used to clean the area of blood withdrawal and the blood sample was drawn into the test strip (BM Lactate, Roche, Basel, Switzerland).

To identify the beginning and the end of the different sprint of RSAt, an experimenter pressed the marker button of the metabolimeter. The contribution of the 3 energy sources to the overall energy requirement of the RSA determined using $\dot{V}O_2$ measurement during and post exercise and [La] concentration data and, then, estimated by GEDAE-LaB. Despite the VO_2 baseline (VO_2rest) can be assumed as a fixed value (i.e. 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$) [28], in this study we measured VO_{2rest} to calculate aerobic system (AS). The anaerobic alactic system (AAS) is considered the fast component of excess post-exercise oxygen consumption. In the present study, we used a bi-exponential model after severe exercise domain [29] and, in order to analyse a possible impact of the time of recovery on calculation of the AAS, the fast component of excess post-exercise oxygen consumption was determined using the $\dot{V}O_2$ data during 6 min of recovery. The anaerobic lactic system (ALS) was estimated using the oxygen equivalent from blood lactate accumulation, while alactic anaerobic system (AAS) was estimated by the fast component of excess post-exercise oxygen consumption. The energy expenditure and energy systems were expressed in liters of oxygen (LO_2^{-1}), kilojoules (caloric equivalents = 20.9 $kJ \cdot LO_2^{-1}$) and kilocalories (caloric equivalents = 5 $kJ \cdot LO_2^{-1}$). Total energy expenditure was calculated as the sum of the three energy systems (AS+AAS+ALS). In addition, the contributions of the three energy systems were also expressed as total energy expenditure percentage. Previously, the VO_{2max} (2538 $mL \cdot min^{-1}$) and the HR_{max} (189 bpm) of female soccer player was assessed by the strength and conditioning coach of soccer team.

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2.4 Statistical Analyses

Data are reported as means and standard deviations (mean ± SD), and a 0.05 level of confidence was selected throughout the study. The RSAt responses of HR and VO_2 were separately evaluated from data acquired breath-by-breath during the 7 sprints: for each sprint the data were normalised to ten samples, then a repeated measure MANOVA over the 7 sprints time series was applied. To analyse the Statistical package IBM SPSS (ver. 24) was used to carry out statistical procedures.

3. Results

Analysis of data showed that Total Time of RSAt was 58.71 s (Ideal Time: 56.98 s) with a Fatigue Index of 3.0 %. Trend analysis of HR and VO_2 during RSAt revealed that only HR showed a significant ($p<0.001$) trend over sprints series. Performance, VO_2, $\%VO_{2max}$, HR, and $\%HR_{max}$ values of each single sprint recorded during RSAt are present in Table 1.

Table 1. Time, heart rate (HR), and oxygen consumption (VO_2), of each single sprint recorded during Repeated Sprint Ability (RSA).

	RSA (s)	VO_2 (mL·min^{-1})			$\%VO_{2Max}$			HR (beats·min^{-1})			$\%HR_{Max}$			Effort
		Mean	±	*St. Dev.*	*Mean*	±	*St. Dev.*	*Mean*	±	*St. Dev.*	*Mean*	±	*St. Dev.*	
Rest		335	±	97	13	±	4	60	±	2	31	±	1	passive recovery
1st Sprint	*8.20*	2343	±	752	92	±	30	138	±	2	72	±	0	active recovery
2nd Sprint	*8.29*	2445	±	483	96	±	19	159	±	0*	84	±	0	low-intensity
3rd Sprint	*8.55*	2438	±	196	96	±	8	163	±	1*	86	±	0	high-intensity
4th Sprint	*8.67*	2452	±	299	97	±	12	164	±	1*	87	±	0	high-intensity
5th Sprint	*8.49*	2524	±	397	99	±	16	166	±	0*	87	±	0	high-intensity
6th Sprint	*8.37*	2523	±	310	99	±	12	166	±	1	87	±	0	high-intensity
7th Sprint	*8.14*	2484	±	533	98	±	21	162	±	1*	85	±	0	low-intensity
Recovery		822	±	431	32	±	17	103	±	8	54	±	2	passive recovery

** = $p<0.001$ with previous sprint*
maximal effort: >95% HR_{max}
high-intensity: 86–95% Hrmax
low-intensity: 76–85% Hrmax
active recovery: 65–75% Hrmax
passive recovery: ≤65% HR_{max}

The HR increased abruptly at the beginning of the RSAt, fluctuated during the performance, decreased smoothly during the recovery phase (Figure 2).

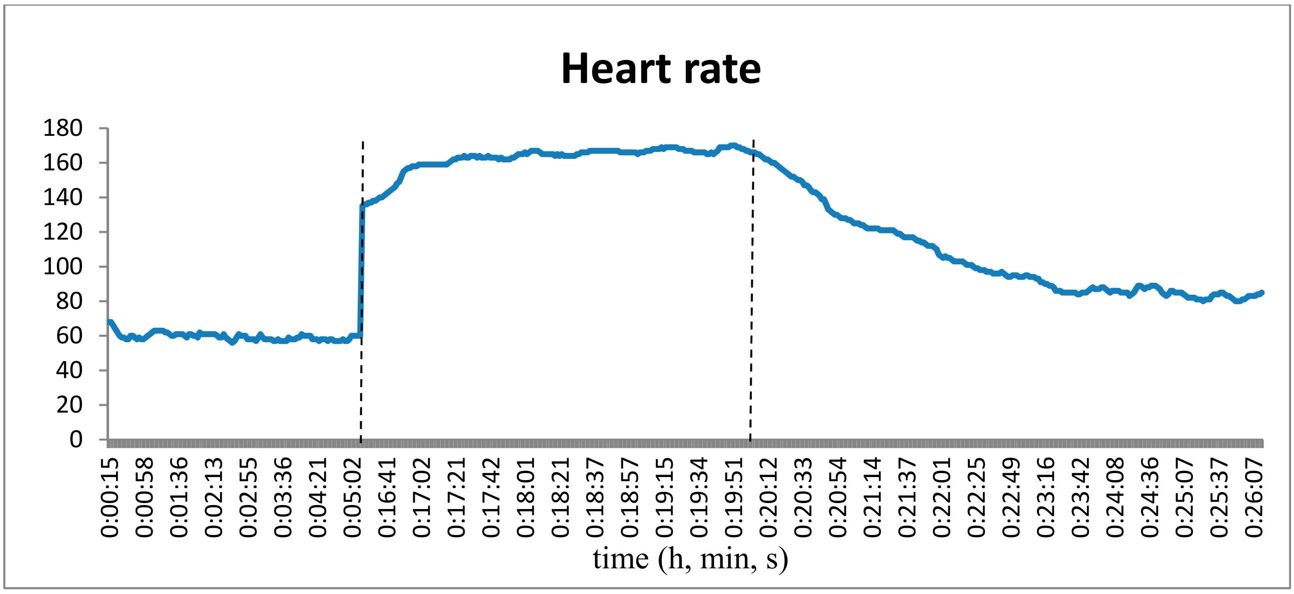

Figure 2. Heart rate curve before, during, and after Repeated Sprint Ability test

Energy cost and energy source contribution during RSAt are reported in Table 2.

	Percentuage	kcal	kj	$L \cdot O_2^{-1}$
Aerobic	80.3	39.9	166.6	8.0
Anaerobic Lactid	19.2	9.5	39.9	1.9
Anaerobic Alactid	0.5	0.3	1.1	0.1
Total	100	49.7	207.9	9.9

kcal = kilocalories
kj = kilojoules
$L \cdot O_2^{-1}$=liters of oxygen

Table 2. Energy cost and energy source contribution during Repeated Sprint Ability test.

4. discussion

Numerous studies [17, 1] showed that the number of high-intensity repeated-sprint bouts performed during a male and female soccer match, is one of a major factor that discriminates elite from sub elite level competition. Study of Bishop and Edge [30] on repeated-sprint ability in female recreational team-sport athletes (netball, basketball and field hockey) showed that the ability to

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minimize fatigue was related to increased performance. Quality of alternation between deceleration and acceleration phase plays an important role during a match [31].

Considering that various protocols are used in literature to evaluate the RSA, it is difficult to compare results between studies. We chose test of Bangsbo et al. [19] because it is easy, validate and it very used in research about RSA in soccer. In addition, we previously used it and, for this reason, we have data about male Italian soccer players to compare. In fact, compared to study of Perroni et al. [32], on semi-professional male soccer players, our data showed worst values in Total Time (+20.8%) but better in IF% (-4,5%). Similar trend (higher TT but lower IF%) was found comparing our case study with previous studies [12, 13] on professional and amateur male soccer players of different countries. The inability to maintain repeated-sprint performance has been attributed at 1) increase in lactate [33], 2) accumulation of H+ [8], 3) depletion of muscle phosphocreatine [34], and 4) changes in the neuromuscular coordination of muscle contraction [35].

Previous studies [36, 37] highlighted VO_{2max} and the velocity at the onset of blood lactate accumulation as important physical fitness components for soccer players. Various studies [38, 39] reported a moderate and/or no correlation of VO_{2max} with RSA and with the ability of skeletal muscle to recover after anaerobic exercise. In literature, the use of VO_{2max} as useful indicator of RSA have contrasting considerations and it appears linked to the type of protocol used. Aziz et al. [38] and Bishop et al. [46] reported a relationship between VO_{2max} and RSA when sprints of less than 40 m (or 6 seconds) are used, Da Silva et al. [13] found both velocity at VO_{2max} and the minimum velocity needed to reach VO_{2max} was negatively correlated with the mean time to complete 7 × 34.2-m sprints, and Dupont et al. [40] reported a positive correlation between the time constant for the fast component of VO_2 kinetics and the total time to complete 15 × 40 m sprints. In this way, Balsom et al. [41] showed that the length of the sprints could alter the contribution of the aerobic system. In this study, the energy system contributions during exercise were calculate using the software GEDAE-LaB, a free open-source software on line (http://www.gedaelab.org) with an easy-to-use interface available and does not require any download, registration or login. Results of

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our study showed that VO_2 increase during RSAt from the first to the last maximal sprint and this trend was in line with previous study of McGawley and Bishop [42]. Previous studies [43, 44], based on mathematical models of metabolic energy production during short (10 s or less) maximal sprints, suggested that 3–8% of the energy required derived from aerobic sources. Contrarily, the present study measured VO_2 directly, and it found a contribution by aerobic mechanism of 80% on all exercise (total time = 58.71 s).

These results were in accordance with Engelen et al. [45] that showed as the HR response during heavy exercise had a similar but not identical appearance to VO_2 due to different kinetics. In this study we have found that VO_2 reach the peak when HR is still rising.

5. Conclusion

The aim of the present study was to analyse the performance and physiological responses to RSAt in an elite female player. To our knowledge, only few study [30, 46] investigated on $\dot{V}O_2$ and the contribution of energy source during a repeated sprint test in female soccer players.

Aerobic and anaerobic capacities of an athlete may determine the outcome of the competition and it is therefore important to evaluate them. Considering that the energy consumption during intermittent exercises (anaerobic and aerobic) requires different metabolism as a result of physiological stimuli proposed, the present findings substantiate the need to choose specific and adequate training methods for female soccer players that aim at increasing their RSA performances. A regular (i.e every 2 months) and adequate (i.e. type of protocol, bout, length of the sprints) RSA testing provides a baseline for future comparison, and assists in establishing personalized training programme. This would have important implications for the design of training programs to improve the ability to recover from high-intensity running and sprinting and decrease the fatigue development that has a detrimental effect on technical performance [2].

The main limitation of the study is the lack of other female soccer players with the same background of our case study to increase the knowledge about energy source contributions during RSAt. The strength of this case study is the novelty of to have metabolically evaluated in detail a simply test, analysed in literature and used by trainer for their simply protocol and not expensive tools (stopwatch and heart rate monitor). Considering that we have highlight that VO_{2max} and HR kinetics have different increase in time, trainer have to be informed on how to improve the performance.

For these reasons, further largescale studies are recommended to analyse how aerobic and anaerobic systems can be influenced by differences in the type of protocol to use for the RSA test (i.e. length of the sprints, bout, Change of direction).

Disclosure statement

No potential conflict of interest was reported by the authors.

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Figure Legends

Figure 1. Repeated Sprint Ability test.

Figure 2. Heart rate curve before, during, and after Repeated Sprint Ability test

Table Titles

Table 1. Time, heart rate (HR), and oxygen consumption (VO_2), of each single sprint recorded during Repeated Sprint Ability (RSA).

Table 2. Energy cost and energy source contribution during Repeated Sprint Ability.

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