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Effect of the Repeated Sprint Ability Test on Lung and Musclefunction and Recovery Kinetics in Young Soccer Players

Boussana Alain[1,2,4], Nsompi Florent[1,2,3], Moukouyou Antoine Eric[1,2,3], Candau Robin[5]

[1]Higher Institute of Physical and Sports Education (ISEPS), Laboratory Education, Health, Expertise and Human Performance Optimization (ESEOPH), Marien Ngouabi University - Brazzaville Congo; [2]Exercise Physiology and Biomechanics Research Unit, Marien Ngouabi University (UMNG), BP 69, Higher Institute of Physical Education and Sport (ISEPS), Congo; [3]Respiratory, Hormonal and Gerontological Sports Explorations Unit University of Abomey-Calavi (UAC), National Institute of Youth, Physical Education and Sport (INJEPS), Benin; [4]Laboratoire ACTES, UFR STAPS, Antilles Guyane, Campus de Fouillole BP 59297159 Pointe à Pitre, Cedex, France; [5]URM 866 – Dynamique Musculaire et Métabolisme, 2, Place Pierre Viala, Bât 22, 34060 Montpellier Cedex 1, France.

ABSTRACT

Introduction. High-intensity, and long distances exercises have been shown to induce the alterations in lung and peripheral muscle function. Nevertheless, alterations and recovery period have not been studied in response of repeated sprint ability (RSA) test (6×35m).

Aim: The purpose of this study was to evaluate the effect of a repeated sprint ability (RSA) test on lung function and lower limb power in young soccer players.

Method: Twelve young male soccer players (20.1 ± 1.8 years old) performed a repeated sprint ability (RSA) test (6×35m). Spirometric parameters, countermovement jump (CMJ) height, lower limb power and heart rate (HR) were assessed before the test, immediately after the test, and 3, 6 and 9 minutes post-test. Spirometric parameters were measured in the sitting position with a portable Spirobank G. Countermovement jump height and lower limb power were assessed with a Myotest during the countermovement jump and the fatigue index percentage (%FI) was calculated.

Results: Immediately after the repeated sprint ability (RSA) test, significant decreases ($P< 0.02$, $P< 0.009$ respectively) were observed in forced vital capacity (FVC) and peak expiratory flow rate (PEFR). Lower limb power during the countermovement jump was significantly reduced immediately after exercise ($P< 0.001$) and was significantly increased at 3 minutes post-RSA. During the repeated sprint ability test, fatigue index percentage (%FI) was significantly high (32.3%).

Conclusion: The repeated sprint ability test induced a decrease in lung function, suggesting airway closure. The muscle power of the lower limbs decreased concomitantly with an increase in fatigue index percentage, suggesting muscle fatigue. However, the alteration in lung and peripheral muscle function was not persistent as these soccer players quickly recovered these functions 3-6 minutes after the repeated sprint ability test, suggesting mild and transient mechanisms.

Key Words: Running speed, Change of direction, Repeated effort, Pulmonary function, Athletic training, Muscle fatigue

INTRODUCTION

Soccer is a team sport that requires adaptations to high physiological and physical demands. Players must repeat short, high-intensity sprint-type actions interspersed with periods of recovery. These intense and maximal actions are repeated and sustained throughout a match in many team sports and have been defined as repeated sprint ability (RSA).[1,2,3,4] According to Spencer et al.,[5] RSA is the ability to perform short, repeated sprints over a short period of time, which can induce fatigue and muscle damage. RSA tests are physically exhausting and can lead to muscle damage, muscle fatigue and decreased performance.[6]

Numerous studies have evaluated the effects of repeated sprints on physiological and physical parameters as a function of the length of the rest period between sprints and the specificity of the sport discipline.[7] However, few have

Corresponding Author:
Boussana Alain, Laboratory ESEOPH, BP 69 Higher Institute of Physical and Sports Education (ISEPS), Marien Ngouabi University – Brazzaville Congo; Tel: +33668734789/+24206611715; E-mail: bboussan@gmail.com

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evaluated the effects on lung function or the recovery period after repeated sprint exercise. Impaired lung function was observed 10 minutes and 24 hours after exercise lasting about 2 hours.,[8] and after short exercise performed at 95% maximum oxygen uptake ($\dot{V}O_2$ max).[9] The muscle fatigue induced by an exhausting exercise, match or training session and the kinetics of recovery after exercise are quantifiable by physiological, biochemical and physical markers.[10,11,7] Performance on countermovement jump (CMJ), is a practical physical marker, most often used in studies to measure athletes' muscle fatigue and muscle recovery period.[11] The performance of six repeated sprints back and forth over a 35-meter distance (6x35m) is a high-intensity, intermittent field exercise that lasts between 3 and 4 minutes and is performed at maximal speed with a 10-second recovery between each sprint. The intensity and duration of this exercise might induce changes in lung function, as this has been shown for respiratory muscles in the laboratory.[12] Today the repeated sprint field test is widely used as an alternative to the Wingate test performed in the laboratory to measure anaerobic power during sprints.[13,14,15]

Interestingly, most of the studies that have measured peripheral muscle fatigue and respiratory muscle fatigue during the RSA test have used an ergocycle in the laboratory.[12] Also, a recent study pointed out that the period of muscle function recovery after repeated sprint exercise has not yet been studied, in contrast to studies carried out after single sprints,[11] nor has pulmonary function. The RSA test of six sprints over 35 meters was validated by Zagatto et al.,[15] and is a very practical field test in team sports. It assesses the athlete's ability to adapt to stressful situations and the demands of competition. This study was the first to assess the effects of the RSA test (6x35m) on lung function under real field conditions.

The twofold aim of the present study was (1) to assess the effects of the RSA test on lung function and lower limb power in young soccer players and (2) to determine the optimal recovery period before resuming a new series of repeated sprints. We hypothesized that despite its short duration but given its high intensity, the RSA test would impair lung function and induce muscle fatigue, and that recovery would be slow after cessation of exercise.

MATERIALS AND METHODS

Participants

Twelve young male soccer players (age: 20.1 ± 1.8 years, weight: 62.0 ± 1.4 kg, and height: 1.70 ± 0.3 cm) took part in this study.The players were members of the U21 team from Marien Ngouabi University, Brazzaville, Republic of Congo. They trained regularly 10.10 ± 1.2 hours per week and competed at the departmental or national level (Table 1). To be included in the study, they had to be a defender, midfielder or striker and had to have participated in at least one sporting season. All players had given their written informed consent. They were informed of the objectives and the interest of the study.The study was approved by the Scientific Committee of Sciences and Techniques of Physical and Sports Activities of the University Marien Ngouabi (02/UMNG / Dir / DA / SP / CS / 2021) and was conducted according to the recommendations of the Declaration of Helsinki.

Experimental design

This experimental study was carried out according to a repeated measure plan at the Massamba Débat stadium in Brazzaville, Republic of Congo, in October 2021. Players had familiarized themselves with the countermovement jump (CMJ) test, spirometric tests and repeated sprints before entering a five-phase protocol that took place (1) before the RSA test (6x35m), (2) immediately after the RSA test, and (3) 3, 6 and 9 minutes after the test. They did a general warm-up followed by specific stretches for 10 minutes. Each phase consisted of heart rate (HR) measurement, spirometric tests and the CMJ test. HR, spirometric measurements and CMJ height were assessed before, immediately after, and 3, 6 and 9 minutes after the RSA test. Players wore a Garmin Forerunner 735XT HRM-Run (GFR) (Garmin Ltd., Olathe, KS, USA) HR monitor that recorded HR and expended energy. The RSA test consisted of six repeated 35-meter sprints at full speed with a 10-second recovery time between each sprint.[15] Immediately after the RSA test, spirometric tests and the CMJ test were performed, and then again at 3, 6 and 9 minutes after the test. HR was measured at rest, immediately after the RSA test and before each CMJ test, then at 3 min, 6 min and 9 min after the RSA test. The ambient temperature was 29.8°C with a maximum of 30.7°C and the relative humidity was 75% with a maximum of 85%. Each participant had between 15 and 20 minutes to complete the different stages of the protocol. Players were instructed not to ingest alcohol, drugs, or caffeine substances and not to exercise for 24 hours before the protocol. They were allowed to go for a little jog on the day of the experiment. During the tests, verbal encouragement was given.

Spirometric testing

Spirometric parameters were measured in the sitting position. Forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), and peak expiratory flow rate (PEFR) were measured using a portable Spirobank G-type spirometer manufactured by Medical International Research (Spirobank G USB, MIR, ROMA, Italy) (volume precision: ± 3% or 50 ml and flow rate precision: ± 5% or 200 ml/s) according to standard techniques and procedures.[16] The Spirobank G consists of a central unit, monitor and turbine with Winspiro-PRO software installed in the central unit. The Spirobank G was connected to a portable Dell microcomputer with a USB cable so that the measurements of the spirometric variables and the flow-volume curve of the spirometry test could be displayed on-screen.

Countermovement jump test

The CMJ was used to determine the explosive power of the lower limbs (PCMJ). The height reach (HCMJ, cm) was initially measured with the arms raised to the maximum. Next, participants had to perform a CMJ. The difference between standing height and countermovement jump height was measured. The measurements were carried out using the Myotest SA (1950 Sion, Switzerland). The CMJ is a feasible field test and has been validated for adults against ground reaction forces on force plates.[17] During the test, each subject performed five repetitions of the jump in search of maximal height. After five repetitions, a double beep announces the end of the test. The results were automatically (PCMJ and HCMJ) displayed on the screen after the test and represented the average of the best three repetitions.

Repeated sprint ability test

The RSA test consisted of six repeated back and forth sprints over a distance of 35 meters (6x35m) at maximal speed with a 10-second recovery period between sprints.[15] The sprint time for each repetition was determined using two pairs of Timing System Brower photocells (Draper City, UT, USA) whose validation and reliability have been demonstrated.[18] As the player started the sprint, the first pair of cells started the stopwatch, and timing stopped when he cleared the finish line where the second pair of cells was placed at 35 meters. The time of the first sprint was recorded as the first split in the clock. The number of sprint repetitions achieved was equal to the number of split times. The time recorded for each sprint was used to determine the horizontal power developed by the player in each sprint. It was calculated for each player using the following formula from Zagatto et al.[15]

Sprint power $= \dfrac{\left(\left(weightxdistance^{2}\right)\right)}{time^{3}}$ where the distance was the sprint distance (35 meters), the weight expressed in kg was the body mass, and the time in seconds was recorded for all soccer players at 35 meters.Power was expressed in watts (w). Once the power of each repeated sprint was determined, the highest value was the maximalpower, the lowest was the minimal power, and an average power was then calculated. The fatigue index percentage (%FI) for the RSA test was obtained using the equation of Zagatto et al.[15]

$$\%FI = \frac{\left(test\,CSR\,maximal\,power - minimal\,power\,test\ RSA\right)}{\left(maximum\,power\,test\,RSA\right)} x100$$

Statistical analysis

Study results were processed using IBM SPSS Statistics version 21 software (IBM Corporation, USA). The normality of the distribution of the variables was proved by the Shapiro-Wilk test. Student'spaired-sample t-test was used to compare CMJ performance, HR and spirometric parameters before and immediately after the RSA test. A one-way ANOVA (measurement time) was used to compare CMJ performance, HR and spirometric parameters recorded before, immediately after, and at 3, 6 and 9 minutes after the RSA test. When ANOVA was significant, Bonferroni's post hoc test was used for multiple comparisons. A Pearson correlation analysis was performed to determine the association between the decrease in performance on the CMJ test, %FI and the decrease in speed in the RSA test. The significance level was set at $p< 0.05$.

RESULTS

The soccer players'anthropometric characteristics of age, height, weight and body mass index (BMI), training time and Power and loss of speed during testing the ability of repeated sprints of the soccer players are presented in Table 1.

Spirometric parameters

The Table 2 represented the values of the spirometric test obtained before, immediately after, and at 6 and 9 minutes after the RSA test. The mean values of FVC and PEFR obtained immediately after the test were significantly lower than those obtained before ($P< 0.05$).There was no significant difference between the values before and 3, 6 and 9 min after the RSA test (Table 2).

Physical and biomechanical characteristics

Figure 1 represents the height of the jump in countermovement (Hcmj) and the results show a significant difference ($P < 0.001$) between the measurements taken before and immediately after the RSA test (47.4 ± 2.1 cm versus 45.1 ± 2.6 cm, i.e., decrease of 5.0 ± 2.2%) and at 3 minutes after the test ($P = 0.006$ and $P = 0.012$ respectively).In contrast, no significant difference was observed between CMJ height before and at 6, 9 minutes of recovery ($P = 0.287$). Lower limb power (Pcmj) was significantly decrease ($P< 0.004$) before and immediately after the RSA test (59.2 ± 11.2 w.kg-1 versus 52.5 ± 10.6 w.kg-1, i.e., decrease of 11.4 ± 4.2%), however, a significant increase was observed at 3 minutes ($P<0.0001$) and remained normal at 6 and 9 minutes ($P < 0.019$) as shown in Figure 2.

%FI after the RSA test was 32.3 ± 8.6% on the RSA test, thus losing 0.53 ± 0.3 s between the first and the last sprint (24.9% versus 45.6%). HR increased significantly by 54.5% ($P< 0.001$) between rest and immediately after the RSA test (69.8 ± 3.1 versus 154.0 ± 7.8 b/min HRmax) and remained significantly increased at 3, 6 and 9 minutes post-test (Figure 3). The energy expenditure during the RSA test was 23.8 ± 3.4 kcal.

Relationship between RSA test performance and loss of CMJ performance

Statistically significant correlations were observed between %FI during the RSA test and the decrease in lower limb power (r = -0.915, $P = 0.001$), between %FI and the speed loss during the RSA test (r = 0.928, P =0.001), between the speed loss and the decrease in CMJ height (r = -0.729, P = 0.04), and between the speed loss and the decrease in CMJ power (r = -0.755, P = 0.030). However, no correlations were observed between lung function and %FI (r = -0.551, P = 0.083).

DISCUSSION

The main results of this study of young soccer players showed that the RSA test induced a significant decrease in peak expiratory flow rate (PEFR) and forced vital capacity (FVC) immediately after the RSA test, although these differences were no longer significant 6 minutes after the end of the RSA. We also observed a significant decrease in CMJ height (Figure 1) and lower limb power (Figure 2) during a jump test performed immediately after the test. This decrease was correlated with the muscle fatigue index percentage (%FI) of 32.3% (Table 2). In addition, the explosive power of the lower limbs returned to normal 3 minutes after the exercise. These changes suggest impaired lung function and peripheral muscle fatigue or muscle damage and/or decreased performance.

The decrease in PEFR and FVC (Table 2) observed immediately after exercise confirmed the results reported in laboratory studies.,[9,19] and after a succession of exercise.[20] The pathophysiological phenomenon suggested by the decrease in FVC and PEFR may be a closure of the small airways or a decrease in pulmonary compliance. In addition, it has been reported that lung volumes and flow rates are lower after high-intensity exercise than after long-duration exercise like a marathon. We hypothesized that the RSA test, which includes periods ofshort-lasting but maximum-intensity exercise, would result in the greatest decrease in FVC and PEFR immediately after the test and that the recovery period would belonger (between 6 and 9 minutes post-test). However, lung volumes and flow rates were normal 6 minutes post-test.This observation suggests that the intensity and duration of the RSA test in our study were not sufficient to induce physiological stress and cause a more significant and persistent decrease in FVC and PEFR at 6 and 9 minutes after the test. It also indicates that 3 to 6 minutes after a series of repeated 6x35m sprints, a new set of repeated sprints can be performed.

The 5.0% drop in height and 11.4% in lower limb power during the CMJ (PCMJ) corroborated the findings of Sánchez-Sánchez et al.,[4] who reported lesions of the contractile properties of the rectus femoris and biceps femoris muscles and muscle fatigue in elite futsal players after an RSA test. In addition, 3 minutes after the RSA, lower limb power in the CMJ increased (Figure 2), suggesting alack of muscle fatigue that might be explained by normal energetic substrates. This result corroborated the report by Baron et al.,[21] who compared the effects of two different rest periods – 2 and 3 minutes – between consecutive sets of an RSA test on the skating ability of ice hockey players and concluded that the 3-minute rest period was more beneficial for increasing speed than the 2-minute rest period. Presumably, 3 minutes of recovery is sufficient to partially restore muscle power after an RSA test despite the decreases in CMJ height that we observed after the test at 3 minutes (Figure 1). The increase in %FI resulted in a significant decrease in lower limb height and power upon vertical relaxation immediately after the RSA test, concomitant with a sharp increase in HR (54.5%), compared to the initial values. Depending on the nature of exercise, it has been shown that when %FI increases and the power of muscle function decreases, the result is a loss in speed.[22]

Fatigue induced by the RSA test

The decrease in %FI of 32.3% showed that RSA test is an intense exercise that requires special attention in its use. These results corroborate those of Balsalobre-Fernández et al.,[23] and Selmi et al.,[22] who found a %FI of 33.1% and 32.6%, respectively, using the RSA test (6x35m) in the field and 10 x 6 s on an ergocycle. Thus, we observed a decrease in speed during the RSA test of 0.53 s or 20%. This result is similar to that of Balsalobre-Fernández et al.,[23] who reported a speed drop of 0.7 s or 27.27%. The %FI suggests muscle damage, muscle fatigue and loss of performance induced by the intensity and repetition of efforts. This index is assessed by a number of markers such as vertical jump tests or countermovement jump. Muscle power is an important factor in soccer players' performances,[24] and is often measured by jump tests.[25]

In our study, we assessed muscle function fatigue using the CMJ test and post-exercise HR measurement. After 3 minutes of rest, a slight increase in the muscle power of the legs was observed. This suggests that the 4-minute recovery period after the RSA test resulted in a normal ATP reserve and that recovery improved muscle function performance. We observed complete recovery of lower limb power and lung function at 6 and 9 minutes, despite a significant decrease observed at 3min in height on the CMJ. Based on our results, we suggested that ATP substrates were normal at 3 to 6 minutes of recovery after the RSA test. At the same time, we also observed that lung volumes had returned to baseline values. This period was apparently necessary to recover neuromuscular function and was sufficient for the performance of a new RSA test, an assumption supported by the HR value, which was below 150 bpm 3 minutes after the end of the test (Figure 3). This gradual return to baseline HR values after the end of the test was probably due to the autonomous nervous system, particularly a decrease in adrenergic action. It was reported that a return to HR below 120 bpm 2 minutes after stopping an anaerobic or aerobic power effort was a normal recovery for a basketball player.[26] Our results corroborate those of Dellal et al.,[27] who showed that HR of less than 150 bpm was a good criterion for performing a new set of intense exercise.

Performance variability after the RSA test

Our results showed that the recovery of muscle functions was slow after an RSA test in soccer players. In a review, Bishop et al.,[7] showed that the decrease in physical performance and the muscle fatigue induced during repeated sprints were strongly influenced by the duration of the recovery between the sprint repetitions. The decrease in CMJ performance observed in our study was due to a decrease in lower limb power (5,3% -11%) as a result of muscle fatigue. However, the 9.2% drop in CMJ height reported in the study by Balsalobre-Fernández et al.[23] was greater than in our study and this difference could be explained by the level of practice of the populations studied.

A decrease in lower limb power and CMJ height after the RSA test could be due to the accumulation of metabolic products (lactate, hydrogen ions). According to Bogdanis et al.,[28] an elevated lactate level is associated with increased concentrations of hydrogen ions, which interfere with the activity of various enzymes involved in the processes of ATP production and decrease the amount of initial energy. The 11% decrease in muscle power showed that an RSA test with a 10-second recovery between sprints was an intense and exhausting test.

The %FI was strongly and negatively correlated with the anaerobic muscle power of the jump ($r = -0.915$, $P < 0.01$) and positively with the decrease in speed during the RSA test ($r = -0.928$, $P < 0.01$). This suggested that the decrease in muscle power in the lower limbs led to a large increase in %FI. On the other hand, %FI increased concomitantly with the decrease in speed. Our results corroborated those of Mendez-Villanueva et al.,[29] who showed a positive and significant correlation between %FI during repeated sprints and the power of the lower limbs ($r = 0.87$, $P<0.05$). In addition, the lack of correlation between lung volumes and the peripheral muscle %FI suggested that the pathophysiological mechanisms involved in the impairment of lung function are different from those involved in peripheral muscle fatigue[30].

CONCLUSION

An RSA test induced a decrease in expiratory volume in one second and peak rate flow, suggesting a decrease in pulmonary compliance or closure of the small airways. We also showed a significant decrease in CMJ height and lower limb power. The decrease in lower limb jump height and power were correlated with the fatigue index, suggesting muscle fatigue or neuromuscular damage. Muscle fatigue was the likely cause of the loss of speed observed during the RSA test. The increase in lower limb power 3 minutes after the repeated sprint exercise, as well and the normalization of lung function parameters, suggested recovery from muscle fatigue and lung impairment and indicated readiness to perform another set of repeated sprints.

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Conflict of Interest

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Author’s Contribution

Boussana A. Conception or design of the work, data collection, Final approval of the version to be published

Moukouyou AE. Study design assistant, recruitment of participants.

Candau R. data analysis, reading and final correction of the manuscript before sending it to a firm responsible for correcting English.

Nsompi F. Follow-up of the experiment, data collection, reading and correction of the article

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Table 1: Anthropometric characteristics, training time and Power and loss of speed during testing the ability of repeated sprints of the soccer players.

Variable	Mean ± SEM
No. of subjects	12
Age (yr)	20.1 ± 1.8
Height (cm)	1.70 ± 0.3
Weight (kg)	62.0 ± 1.4
BMI (kg/m²	21.4 ± 1.6
Training load (hr/wk)	10.1 ± 1.2

Table 1: ***(Continued)***

Variable	Mean ± SEM
Power and lossof speed during testingthe ability of repeatedsprints	
Pmax (W)	605.8 ± 70.7
Pmin (W)	406.2 ± 42.1
LSP (s)	0.53 ± 0.3
Percentage Index Fatigue (%IF)	32.35
EE (Kcal)	23.8± 3.4

SEM, standard error of the mean; BMI, body mass index; Pmax, maximal power; Pmin, minimum power; LSP, loss of speed; EE, Energy expenditure.

Table 2: Mean spirometric values measured before (pre-RSA), after (post-RSA), 3-6 and 9 min after RSA (post-RSA-3, 6, 9). Values are expressed as mean ± SEM.

Parameters	pre-RSA	post-RSA	post-RSA-3 min	post-RSA-6 min	post-RSA-9 min	*P*
FVC (l)	3.98 0.9	3. 29* 0.6	3.83 0.8	3.89 1.1	3.93 1.2	0.022
FEV_1 (l)	4.62 0.7	4.40 0.1	4.44 0.9	4.54 0.7	4.58 0.9	0,703
PEFR($l.s^{-1}$)	9.19 1.2	8.11 * 0.8	8.91 0.9	9.12 0.7	9.21 0.6	0.009
FEF_{50} ($l.s^{-1}$)	4.74 1.1	4.69 0.6	4.72 1.0	4.70 0.8	4.71 0.7	0.547

Abbreviations: RSA,repeated sprint ability; SEM, pre-RSA, before RSA; post-RSA, immediately after RSA; post-RSA-3 min, 3-min after exercise; post-RSA-6 min; 6-min after exercise and post-RSA-9 min, 9 min after exercise. FVC, forced vital capacity; FEV_1, forced expiratory volume in one second; PEFR, peak expiratory flow rate; ($FEF_{50\%}$), forced expiratory flow rate at 50% of FVC; * Significant difference, between post-RSA versus pre-RSA (p<0.05).

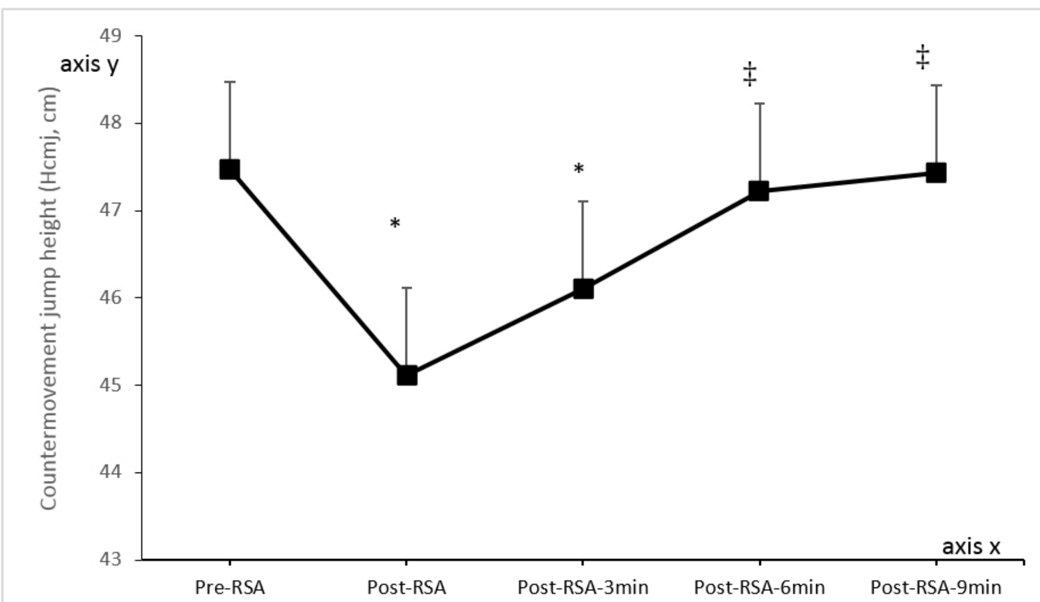

Figure 1: Countermovement jump height (Hcmj), pre-Repeated Sprint Ability (pre-RSA) versus post-RSA, post-RSA-3min, post-RSA-6min and post-RSA-9min. * significant (*P*< 0.05) difference between pre-RSA versus post-RSA, post-RSA-3min. ‡significant (*P*< 0.05) difference between post-RSA versus post-RSA-6min and post-RSA-9 min.

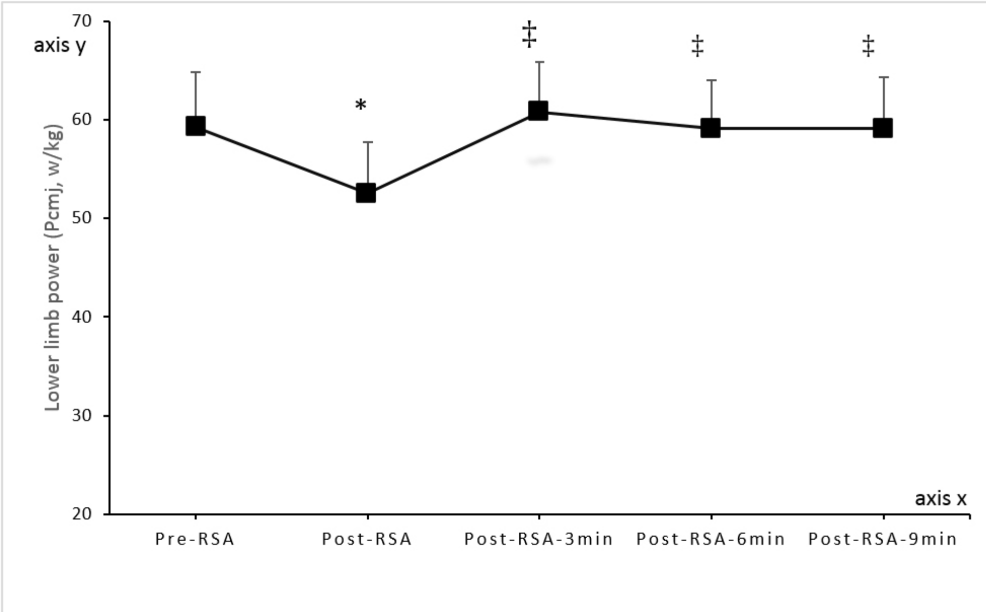

Figure 2: Lower limb power (Pcmj), * significant ($p < 0.05$) difference between pre-Repeated Sprint Ability (pre-RSA) versus post-RSA. ‡significant ($p < 0.05$) difference between post-RSA versus post- RSA-3 min, 6 min and 9 min.

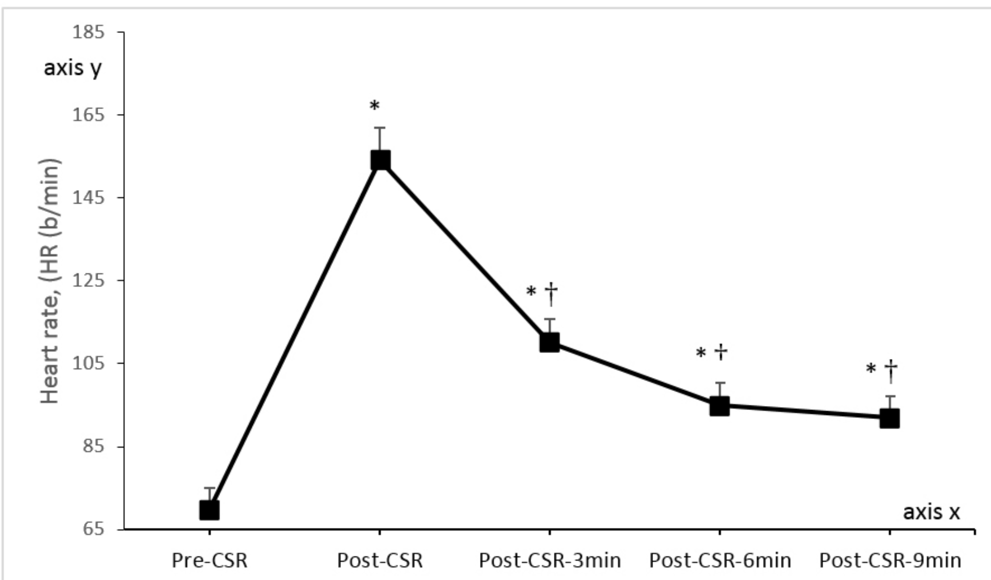

Figure 3: Heart rate (HR), * significant ($p < 0.05$) difference between pre-Repeated Sprint Ability (pre-RSA) versus post- RSA, post- RSA -3min, post- RSA -6min and post- RSA -9min. *†significant ($p < 0.05$) difference between post- RSA versus post- RSA -3min, post- RSA -6min and post- RSA -9 min.