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Aerobic fitness is associated with improved repeated sprints ability of basketball players after six weeks of training during preseason

Aptidão aeróbica é associada com a melhora da capacidade de sprints repetidos de atletas de basquetebol após seis semanas de treinamento durante o período preparatório

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Abstract – The repeated sprints ability (RSA) is considered an important attribute for basketball, being aerobic fitness pointed out as limiting factor for repetition of sprints. The aim of the study was to verify if the change in VO_{2PEAK} is related to the improvement of RSA after six weeks of training during preseason. Twelve male college basketball players aged 18-24 participated in the study. Players were submitted to body composition evaluation, maximum incremental treadmill test and RSA test (6x30-m) before and after six weeks of training. For the purpose of the study, the calculation of the change percentage delta was used. Paired t-test was used to verify differences after training and Pearson's correlation and simple linear regression were used to verify the relationship between $\Delta\%VO_{2PEAK}$ and $\Delta\%RSA$. There were improvements in RSA_{PEAK} ($t_{(1.11)} = 2.7, p = 0.023$); RSA_{MEAN} ($t_{(1.11)}$= 2.8, p= 0.019); RSA_{TOTAL} ($t_{(1.11)}$= 2.6, p= 0.028); RSA_{DEC} ($t_{(1.11)}$= 2.9, p= 0.015); and sprints 4 ($t_{(1.11)}$= 2.4, p= 0.037); 5 ($t_{(1.11)}$= 3.14, p= 0.010); and 6 ($t_{(1.11)}$= 3.65, p= 0.004) and $VO2_{PEAK}$ ($t_{(1.11)}$= -5.4, p <0.001); $\Delta\%VO2_{PEAK}$ was related to $\Delta\%RSA_{MEAN}$ (r= -0.667; r2= 0.383), $\Delta\%RSA_{TOTAL}$ (r= -0.673; r2= 0.393), Δ%Sprint 3 (r= -0.669; r2= 0.387), Δ%Sprint 4 (r= -0.659 ; r2 = 0.371), Δ%Sprint 5 (r= -0.689; r2 = 0.413), Δ%Sprint 6 (r= -0.678; r2 = 0.400). It is possible to conclude that ~ 39% of the improvement in variables associated with the maintenance of repeated sprints (RSA_{MEAN}, RSA_{TOTAL}, Sprints 3,4,5 and 6) of basketball players was accompanied by an increase of ~ 7.5% in $VO2_{PEAK}$.

Key words: Athletes; Athletic performance; Physical fitness; Sports.

Resumo – *A capacidade de sprints repetidos (CSR) é considerada um importante atributo para o basquetebol, sendo a aptidão aeróbica apontada como fator limitante para a repetição dos sprints. O objetivo do estudo foi verificar se a mudança no* VO_{2PICO} *se relaciona com a melhoria da CSR após seis semanas de treinamento durante o período preparatório. 12 atletas de basquetebol universitário do sexo masculino com idade entre 18-24 anos participaram do estudo. Os atletas foram submetidos a uma avaliação da composição corporal, teste incremental máximo em esteira e teste de CSR (6x30-m) antes e após seis semanas de treinamento. Para efeito do estudo recorreu-se ao cálculo do delta percentual de mudança. Teste t pareado foi utilizado para verificar as diferenças após o treinamento e a correlação de Pearson e regressão linear simples foram utilizadas para verificar a relação entre o* $\Delta\%VO_{2PICO}$ *e Δ%CSR. Observou-se melhorias nos índices* CSR_{PICO} ($t_{(1,11)}$*= 2,7; p=0,023);* $CSR_{MÉDIA}$ ($t_{(1,11)}$*= 2,8; p=0,019);* CSR_{TOTAL} ($t_{(1,11)}$*= 2,6; p=0,028);* CSR_{DEC} ($t_{(1,11)}$*= 2,9; p=0,015); e sprints 4* ($t_{(1,11)}$*= 2,4; p=0,037); 5* ($t_{(1,11)}$*= 3,14; p=0,010); e 6* ($t_{(1,11)}$*= 3,65; p=0,004) e* $VO2_{PICO}$ ($t_{(1,11)}$*= -5,4; p<0,001); O* $\Delta\%VO2_{PICO}$ *se relacionou com o* $\Delta\%CSR_{MÉDIA}$ *(r=-0,667;* r^2*= 0,383),* $\Delta\%CSR_{TOTAL}$ *(r= -0,673;* r^2*= 0,393), Δ%Sprint 3 (r=-0,669;* r^2*=0,387), Δ%Sprint 4 (r=-0,659;* r^2*=0,371), Δ%Sprint 5 (r=-0,689;* r^2*=0,413), Δ%Sprint 6 (r=-0,678;* r^2*=0,400). É possível concluir que ~39% da melhoria das variáveis associadas com a manutenção de sprints repetidos (*$CSR_{MÉDIA}$*;* CSR_{TOTAL}*; sprints 3,4,5 e 6) dos atletas de basquetebol foi compartilhada pelo aumento de ~7,5% no* VO_{2PICO}.

Palavras-chave: *Atletas; Aptidão física; Desempenho atlético; Esportes.*

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INTRODUCTION

To conduct a training program for a specific sport, understanding its physical and physiological demands is crucial for coaches and other professionals involved in preparing athletes. In team sports, it has been demonstrated that one of the main movements carried out is high-intensity and short-duration sprints, interspersed by short periods of low-moderate intensity recovery that may involve walking and running actions[1-3]. Specifically in basketball, athletes perform on average 55-105 sprint movements, which can be repeated every 21-39s[1,4], with maximum or near maximum sprints being maintained as an important condition for competitive performance.

The ability to maintain the best performance in successive sprints is called repeated sprints ability (RSA), which is characterized by short high-intensity (<10-s) stimuli interspersed by short recovery periods (<60-s)[5]. RSA has proved to be a validated and reliable field test to be used in modalities such as soccer[6], indoor soccer[7], basketball[8], handball[9] and tennis[10], mainly because they present characteristics similar to physical and physiological demands during the game[1-3].

Considering the information above, the importance of understanding which factors may be associated with the improvement of RSA becomes evident. From the point of view of energy demand, despite a greater anaerobic contribution in RSA[11,12], previous studies have reported the importance of aerobic fitness in RSA performance, and a significant and negative correlation with greater aerobic power[13,14] was found. These authors have argued that this relationship is mainly due to the importance of oxidative metabolism in providing adenosine triphosphate (ATP) for resynthesis of phosphocreatine (PCr) and removal of metabolites (H^+ and $[P_i\text{-}]$)[5]. In this context, previous studies have shown that the PCr resynthesis rate is dependent on the oxygen supply[15,16]. Additionally, it was reported that as sprints repeat, the aerobic contribution to energy supply is greater[11,17], which may delay the onset of fatigue[18].

In order to evaluate the relationship between RSA and aerobic power, most studies have presented transversal designs and did not aim to investigate the relationship between increase in aerobic power and RSA performance[6,13,14,19]. Moreover, these studies have not presented consistent data on the relationship between aerobic power and RSA, and some studies have found a significant linear relationship[13,14], while others have not observed this relationship[6,19]. In view of the above, it is important to investigate whether the increase in aerobic power is related to the improvement in RSA through experimental designs, considering the importance of this attribute for athletic performance in basketball and similar modalities, as illustrated above. Therefore, the aim of the present study was to verify the relationship between improvement of aerobic power ($\Delta\%\ VO2_{PEAK}$) and RSA performance after 6 weeks of preseason training of college basketball athletes. It has been hypothesized that the improvement of aerobic power would be related to the improvement of RSA indexes related to the repetition of efforts.

METHODOLOGICAL PROCEDURES

Subjects

This is a non-controlled experimental study involving male basketball athletes. The sample selection was intentionally performed, being composed of 12 athletes of the same team, aged 18-24 years (age = 21.50 + 2.73 years, body mass = 80.61 + 14.31 kg, height = 180.25 + 1.60 cm, fat percentage = 23.03 + 1.24, free fat mass = 60.53 + 1.62), participants of college competitions at regional and national level. Athletes trained on average 2 hours daily, often three times a week. To be included in the study, athletes should: a) be in competitive basketball activity for more than three years; b) not present any lesion that would make the study procedures unfeasible; c) do not use ergogenic nutritional substances that could influence the study data. Athletes with attendance less than 85% were excluded in the training sessions. At the end of the experimental protocol, one athlete was excluded (attendance <85% in the training sessions), resulting in 11 athletes. The study was approved by the Ethics Research Committee of the Federal University of Rio Grande do Norte (CAAE: 58886816.2.0000.5537) and complied with the norms of Resolution 466/12 of the National Health Council for research on human beings, also in compliance with the ethical principles contained in the Declaration of Helsinki (2013) of the World Medical Association. Athletes were informed about the study and signed the informed consent form.

Study Design

The present investigation was conducted at the end of the athletes' preparatory period and lasted nine weeks (one week for the test familiarization sessions, one week for pre-test, six weeks of training and one week for post-test). The tests included were dual-energy radiological absorptiometry (DEXA), incremental maximal treadmill test and RSA, which were performed in the pre- and post-intervention period, with a 72-h interval between tests. After a 48-hour period from RSA, athletes performed six weeks of training, which consisted of techinical-tactical and repeated sprint actions, as shown in Figure 1. All athletes received verbal stimuli and were instructed not to perform vigorous physical activities during the 24 hours preceding the tests, in addition to avoiding the consumption of ergogenic nutritional substances and to make the last meal in a period of 3 hours before each test.

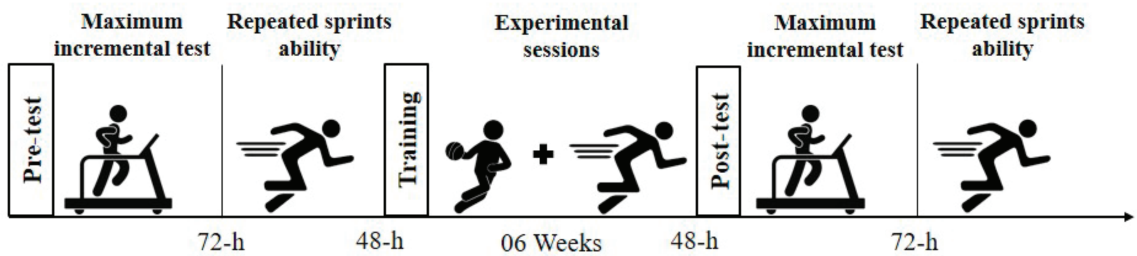

Figure 1. Experimental design
Vertical lines represent the recovery between procedures; experimental session (technical-tactical + repeated sprints training)

Protocols and instruments

- **Body composition**

Body mass and stature were measured using an electronic scale (Welmy®, São Paulo, Brazil), with 300 kg capacity and 50-g precision and a stadiometer, with 0.1 cm precision, respectively. Body composition, fat percentage and free fat mass were measured using dual energy radiological absorptiometry (DEXA) (Lunar® / G.E PRODIGY - LNR41.990, United States)[20].

- **Maximum incremental test**

Aerobic fitness was identified by maximal treadmill running protocol (Centurion 200®, Micromed, Brasilia, Brazil) using an ergospirometry system. Athletes were maintained at initial velocity of 8km / h for three minutes, and then velocity was increased by 1km / h every minute until voluntary exhaustion. During the protocol, heart rate was constantly monitored through a Polar frequency meter (RS800cx, Polar Electro®, Oy, Kempele, Finland). To characterize maximum effort during the test, the following criteria were adopted: a) ratio of respiratory changes R > 1.1; b) peak heart rate > 90% predicted by age (HRmax = 220-age); and c) ratings of perceived exertion (RPE) = 19 reported by the Borg scale[21]. Ventilatory analyses were recorded every 20-s by a gas analyzer (Metalyzer® 3B, Cortex Biophysik GmbH, Leipzig, Germany), calibrated for gas and volume according to the manufacturer's recommendations. The ambient temperature in the laboratory was ~24° during the incremental test.

- **Repeated sprint ability (RSA)**

RSA test involved 06 repetitions of 30-m all-out sprints[22], with passive 20-s recovery between each sprint. Sprints were recorded through a photocell system (Speed Test 6.0 CEFISE®, São Paulo, Brazil), positioned for every 10 of the total 30 m. After specific warm-up exercise (5-7-min), athletes performed a maximum 30-m velocity test (V30). For RSA test acceptance criteria and to avoid pacing strategy, athletes were instructed to achieve a score > 90% of individual performance on the V30 test in the first sprint. In addition to the six sprints, the following indexes were used for analysis: the best performance among sprints (RSA_{PEAK}); total time of all sprints (RSA_{TOTAL}); mean time between all sprints (RSA_{MEAN}) and sprint decrease (RSA_{DEC}), the latter being identified by the following equation: Sprint decrease = {(total time / ideal time) -1} x 100. The ideal time is the best performance multiplied by six[5].

- **Training Sessions**

Training sessions began with a ~10-min warm-up that involved specific basketball actions (e.g. dribbling and throwing) followed by repeated sprint training (RST). The remaining training time has been devoted to general and specific exercises for athletes according to their playing positions (e.g. point guard, small forward and center). The daily training routine involved technical-tactical actions and simulated games. The technical training included exercises of throws, passes, dribbles and rebounds. Tactical training included zone, individual and pressure defense exercises, counter-attack moves, half-court and offensive actions. RST consisted of all-out sprints in the straight line. In the first week, 2 series of 6x30-m, in the second to the fifth week, 3 series 6x30-m, and in the sixth week, 2 series of 6x30-m were performed. Sprints were interspersed with a 20-sec period of passive recovery and each series was separated by 5-min active recovery involving running at low intensity, ratings of perceived exertion = 9 (easy) on the 6-20 scale[21].

Statistical analysis

Data are presented as mean and standard deviation. The normality of data was verified through the Shapiro-Wilk test. T-test for paired sample was used to compare the RSA and $VO2_{PEAK}$ performance after experimental session. The effect size was calculated using the Cohen's equation d = (post-test / pre-test), with the adoption of the following thresholds: <0.2 trivial,> 0.2 to <0.6 small, > 0.6 to 1.2 moderate,> 1.2 to 2.0 large,> 2.0 to 4.0 very large[23]. The change percentage (Δ%) of RSA and $VO2_{PEAK}$ was calculated according to equation: Δ% = ([post - pre] / pre * 100). The relationship between Δ%RSA and Δ%$VO2_{PEAK}$ was verified through Pearson's correlation, and a simple linear regression analysis was performed for dependent variables that were significantly related to Δ%$VO2_{PEAK}$. The following correlation thresholds were considered: coefficient r <0.01 reflects trivial correlation; 0.1 <0.3 small; 0.3 <0.5 moderate; 0.5 <0.7 strong; 0.7 <0.9 very strong; 0.90 – 0.99 almost perfect; and 1.0 perfect[23]. Data were analyzed using Statistical Package for Social Sciences (SPSS) software version 20.0 (New York, USA). The significance level was set at 5%.

RESULTS

Table 1 shows the effect of the six weeks of training on athletes' physical performance. Significant improvements were observed for RSA_{PEAK} ($t_{(1.11)}$ = 2.7, p = 0.023); RSA_{MEAN} ($t_{(1.11)}$= 2.8, p= 0.019); RSA_{TOTAL} ($t_{(1.11)}$= 2.6, p= 0.028); RSA_{DEC} ($t_{(1.11)}$= 2.9, p= 0.015); and sprints 4 ($t_{(1.11)}$= 2.4, p= 0.037); 5 ($t_{(1.11)}$= 3.14, p= 0.010); and 6 ($t_{(1.11)}$= 3.65, p= 0.004); however, no improvement was observed in sprints 1 ($t_{(1,11)}$ = 0.3, p = 0.773); 2 ($t_{(1.11)}$ = 1.9, p = 0.077); and 3 ($t_{(1.11)}$ = 1.8, p = 0.104). Figure 2 shows the significant improvement of $VO2_{PEAK}$ after training ($t_{(1.11)}$ = -5.4, p <0.001, d = 1.6). No differences were observed between fat percentage values pre- (22.45 ± 4.0) and post-training (22.38 ± 3.8, p = 0.630), as well as in the free fat mass pre- (59, 53 ± 6.27) and post-training (59.78 ± 6.4; p = 0.89).

Table 2 shows correlation and linear regression (adjusted r^2) between Δ%VO_{2PEAK} e a Δ%RSA after six weeks of training. Significant negative relationships were observed in indexes associated with sprints repetition, Δ%RSA_{MEAN}, Δ%RSA_{TOTAL}, Δ% Sprints 3, 4, 5 and 6; on the other hand, no relation of Δ%VO_{2PEAK} was observed with the indices and sprints associated with the initial stimuli Δ%RSA_{PEAK}, Δ%Sprints 1 and 2 and Δ%RSA_{DEC}.

Table 1. Effect of training on the repeated sprints ability

Variables	Pre	Post	Δ% (CI 95%)	Cohen's d
RSA_{PEAK} s)	4.58 ± 0.21	4.37 ± 0.13	-4.24 (-7.68. -0.80)*	0,8 (moderate)
RSA_{MEAN} (s)	4.84 ± 0.31	4.67 ± 0.19	-3.28 (-5.88. -0.60)*	0,8 (moderate)
RSA_{TOTAL} (s)	29.00 ± 1.91	28.05 ± 1.15	-3.10 (-5.79. -0.41)*	0,8 (moderate)
RSA_{DEC} (%)	7.64 ± 5.76	3.27 ± 1.72	-45.73 (-70.73. -20.74)*	0,9 (moderate)
Sprint 1 (s)	4.55 ± 0.24	4.52 ± 0.15	-0.34 (-5.03. 4.35)	0,1 (trivial)
Sprint 2 (s)	4.69 ± 0.28	4.56 ± 0.17	-2.53 (-2.63. -2.19)	0,6 (moderate)
Sprint 3 (s)	4.79 ± 0.37	4.66 ± 0.19	-2.45 (-5.57. 0.66	0,5 (small)
Sprint 4 (s)	4.91 ± 0.41	4.73 ± 0.22	-3.44 (-6.36. -0.51)*	0,7 (moderate)
Sprint 5 (s)	4.97 ± 0.39	4.75 ± 0.22	-4.08 (-6.72. -1.44)*	1,0 (moderate)
Sprint 6 (s)	5.07 ± 0.42	4.80 ± 0.24	-5.01 (-7.76. -2.26)*	1,1 (moderate)

RSA = repeated sprints ability; RSADEC = sprint decrease; Δ% = change percentage; * p <0.05; CI 95% = 95% confidence interval.

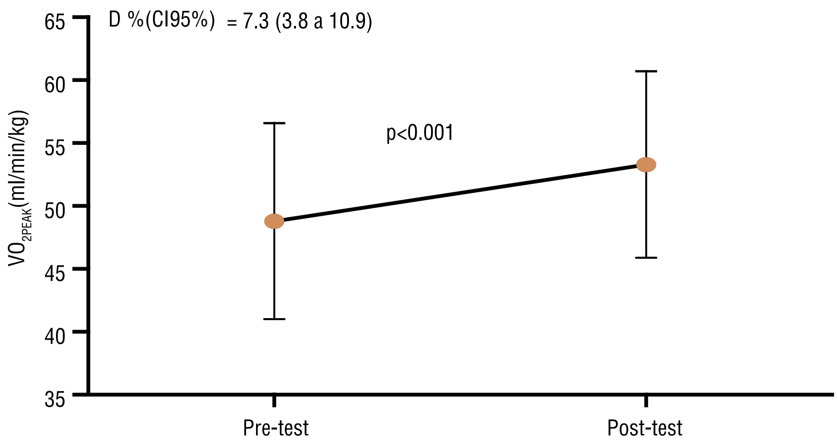

Figure 2. Effect of training on VO2PEAK
Δ% = change percentage; * p <0.05; 95% CI = 95% confidence interval.

Table 2. Relationship between Δ% VO2PEAK and Δ% RSA and Δ% Sprints after six weeks of preseason training.

Variables	Δ%VO_{2PEAK} (ml/kg/min)		
	r	r^2	p
RSA_{PEAK}	-0.481	-	0.134
RSA_{MEAN}	-0.667	0.383	0.025*
RSA_{TOTAL}	-0.673	0.393	0.023*
RSA_{DEC}	-0.360	-	0.277
Sprint 1	-0.315	-	0.346
Sprint 2	-0.541	-	0.085
Sprint 3	-0.669	0.387	0.024*
Sprint 4	-0.659	0.371	0.027*
Sprint 5	-0.689	0.413	0.021*
Sprint 6	-0.678	0.400	0.022*

RSA = repeated sprints ability; RSA_{DEC} = sprint decrease; * p <0.05.

DISCUSSION

The main findings of this study demonstrated that six weeks of technical-tactical + repeated sprints training promoted significant improvements in RSA and aerobic fitness of basketball athletes, and that ~ 39% of variance of Δ% RSA_{MEAN}, Δ% RSA_{TOTAL}, Δ% Sprint 3, 4, 5 and 6 was accompanied by Δ% $VO2_{PEAK}$ of ~ 7.5%. These findings add relevant information to the current knowledge and confirm the hypothesis that increased aerobic power is related to the improvement in RSA.

RSA and aerobic power improvement after RST in addition to the technical-tactical training routine is an interesting finding for the context of team sports, considering their specific physical and physiological demands[2,3,24]. During a basketball game, high-intensity actions (e.g., sprints, jump and specific moves) are repeated 193-214 times[1,4], and a sprint movement is performed every 21-39 s. Muscle biopsy analysis has shown that this short interval is able to resynthesize only ~ 70% of the PCr content relative to the resting level after a 6-s sprint[25]. Considering this partial PCr resynthesis, it has been argued that aerobic fitness plays an important role in maintaining the performance of active muscles in successive sprints[18,26]. McGawley; Bishop[17] demonstrated an aerobic contribution of ~ 10% in the first sprint and ~ 40% in the last effort of five 6-s sprints. More recently, Milioni et al.[11] also reported a greater aerobic contribution after sprints repetition. These findings are consistent with those of the present study, showing that ~39% of variance in Δ% RSA_{MEAN}, Δ% RSA_{TOTAL}, Δ% Sprints 3, 4, 5 and 6 were accompanied by an improvement of ~ 7, 5% in Δ% $VO2_{PEAK}$. These relationships found in our study are an interesting finding for coaches and other professionals involved with basketball specifically for confirming that the increase in aerobic power is negatively and strongly related with the ability to prolong peak performance in successive series of sprints during training and / or games. Therefore, professionals involved in the preparation of athletes are encouraged to increase the aerobic power of basketball athletes during training sessions.

From the energetic point of view, the absence of a relationship between Δ%VO_{2PEAK} and Δ%RSA_{PEAK} can be easily explained. It is well established that during the initial efforts of high intensity and short duration, there is a predominance of the phospha- genic metabolism[5,12,27]. Classical studies conducted by Gaitanos et al.[27] and Bogdanis et al.[12] reported a 57-84% depletion of PCr content in relation to rest, after sprints of 6 and 30 s, respectively. It is important to note that, in our study, Δ%RSA_{PEAK} was characterized by sprints 1 or 2, which may explain the absence of correlation with Δ%VO_{2PEAK}. Therefore, it is argued that the improvement in the explosive strength of the lower limbs found in RSA_{PEAK} is attributed to increased motor unit synchronization, elastic energy stock efficiency during the performance of the stretching-shortening cycle, or musculotendinous stiffness[26].

The increase in RSA and aerobic power was previously found after similar experimental design including RST and specific technical-tactical training in different intermittent sports[10,28,29]. Bravo et al.[28] found similar improvement in $VO2_{MAX}$ and superior effect in RSA_{MEAN} after seven weeks of RST (all-out sprints with change of direction) when compared to high intensity interval aerobic training (4 series of 4' at 90-95 % of HR_{MAX} and 3' of active recovery at 60-70% of HR_{MAX}) during the competitive period of young soccer athletes. Fernandez-Fernandez et al.[10] demonstrated improvement in RSA_{MEAN} and VO_{2PEAK} (Δ% = 5.39) in tennis athletes after six weeks of RST (all-out sprints with change of direction) during preseason. More recently, Kaynak et al.[29] observed improvements in RSA_{MEAN}, RSA_{DEC} and VO_{2PEAK} in volleyball athletes after six weeks, 3x/week of RST in the preparatory period. Together, these data demonstrated a parallel increase in the ability to extend maximum performance in successive sprints and aerobic power. In addition, Abdelkrim et al.[1] demonstrated that the aerobic power estimated by the 20-m multiple stage test with change of direction was positively related to the time spent in high-intensity activities during the game in U-19 basketball athletes. For these reasons, it would be reasonable to expect that $\Delta\%VO_{2PEAK}$ would have a linear and negative relationship with $\Delta\%\ RSA_{DEC}$, however, this hypothesis was not supported in our study.

Evidence through muscle biopsy has supported that muscle power recovery is dependent on resynthesis of intramuscular PCr[12,16], where low aerobic power is considered a limiting factor of RSA[15]. Therefore, it is possible that this lack of correlation between $\Delta\%VO_{2PEAK}$ and $\Delta\%\ RSA_{DEC}$ in our study is associated with the learning effect inherent to the repetition of the stimuli that are similar to the RSA test (e.g., increased coordination and pacing strategies)[30]. It is noteworthy that despite the strong correlations found in our study, $\Delta\%VO_{2PEAK}$ was accompanied by ~ 39% of variance (e.g., RSA_{MEAN}, RSA_{TOTAL}, Δ% Sprints 3,4,5 and 6) not being able to explain most of it. Thus, it is possible that $\Delta\%\ RSA_{DEC}$ is attributed to other mechanisms (e.g., neural adaptations, promoting increased intermuscular coordination, recruitment and firing rate of motor units)[26]. Additionally, it is well established that muscle fatigue (decreased performance) is multifactorial and complex. Therefore, it cannot be only associated with aerobic power. Thus, future investigations should seek to identify other factors that may be associated with the improvement of RSA in a longitudinal way.

From the practical point of view, the findings of the present study provide relevant contributions to coaches and other professionals involved in the preparation of basketball athletes and modalities with similar characteristics. First, it was observed that the increase in aerobic power after six weeks of RST additional to the tactical-technical training was negatively and strongly related to the improvement of the ability to extend peak performance in successive sprints. In basketball, RSA is considered one of the most frequent movements in training and games, and plays an important role for success in sport[8]. Therefore, coaches and professionals involved with the preparation of athletes should aim at improving aerobic power. Second, RST additional to tactical-technical training appears to be a strategy capable of promoting neuromuscular adaptations (e.g., RSA_{PEAK} and RSA_{DEC}) and aerobic power. However, it is important to note that in the present study, a control group was not used. Therefore, caution should be taken in interpreting the effect of RST additional to tactical-technical training on aerobic power and RSA, and future investigations should be performed considering a control group. Although the present study adds relevant information to the current knowledge on this subject, this study has some limitations such as the absence of a control group, which could promote greater robustness in the study. However, since it included athletes, it is understandable that athletes could not spend a period of six weeks during the preparatory period without specific training. In addition, it is possible that the additional training of repeated sprints by presenting characteristics similar to the RSA test may have promoted learning effect by the repetition of the movement and therefore, other investigations with different training strategies should verify the effect of VO_{2PEAK} on the improvement of RSA.

CONCLUSION

It is possible to conclude that ~ 39% of the improvement in variables associated with the maintenance of repeated sprints (RSA_{MEAN}, RSA_{TOTAL}, Δ% Sprints 3,4,5 and 6) of basketball athletes was accompanied by an increase of ~ 7.5% in VO_{2PEAK} after six weeks of repeated sprints training in addition to routine technical-tactical training during preseason. These data demonstrate that coaches and coaching staff should be encouraged to incorporate training strategies that focus on athletes' aerobic fitness (e.g., RST) in order to promote increased ability to maintaining peak performance in successive sprints required during training and games.

REFERENCES

1. Abdelkrim N, Fazaa E, Ati E. Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. Br J Sports Med 2007;41(2):69–75.
2. Dogramaci SN, Watsford ML, Murphy AJ. Time-motion analysis of international and national level futsal. J Strength Cond Res 2011;25(3):646–51.
3. Póvoas SCA, Seabra AFT, Ascensão AAMR, Magalhães J, Soares JMC, Rebelo ANC. Physical and physiological demands of elite team handball. J Strength Cond Res 2012;26(12):3365–75.
4. McInnes S, Carlson J, Jones C, McKenna M. The physiological load imposed on basketball players during competition. J Sports Sci 1995;13(5):387–97.
5. Girard O, Mendez-Villanueva A, Bishop D. Repeated-sprint ability part I: factors contributing to fatigue. Sport Med 2011;41(8):673–94.
6. Castagna C, Manzi V, D'Ottavio S, Annino G, Padua E, Bishop D. Relation between maximal aerobic power and the ability to repeat sprints in young basketball players. J Strength Cond Res 2007;21(4):1172–6.
7. Nascimento PC, De Lucas RD, Dal Pupo J, Arins FB, Castagna C, Guglielmo LGA. Effects of four weeks of repeated sprint training on physiological indices in futsal players. Rev Bras Cineantropometria e Desempenho Hum 2014;17(1):91.

8. Padulo J, Laffaye G, Haddad M, Chaouachi A, Attene G, Migliaccio GM, et al. Repeated sprint ability in young basketball players: one vs. two changes of direction (Part 1). J Sports Sci 2015;33(14):1480–92.
9. Dello Iacono A, Ardigò LP, Meckel Y, Padulo J. Effect of small-sided games and repeated shuffle sprint training on physical performance in elite handball players. J Strength Cond Res 2016;30(3):830–40.
10. Fernandez-Fernandez J, Zimek R, Wiewelhove T, Ferrauti A. High-intensity interval training vs. repeated-sprint training in tennis. J Strength Cond Res 2012;26(1):53–62.
11. Milioni F, Zagatto AM, Barbieri RA, Andrade VL, Dos Santos JW, Gobatto CA, et al. Energy systems contribution in the running-based anaerobic sprint test. Int J Sports Med 2017;38(2):226–32.
12. Bogdanis GC, Nevill ME, Boobis LH, Lakomy HK. Contribution of phosphocreatine and aerobic metabolism to energy supply during repeated sprint exercise. J Appl Physiol 1996;80(3):876–84.
13. Gantois P, Aidar FJ, Matos DG, Souza RF, Silva LM, Castro KR, et al. Repeated sprints and the relationship with anaerobic and aerobic fitness of basketball athletes. J Phys Educ Sport 2017;17(2):910–5.
14. Stanula A, Roczniok R, Maszczyk A, Pietraszewski P, Zając A. The role of aerobic capacity in high intensity intermittent efforts in ice hockey. Biol Sport 2014;31(3):193–9.
15. Haseler LJ, Hogan MC, Richardson RS, Mccully KK, Mulcahy TK, Ryan TE, et al. Skeletal muscle phosphocreatine recovery in exercise-trained humans is dependent on O2 availability. J Appl Physiol 1999;86(6)2013–8.
16. Mendez-Villanueva A, Edge J, Suriano R, Hamer P, Bishop D. The recovery of repeated-sprint exercise is associated with PCr resynthesis, while muscle pH and EMG amplitude remain depressed. PLoS One 2012;7(12):4–13.
17. McGawley K, Bishop DJ. Oxygen uptake during repeated-sprint exercise. J Sci Med Sport 2015;18(2):214–8.
18. Bishop D, Edge J, Goodman C. Muscle buffer capacity and aerobic fitness are associated with repeated-sprint ability in women. Eur J Appl Physiol 2004;92(4–5):540–7.
19. Dardouri W, Selmi MA, Sassi RH, Gharbi Z, Rebhi A, Yahmed MH, et al. Relationship between repeated sprint performance and both aerobic and anaerobic fitness. J Hum Kinet 2014;40(1):139–48.
20. Naimo M, de Souza E, Wilson J, Carpenter A, Gilchrist P, Lowery R, et al. High-intensity interval training has positive effects on performance in ice hockey players. Int J Sports Med 2014;36(1):61–6.
21. Borg G. Borg's perceived exertion and pain scales. Champaign: Human Kinetics; 1998.
22. Rossignol P Le, Gabbett TJ, Comerford D, Stanton WR. Repeated sprint ability and team selection in australian football league players. Int J Sports Physiol Perform 2014;9(1):161–5.
23. Hopkins WG. A scale of magnitudes for effect statistics. A new view of statistics. 2002. Disponível em: < http://www.sportsci.org/resource/stats/effectmag.html> [20 nov 2017]
24. Narazaki K, Berg K, Stergiou N, Chen B. Physiological demands of competitive basketball. Scand J Med Sci Sport 2009;19(3):425–32.
25. Dawson B, Goodman C, Lawrence S, Preen D, Polglaze T, Fitzsimons M, et al. Muscle phosphocreatine repletion following single and repeated short sprint efforts. Scand J Med Sci Sport 1997;7(4):206–13.
26. Bishop D, Girard O, Mendez-Villanueva A. Repeated-sprint ability - part II: recommendations for training. Sport Med 2011;41(9):741–56.
27. Gaitanos G, Willians L, Boobis L, Brooks S. Human muscle metabolism maximal exercise. Appl Physiol 1993;75(2):712–9.

28. Bravo D, Impellizzeri FM, Rampinini E, Castagna C, Bishop D, Wisloff U. Sprint vs. interval training in football. Int J Sports Med 2008;29(8):668–74.
29. Kaynak K, Eryılmaz SK, Aydoğan S, Mihailov D. The effects of 20-m repeated sprint training on aerobic capacity in college volleyball players. Biomed Hum Kinet 2017;9(1):43–50.
30. Buchheit M. Should we be recommending repeated sprints to improve repeated-sprint performance? Sports Medicine 2012;42(2):169-73.

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