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original article

Effects of four weeks of repeated sprint training on physiological indices in futsal players

Efeito de quatro semanas de treinamento de sprints *repetidos sobre índices fisiológicos em atletas de futsal*

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Abstract – The aim of this study was to investigate the effects of short repeated-sprint ability (RSA) training on the neuromuscular and physiological indices in U17 futsal players during the competitive period. Fourteen players were divided into two groups: intervention group (n = 8) and control group (n = 6). Both groups performed a repeated maximal sprint test (40-m MST), intermittent shuttle-running test (Carminatti's test) and vertical jumps before and after the training period. The intervention group was submitted to an additional four-week repeated sprints program, twice a week, while the control group maintained their normal training routine. There was no significant interaction between time and groups for all variables analysed ($p > 0.05$). However, a significant main effect was observed for time ($p < 0.01$) indicating an increase on speed at heart rate deflection point (V_{HRDP}) and the continuous jump performance while the peak lactate (40m-LAC_{peak}) and sprint decrement decreased after training, in both groups. Still, based on effect sizes (ES) the greater changes with practical relevance were verified for intervention group in important variables such as peak velocity (ES = 0,71), V_{HRDP} (ES = 0,83) and 40m-LAC_{peak} (ES = 1,00). This study showed that RSA-based and normal training routine are equally effective in producing changes in the analysed variables during a short period of intervention. However, the effect size suggests that four weeks of RSA training would be a minimum time that could induce the first changes of futsal player's physical fitness.

Key words: Aerobic capacity; Blood lactate; Repeated-sprint ability; Team sports; Competitive period.

Resumo – *O objetivo deste estudo foi investigar os efeitos do treinamento de sprints repetidos (RSA) nos índices fisiológicos e neuromusculares em atletas de futsal sub17 durante a temporada competitiva. Quatorze jogadores foram divididos em dois grupos: grupo intervenção (n = 8) e controle (n = 6). Ambos os grupos desempenharam testes de sprints máximos repetidos (40-m MST), teste de corrida intermitente (teste de Carminatti) e saltos verticais antes e depois do período de treinamento. O grupo intervenção foi submetido a um programa adicional de quatro semanas de RSA, duas vezes por semana, enquanto o grupo controle manteve a rotina normal de treinos. Não houve interação significante entre tempo e grupo para todas as variáveis analisadas ($p > 0.05$). Entretanto, um efeito principal significante foi observado para o tempo ($p < 0.01$), indicando um aumento na velocidade do ponto de deflexão da frequência cárdica (V_{HRDP}) e na performance do salto contínuo, bem como, diminuição no pico de lactato (40m-LAC_{peak}) e no decréscimo dos sprints após o treinamento em ambos os grupos. Ainda, baseado no effect size (ES), maiores mudanças com relevância prática foram verificadas para o grupo intervenção em importantes variáveis tais como: pico de velocidade (ES = 0,71) V_{HRDP} (ES = 0,83) e 40m-LAC_{peak} (ES = 1,00). Este estudo demonstrou que o treinamento de RSA e a rotina normal de treinos são igualmente efetivos em produzir mudanças nas variáveis analisadas durante um curto período de intervenção. Porém, o effect size sugere que quatro semanas de treinamento de RSA pode ser um tempo mínimo para que ocorram as primeiras alterações no desempenho físico de atletas de futsal.*

Palavras-chave: *Capacidade aeróbia; Lactato sanguíneo; Sprints repetidos; Esportes coletivos; Período competitivo.*

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INTRODUCTION

Futsal is the indoor version of soccer, a 5-a-side game played on a court with reduced dimensions (40 x 20 m) and unlimited substitutions are permitted during the matches. Consequently, physical demands of the game may result in being very high[1]. Analysis of movement demands during the 40-minute period (2 x 20 min of stop-time) characterizes futsal as an intermittent and high-intensity modality that requires both aerobic and anaerobic metabolism[1-4]. One must consider that despite appearing to be similar, the modality have intrinsic differences in comparison with the soccer, among which one must consider the characteristics of the movement pattern whereas the futsal shows the execution of a greater number of runs of high intensity , sprints and changes of direction, resulting in a greater demand for braking and accelerations therefore, there is a claim to a greater degree of anaerobic pathways to supplement the energy demand of metabolism[1,3].

The repeated-sprints ability (RSA) has been considered as one of the most important aspects for futsal players' performance[3-5]. It has been shown that during official matches, professional futsal players spent at least 20% of the game-time in high-intensity actions (i.e., sprinting and high-intensity running)[1,3]. The physiological demand of RSA and several actions during futsal matches have similar metabolic responses (e.g., decrease in pH muscle level, creatine phosphate, ATP and an important demand on both glycolytic and oxidative systems)[1,4,6,7].

An efficient strategy to develop some physiological markers for team sports[8] seems to be the repeated-sprints performed with directional changes and therefore could be adopted as a training model to improve futsal players' performance. According to previous studies, RSA-based training might promote improvement in the ability to repeat high intensity exercise, and increases of aerobic fitness in non-athletes[9-12] and team-sport athletes[8,13].

Although RSA-based training has been used for the physical training, there is no sufficient scientific information in the literature regarding the physiological and neuromuscular impact from this training model on futsal, especially during a competitive period[4,5]. Oliveira et al.[5] have reported that 2-3 official matches played per week during in-season for high level futsal players was enough to maintain aerobic fitness and improve the best sprint of RSA, even with observed low physical training demand. In comparison to professional futsal players, the frequency of official weekly matches observed in amateur players during competitive season is only once a week supposedly requiring additional training sessions.

Therefore, the aim of this study was to investigate the effects of repeated sprint training during a 4-week competitive period on the physiological (aerobic and anaerobic) and neuromuscular indices in amateur futsal players. Our main hypothesis is that a short period of RSA training will mainly improve the index related to aerobic power (i.e. peak velocity), since it is influenced by both aerobic and anaerobic metabolism, as observed in RSA[14].

METHODOLOGICAL PROCEDURES

Participants

Subjects selection was intentional non-probabilistic. Eighteen amateur male U17 futsal players (16.7 ± 0.5 years, 68.5 ± 6.6 kg, 176.6 ± 4.5 cm and 10.1 ± 4.0% body fat) volunteered to participate in this study. All players were from the same team located in Florianópolis, SC, Brasil. The main inclusion criterion to participate in this investigation was that all subjects should be involved in a systematic training program in the last four years. The athletes had competed at the regional level usually playing one official match per week. The participants were divided randomly into two groups: intervention (G_{RSA}, n = 10) and control ($G_{CONTROL}$, n = 8). However, during the period of the study, there were two participants in each group that presented muscle injuries during the matches and were withdrawn from the study. Thus, the final sample size was 8 for G_{RSA} and 6 for $G_{CONTROL}$.

Written informed consent was received from all participants and legal guardians of the under-age players after a brief but detailed explanation about the aims, benefits and risks involved with this investigation. All procedures were approved by the ethics committee of the Federal University of Santa Catarina, Florianopolis, Brazil (number 224/08), in accordance to the Helsinki declaration.

Design

The G_{RSA} performed a short period of four weeks of the RSA-based training program, with a frequency of two sessions per week. However, on the others days of week, both groups (G_{RSA} and $G_{CONTROL}$) maintained their normal training routine (Table 1 and 2). In the first (i.e., pretest) and the sixth week (i.e., post testing) the players performed the following assessments: 1) determining the vertical jumping performance, 2) progressive distance intermittent shuttle-running protocol, and 3) repeated maximal sprint test. Prior to each testing session, stretching and warm-up exercises were performed for about 20 min. The entire study period (testing and intervention) took place during the competitive season and it was incorporated into the daily routine of team training (2 hours per day, 5 days a week). The tests were applied at the same time of the day, at least 24 hours apart, and all the athletes were instructed to maintain a similar nutrition and hydration routine before the performance evaluations. Players were familiarized with these tests, since during the season the players were submitted to these protocols.

Training Protocol

During the four weeks of the season, the G_{RSA} was submitted to additional two sessions per week of a training protocol adapted from the model proposed by Ferrari Bravo et al.[8] All RSA-based training which consists of short sprints over a distance of 40 m took place before the technical and tactical work, preceded by warming up and stretching. Each session

consists of three sets of six sprints, with 20 s of passive recovery between the sprints and 4 min of passive recovery between the sets. All sprints were performed with 180º direction changes every 10 m. The distance of 10 m, instead of 20 m was adopted in the present study in order to adjust to the shorter displacement of futsal players during a game. At the end of each repeated sprint intervention session the distance the athletes travelled was 720 m. During the entire intervention period both groups performed the training established by the coaches at the beginning of the season (e.g., tactical and technical training, drills), except for the days in which the G_{RSA} performed the additional repeated sprints and $G_{CONTROL}$ maintained the normal work routine (Table 1 and Box 1).

Table 1. Training conducted by control group during the eight sessions of additional sprint training for intervention group.

Weeks	G_{RSA} (n = 8)	$G_{CONTROL}$ (n = 6)
First	3 sets of 6 sprints 40 meters	3 sets of 4 min Coordination+agility +sprint 10m+5m
First	3 sets of 6 sprints 40 meters	Technical-tactical training
Second	3 sets of 6 sprints 40 meters	3 sets of 4 min coordination+agility +sprint 10m+5m
Second	3 sets of 6 sprints 40 meters	3 sets of 3 min plyometrics+sprint 10m+5m+lateral displacement in squat
Third	3 sets of 6 sprints 40 meters	3 sets of 4 min coordination+agility +sprint 10m+5m
Third	3 sets of 6 sprints 40 meters	3 sets of 3 min plyometrics+sprint 10m+5m+lateral displacement in squat
Fourth	3 sets of 6 sprints 40 meters	3 sets of 4 min Coordination+agility +sprint straight 20m
Fourth	3 sets of 6 sprints 40 meters	3 sets of 3 min plyometrics+sprint 10m+5m+lateral displacement in squat

G_{RSA} = Intervention group. $G_{CONTROL}$ = Control group.

Aerobic indices measurements

The progressive distance intermittent shuttle-running protocol (Carminatti's test -TCAR)[15,16] was performed by the futsal players to determine the aerobic indices. This test has been shown highly reliable (ICC = 0.94, CV = 1.4% for PV) for soccer players.[15] Carminatti's test consists of progressive intermittent shuttle runs performed between 2 lines set at progressive distances. The test protocol considers a starting speed of 9 km·h^{-1} and a corresponding running base of 15 m, which is increased by 1 m every 90 seconds. Each distance stage (i.e. from 15 m to exhaustion) is composed of 5 repetitions of 12 s interspersed by a 6 s walk to be performed between 2 lines set 5 m apart from the starting/ending line. Running pace is dictated

by a constant frequency (i.e. 6 s) audio cue (beep), which determines the running speed to be performed between the parallel lines demarcated in the ground and marked by cones. The test ends when the subject fails to stay on time with the audio cues on the front line for 2 successive occasions (i.e. objective criteria) or the perceived inability on the part of the subject to cover more distance at the attained speed level (i.e. subjective criteria). Four experienced staffs from research team were responsible for making sure that the participants fulfilled the testing criteria and to control possible pacing strategy. This control held by verbal encouragement to the players when they presented exhaustion signals. The heart rate (HR) was recorded at the end of each stage by means of a frequency (Polar, model S610i; Kempele, Finland) for subsequent calculation of the HR deflection point (HRDP), through the mathematical method named Dmax[17]. The velocity of HRDP (V_{HRDP}) was defined as the speed for the HRDP and considered as an aerobic capacity index. The highest speed achieved (peak velocity – PV) by the athletes during the test was considered as an aerobic power index. A previous study[16] showed no significant difference of PV obtained during Carminatti's test with the velocity at maximal oxygen uptake (vVO_2max) obtained on the traditional treadmill incremental test.

Box 1. Training program conducted by both groups during the period four weeks of intervention.

Days / Weeks	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1 (pre-test)	NT 10% warm-up 20% TPC 40 % technical 30% tactical	intermittent shuttle-running test (Carminatti's test)	vertical jump performance	repeated maximal sprint test (40m-MST)	NT 10% warm-up 20% TPC 40 % technical 30% tactical	Rest	Rest
2	NT 10% warm-up 20% TPC 40 % technical 30% tactical	RSA 10% warm-up 20% RSA 50% technical 20% tactical	NT 10% warm-up 50 % technical 40% tactical	RSA 10% warm-up 20% RSA 50% technical 20% tactical	NT 10% warm-up 20% TPC 40 % technical 30% tactical	NT 10% warm-up 20% TPC 40 % technical 30% tactical	Rest
3	NT 10% warm-up 20% TPC 40 % technical 30% tactical	NT 10% warm-up 20% TPC 40 % technical 30% tactical	RSA 10% warm-up 20% RSA 50% technical 20% tactical	Game ~70 min	NT 10% warm-up 50 % technical 40% tactical	RSA 10% warm-up 20% RSA 50% technical 20% tactical	Rest
4	RSA 10% warm-up 20% RSA 50% technical 20% tactical	NT 10% warm-up 50 % technical 40% tactical	RSA 10% warm-up 20% RSA 50% technical 20% tactical	NT 10% warm-up 20% TPC 40 % technical 30% tactical	Rest	Game ~70 min	Game ~70 min
5	Rest	NT 10% warm-up 20% TPC 40 % technical 30% tactical	RSA 10% warm-up 20% RSA 50% technical 20% tactical	NT 10% warm-up 50 % technical 40% tactical	RSA 10% warm-up 20% RSA 50% technical 20% tactical	Game ~70 min	Rest
6 (post testing)	NT 10% warm-up 20% TPC 40 % technical 30% tactical	intermittent shuttle-running test (Carminatti's test)	vertical jump performance	repeated maximal sprint test (40m-MST)	NT 10% warm-up 50 % technical 40% tactical	Game ~70 min	Rest

NT = normal training. RSA = repeated sprint ability training. TPC = traditional physical conditioning. Session with ~120 min.

Anaerobic indices measurements

To determine the anaerobic indices, a repeated maximal sprint test (40-m MST) was performed as proposed by Baker et al.[18]. The protocol consists of eight sprints of 40 m with two changes of direction (180°) and 20 s of passive recovery period between each sprint. Measures of best and mean time in the 40-m MST showed very good test-retest reliability (ICC=0.92 and 0.91, respectively)[19]. This test consists of a run starting from the midpoint between 20 m, marked by a pair of photocells, to the first mark 10 m away, followed by a return of 20 m running in the opposite direction until the second mark and finishing with a run of 10 m to pass photocells again. The time was electronic recorded by a pair of photocells (CEFISE Speed Test 6.0; 0.001 s resolution; São Paulo, Brazil) placed a meter above floor level, approximately on the height of the hips. To prevent any erroneous timing start due the arms movement the starting line was brought forward 50 cm. The timer was started automatically when athletes passed through the infrared signal from the photocells and stopped when they passed the photocells at 40 m. The best time (40m-BT), mean time (40m-MT) and percentage decrement score (40m-S_{dec}) were measured in the sprints. The 40m-S_{dec} was calculated using the following equation: [(Σ 8TIMES / BT * 8) -1] * 100 [20].

Blood Lactate measurements

To determine the peak blood lactate concentration (40m-LAC_{peak}) in the repeated maximal sprint test, 25 µL of blood samples were collected from the earlobe using a heparinized capillary after 1st, 3rd, 5th, 7th and 10th minutes of recovery. The blood was stored in polyethylene microtube covers (Eppendorff) and subsequently the lactate concentrations were assessed using an electrochemical analyzer (YSI 2700 STAT; Yellow Springs, OH, USA), calibrated according to the manufacturer's recommendations before each analysis. The 40m-LAC_{peak} was considered as the highest value of lactate concentration obtained during the recovery period.

Vertical jumps measurements

To evaluate the lower limbs muscular power, athletes performed three counter movement jumps (CMJ) and one set of continuous jumps (CJ) for 15 s with the hands on the hips [21]. The tests were performed on a piezoelectric force platform (QUATTRO JUMP, model 9290AD; Winterthur, Switzerland), operating at a frequency of 500 Hz. Jump height was calculated by double ground reaction force (GRF) integration. First, the acceleration curve was calculated by dividing GRF values by body mass, measured on the platform itself. After that, a trapezoidal integration of the acceleration curve was used to obtain the velocity curve. The latter was integrated again to obtain distance at each time point of the movement, and the greatest vertical distance was entered as the jump height[22]. The mean height of the three CMJ was used in the analysis.

Statistical analyses

Data are presented as means and standard deviations (mean ± SD). An ANOVA mixed-model was used to determine differences over time and

groups. Assumptions of sphericity were assessed using the Mauchly test and any violations were corrected using the Greenhouse-Geisser correction factor. The level of significance adopted was set at $p < 0.05$. Further, to analyze the magnitude of the effects caused by the training, the effect sizes (ES) were calculated as the difference between the means divided by the mean standard deviation to characterize the practical (clinical) significance rather than the statistical significance, according to Hedges and Olkin[23]. The following criteria for effect sizes were used: < 0.1 = trivial, 0.1–0.3 = trivial/small, 0.3–0.5 = small, 0.5–0.7 = small/moderate, 0.7–1.1 = moderate, 1.1–1.3 = moderate/large, 1.3–1.9 = large, 1.9–2.1 = large/very large and > 2.1 = very large, which were adopted according to the criteria established by Batternham and Hopinks.[24] Analyses were performed using the Statistical Package for Social Sciences Windows® (SPSS Inc. version 15.0; Chicago, IL, USA).

RESULTS

The indices assessed before and after the short training period in both groups (G_{RSA}, $G_{CONTROL}$) are described in Table 2. No significant interaction (time *vs.* group) was observed for variables analysed ($p > 0.05$). However, a significant main effect for time was observed for V_{HRDP} ($F = 19.95$; $p < 0.001$), 40m-LAC_{peak} ($F = 12.70$; $p = 0.003$), 40m-S_{dec} ($F = 18.53$; $p = 0.001$) and CJ performance ($F = 7.67$; $p = 0.017$). This result indicates an improvement on V_{HRDP} and CJ while 40m-LAC_{peak} and 40m-S_{dec} decreased after 4-week period, in both groups. However, the ES presented in Table 3 showed a trend of greater changes for G_{RSA} compared to $G_{CONTROL}$ (Figure 1).

Table 2. Aerobic and anaerobic variables and jump performances of both groups before and after the training period.

Variables	G_{RSA} ($n = 8$)		$G_{CONTROL}$ ($n = 6$)	
	Pre	Post	Pre	Post
PV ($km \cdot h^{-1}$)	16.78 ±0.83	17.40 ±1.01	15.82 ±0.46	15.92 ±1.12
V_{HRDP} ($km \cdot h^{-1}$)	13.25 ±1.28	14.25* ±1.23	12.40 ±0.90	12.95* ±1.11
HRDP ($beats \cdot min^{-1}$)	181 ± 10	182 ±07	180 ±04	182 ±10
40m-BT (s)	8.14 ± 0.18	8.27 ± 0.26	8.53 ± 0.34	8.63 ± 0.27
40m-MT (s)	8.53 ± 0.15	8.56 ± 0.22	9.09 ± 0.39	9.00 ± 0.28
40m-S_{dec} (%)	4.77 ± 0.82	3.52* ± 0.72	6.50 ± 1.10	4.30* ± 1.54
40m-LAC_{peak} ($mmol \cdot l^{-1}$)	16.20 ± 2.81	13.01* ± 4.05	13.18 ± 2.68	12.20* ± 2.44
CJ (cm)	39.92 ± 4.46	40.89* ± 5.33	35.58 ± 5.43	37.95* ± 5.01
CMJ (cm)	45.14 ± 6.65	45.55 ± 5.75	40.28 ± 3.87	41.32 ± 4.40

Data are means ± SD. *p < 0.01 (pre vs. post). G_{RSA} = Intervention group. $G_{CONTROL}$ = Control group. PV = Peak velocity. V_{HRDP} = velocity corresponding at heart rate deflection point. HRDP = heart rate deflection point. 40m-BT = Best time. 40m-MT = Mean time. 40m-Sdec = percentage decrement score. 40m-LACpeak = peak of lactate concentration. CJ = Continuous jump. CMJ = Counter movement jump.

Table 3. Effect sizes and absolute change for all variables measured.

Variables	G_{RSA} (n = 8)			$G_{CONTROL}$ (n = 6)		
	Absolute change	Effect size	Descriptor	Absolute change	Effect size	Descriptor
PV ($km \cdot h^{-1}$)	0.62 ± 0.92	0.71	Moderate	0.10 ± 0.93	0.13	Trivial/ small
V_{HRDP} ($km \cdot h^{-1}$)	1.00 ± 0.62	0.83	Moderate	0.55 ± 0.67	0.55	Small/ moderate
HRDP (bpm)	1.75 ±6.84	0.21	Trivial/ small	1.17 ± 9.37	0.25	Trivial/ small
40m-BT (s)	0.13 ± 0.23	0.87	Moderate	0.09 ± 0.27	0.33	Small
40m-MT (s)	0.04 ± 0.20	0.20	Trivial/ small	-0.09 ± 0.18	0.27	Trivial/ small
40m-S_{dec} (%)	-1.25 ± 1.01	1.79	Large	-2.19 ± 1.95	1.72	Large
40m-LAC_{peak} ($mmol \cdot l^{-1}$)	-3.18 ± 2.38	1.00	Moderate	-0.98 ± 1.82	0.39	Small
CJ (cm)	0.96 ± 2.52	0.22	Trivial/ small	2.37 ± 1.74	0.45	Small
CMJ (cm)	0.41 ± 2.81	0.09	Trivial	1.03 ± 2.0	0.25	Trivial/ small

G_{RSA} = Intervention Group. $G_{CONTROL}$ = Control Group. PV = Peak velocity. V_{HRDP} = velocity corresponding at heart rate deflection point. HRDP = heart rate deflection point. 40m-BT = Best time. 40m-MT = Mean time. 40m-S_{dec} = percentage decrement score. 40m-LAC_{peak} = peak of lactate concentration. CJ = Continuous jump. CMJ = Counter movement jump.

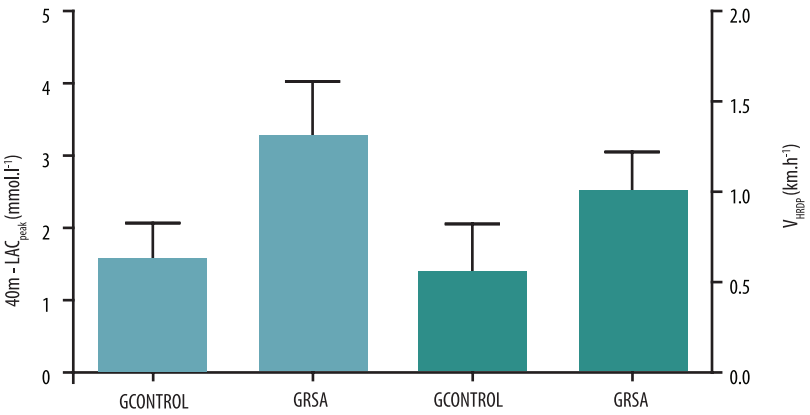

Figure 1. Absolute change for 40m-LACpeak and V_{HRDP}, 40m-LACpeak = peak of lactate concentration (blue bar). VHRDP = velocity corresponding at heart rate deflection point (green pattern).

DISCUSSION

The main finding in this study indicates that there was a marked improvement in both groups in indices related to aerobic (V_{HRDP}) and anaerobic (40m-S_{dec}, 40m-LAC_{peak}) performance as well as vertical jump performance (CJ), demonstrating that both RSA and normal training routine are equally effective in producing changes in the analysed variables in a short period of intervention during the season.

There was a gap in the literature regarding the effect of RSA-based training on physiological and neuromuscular indices in futsal players. Similar to our results, Ferrari Bravo et al.[8] evaluated soccer players and

observed no differences in the analysed variables between groups (RSA and interval training groups). On the other hand, recent studies utilizing RSA training intervention have reported significant increases in indices related to anaerobic and aerobic power[8,10], however in a greater period of time than what has been employed in the present investigation. The researchers have attributed these findings to an increase in both glycolytic[26,27] and oxidative enzymes activity,[9, 26] muscle buffering capacity[9,28] and ionic regulation[28]. Additionally, Spencer et al.[6] observed that the energetic supply of repeated short sprints requires ATP resynthesis from each energy system. Therefore, a wide range of metabolic aerobic and anaerobic adaptations can be expected to result from such training[10]. It is important to highlight that most of the aforementioned studies were conducted with active or untrained populations, compared to trained athletes in the present investigation.

In the present study we hypothesized that a short period of RSA-based training during the competitive phase would improve indices mainly related to the aerobic power (i.e. peak velocity) in futsal players, since this index is also influenced by underlying capacities (i.e. anaerobic capacity and muscle power)[14]. However, this hypothesis was not confirmed in this investigation. Though, the ES showed greater improvements with practical significance of PV in the G_{RSA} (moderate) when compared to $G_{CONTROL}$ (trivial). From a practical view, this represents a considerable improvement in aerobic power performance (0.6 $Km{\cdot}h^{-1}$; 3.8%). This percentage of improvement is more than twice the typical error reported to the PV (CV = 1.4 %)[15], suggesting an effective change triggered by the RSA training. Considering that PV may be an index determined by the anaerobic capacity, muscle power and neuromuscular skill to run at high speeds[14], the 'moderate' ES calculated for $G_{RSA,}$ may be justified by physiological adaptations that are inherent to RSA training. Studies[2,6] have shown that subjects with greater aerobic power have superior ability to resist fatigue during repeated sprints, especially during the latter stages.

The index related to aerobic capacity (i.e. V_{HRDP}) increased significantly in both groups, but represented a greater percentage of change (+7.7%) in the G_{RSA} (ES = 0.83, moderate). The aerobic capacity seems to be positively affected by the RSA training as demonstrated by Ferrari Bravo et al.[8] which assessed the ventilatory threshold in soccer players after seven weeks of RSA training sessions during a competitive phase. This may suggest important changes in the performance of futsal players since the oxidative metabolism pathways are essential for phosphocreatine resynthesis during the recovery from high-intensity exercise such as repeated sprints[2,6,9]. This suggests that individuals with an elevated aerobic fitness should be able to resynthesize phosphocreatine faster between repeated sprints[6,8,10] allowing the athletes to perform a greater number of sprints at maximum or near maximum intensity during matches[2].

Despite the non-significant difference found between groups in the analysed variables, the ES revealed that the 40m-LAC_{peak} (indicative of lactic anaerobic capacity) showed a greater decrease (-19.7%) after the intervention

in the $G_{RSA.}$ From a practical point of view, one can observe that the players sustained the same maximal intensity with a lower induction of metabolic acidosis, which could result in better performances during matches. Futsal match dynamics differ to soccer, mainly due to constant substitution of players as well as the dimensions of the court. Thus, one could consider a massive contribution of anaerobic pathways during a match. According to Dawson et al.[10] the rapid rate of phosphocreatine resynthesis appears to be a significant functional adaptation of the RSA training. Thus, the short period of RSA-based training would be a minimum period of time in which positive adaptations of anaerobic metabolism could be observed.

The sprint training also appears to influence the anaerobic capacity as demonstrated by Tønnessen et al.[29] that applied a protocol of intermittent sprint training with alactic anaerobic characteristics (3-5 sets, 4-5 repetitions of 40 m, recovery time between sprints 90 s and 10 min between sets) for 10 weeks (once a week) with 10 soccer players. Interestingly, the authors found significant improvements in mean time of the RSA test (10x 40 m) for both intervention and control groups, although the intervention group improved mean time with greater magnitude than the control group. Thus, the researchers concluded that the extra RSA training may provide anaerobic metabolic adaptations. In contrast to the present study, Ferrari Bravo et al.[8] observed a significant decrease in the 40m-MT values (2.1%); on the other hand, no significant differences in the 40m-S_{dec} was found after seven weeks of RSA training in the group of soccer players. A possible explanation may be attributed to the fact that these authors applied a test with characteristics very similar to the training protocol used. This way, the values of the variables 40m-MT and 40m-S_{dec} may have been a consequence of the greater specificity from the method of evaluation, which may have influenced the particular adaptations.

The non-significant changes in the 40m-BT after training in the present study corroborates the findings of the literature for soccer players[8]. On the other hand, using a sample group of 30 students, Markovic et al.[13] observed that after 10 weeks of sprint training there was an improvement of 3.1% in a single sprint performance. In addition, Dawsom et al.[10] observed similar effects when analyzing nine physically active subjects during a six-week period. Thus, it appears that sprint training causes significant changes in anaerobic performance; however, it seems to depend on a specific model of sprints (i.e. volume of training) and the level of the subject's physical fitness. Whereas a wide range of performance and metabolic adaptations can be expected as a result from such training, especially in subjects who are not well-trained either aerobically or anaerobically[10].

In addition to the physiological variables measured, we examined the influence of the RSA-based training on neuromuscular parameters as vertical jump performance. This variable that reflects lower limb muscle power[22] may be considered as one of the determining aspects of futsal players performance as it is related to most of the active functions of the game, such as kicks, headers and sprints[1,5]. Additionally, it is necessary to highlight the

importance of lower limb muscle power in the sprints with changes of direction, which require a braking force followed by a propulsive force, factors that can determine the performance of these actions[2,3,6,30].Lakomy and Haydon[30] suggest that the muscle contraction during RSA, required for acceleration and deceleration of body mass, may be beneficial to the improvement of muscle power and the ability to change directions. In the present study, there was no significant improvement in CMJ for both groups. The short period of training intervention and the characteristics of RSA training might explain this result. On the other hand, Dawson et al.[10] and Markovic et al.[13] demonstrated that RSA training with volumes considerably larger than the present research (a greater number of repetitions, sets, distances, and sessions per week) was capable of improving muscle power in CMJ in physically active subjects after 6 and 10 week interventions, respectively. Still, Tønnessen et al.[29] in the aforementioned study, found significant improvements in CMJ after 10 weeks of sprint training in U17 soccer players. Markovic et al.[13] suggested that significant improvements in CMJ power and height, obtained from sprint training may be explained by fast and efficient utilization of elastic energy in stretch-shortening muscle cycles and increased strength and power of knee extensor muscles, strongly engaged in the actions of fast running.

Regarding CJ, there was a significant main effect for time, showing an increase in performance for both groups. This result might be explained by characteristics of this 15-s continuous jump test, since it is determined by both metabolic and neuromuscular factors.[21] The reasons for the non-significant differences found between groups may be attributed to the plyometric training performed by $G_{CONTROL}$ during the intervention period, that is considered a valid alternative when the aim is the improvement of muscular power levels[13]. Future studies monitoring electromyography activity during RSA may indicate whether such increases in muscular power would be due to neural or muscular adaptations.

A limitation of the present study was the final sample size. There were two subjects in each group who did not complete the study due to muscle injury during the matches. Other limitation was the short period of training intervention due to the periodization of the team. Thus, the results of the present study should be interpreted with caution.

CONCLUSION

The short period of RSA-based training was not enough to induce improvements different from those observed in normal training routines, i.e., both were equally effective in producing changes in the analyzed variables. However, the effect size showed that RSA training induced greater improvements with practical significance in variables related to aerobic power and aerobic capacity, as well as lactic anaerobic capacity, suggesting that four weeks would be a minimum training time that could enhance the physical fitness of futsal players.

The originality of the present study highlights the importance of the

findings and points out that the methodology used could be an alternative way to improve the aerobic and anaerobic capabilities. Thus, this method seems to be more suitable to team sport athletes. Nevertheless, we believe that the proposed training should be conducted for a longer periods of time compared to that used in this intervention. Also, given the importance of the neuromuscular aspects on futsal performance, additional power and strength training may be required to improve muscle power and short-sprint ability, considering that these aspects have not improved with 4-week RSA training.

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