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Research Article

Comparison of Physical Performance and Physiological Responses Between Square-Wave Endurance Exercise Test Training and the Repeated Sprint Exercise Training in Young Soccer Players

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Abstract

Objective: The purpose of this study was tocompare the effect of repeated sprint training on field (RSF) and Square-Wave Endurance Exercise Test (SWEET) on velocity performances, repeated sprint performances on field, repeated sprint on cycle ergometer and anaerobic and aerobic parameters in soccer players.

Subjects and methods: twenty two young male soccer players (age 19.9 ± 1.4 years; body mass: 71.3 ± 7.6 kg; height: 1.80 ± 0.06 m) participated in the study. After the baseline test, soccer players were assigned to either a repeated sprint training group on field [RSF, (3 x 6 x (20+20m), with 4 min series and 30 s of passive recovery between series and repetitions respectively; n = 11] or Square Wave Endurance Exercise Test group (SWEET, 1 min at 90% VO_2 peak, 4 min at 50% VO_2 peak during 30 min; n = 11) on field in addition to their traditional soccer training. The following parameters were measured before and after seven weeks of training (with 2 sessions per week): 10, 20, and 30 m linear sprints, blood lactate, repeated sprint performances (peak time, total time and fatigue index), the 5-jump performance, repeated sprint on cycle ergometer and peak oxygen uptake (VO_2 peak) on treadmill (Cosmed 170, Fridolfing, Germany).

Results: The test of normality showed that our two groups were homogenous and presented no significant baseline differences for any of the variables studied. The 2-way ANOVA showed significant group x time interaction for sprint times (10, 20 and 30 m, $p < 0.001$). Sprint linear improvements were higher after RSF than SWEET training ($p < 0.01$). In the same context, RSF training showed larger improvements in the 5-jump test scores and in repeated sprint test (total time, best time performance, and fatigue index). Peak power output and pedaling speed (rpm) improved significantly during the three sets in the RSF training than SWEET training ($p < 0.01$). Delta blood lactate concentration was reduced after training. The reduction was more pronounced in SWEET group. Significant group x time interaction was found for VO2peak measured on treadmill ($p <0.001$), with SWEET showing larger improvement (4.9 ± 1.3%) than RSF group (4.3 ± 1.5%). Blood lactate decreased in both groups ($p < 0.05$).

Conclusion: Our data shows that a specific training program based on ¶RSF seems more effective than SWEET program in improvements of anaerobic performances in young soccer players. Enhancements of the aerobic fitness were quiet similar in both groups.

Keywords: Repeated Sprint Training; Peak Power Output; Square-Wave Test; Soccer; Velocity

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Abbreviations

RSF: Repeated Sprint on Field; SWEET: Square Wave Endurance Exercise Test; PT: Peak Time; TT: Total Time; FI: Fatigue Index; RSC: Repeated Sprint on Cycle; RER: Respiratory Exchange Ratio

Introduction

Performance in soccer depends on a variety of technical, physical, and tactical [1,2]. From a physical point of view, match analyses have shown that high intensity actions, such as sprints, and jumps are frequent and important to soccer performance. These actions are interspersed by periods of low to moderate intensity exercise. A soccer player should show a strong explosive strength, and be able to develop this quality during an entire match [3]. A well-developed aerobic capacity is also important, allowing a player to maintain high-intensity actions throughout the match. Finally, a high muscular anaerobic power permits the athlete to perform sprints, jumps, and changes of direction at the high intensities required by this game [4].

In addition to participation in traditional game-related soccer training, many coaches have injected other training modalities designed to enhance these specific requirements, including strength training [5], repeated sprints [3,5,6], and interval training programs [7] intended to enhance both aerobic and anaerobic processes [8]. One report demonstrated that a "speed, quickness and agility" component improved single sprint performance, power, agility, and repeated sprint ability relative to standard game-related training [9]. The introduction of repeated sprint training also had positive effects on soccer players' repeated sprint ability, power, and aerobic capacity [10]. Intermittent exercise soliciting aerobic and anaerobic metabolism [8] also improved aerobic power and oxidative enzyme activity [11]. But although a high peak power and capacity are important determinants of soccer performance, to our knowledge no studies have compared the value of repeated sprint exercises performed on the playing field (RSF) relative to repeated square wave endurance exercise training (SWEET) in soccer players. Thus, the aim of this study was to compare the effectiveness of these two training methods in enhancing the isolated velocity, 5-jump performance, repeated sprint performance and VO_2 peak in young soccer players.

Materials and Methods

Subjects' characteristics

One team of twenty two healthy young male soccer from a national league in Tunisia (high-level) volunteered to participate in the study. The study protocol was approved by the University of Sousse Committee on Human Experimentation. All players signed an appropriate form indicating their informed consent after the health risks and benefits of the procedures had been fully explained to them. The participants were aged (mean ± SD 19.9 ± 1.4 yrs, with a height of 1.80 ± 0.06 m, and a body mass 71.3 ± 7.6 kg). They were training for 90 minutes, 5 days per week, and also competed in a soccer match every Sunday. The players had a minimum 5 years of training experience After completing baseline tests, the sample were randomly assigned to two experimental groups, following either the RSF training program (RSF, n = 11) or the SWEET program (SWEET, n = 11). The training intervention took place at the middle of the training season. Goalkeepers were excluded from the analysis.

Study design

Before the training intervention, all participants performed a series of familiarization trials to become oriented with both testing procedures and the required training programs. All participants then undertook the following tests, both before and after training: 1) an incremental test on a treadmill (Cosmed 170, Fridolfing, Germany), 2) three sets of repeated sprint exercises on a cycle ergometer (Monark 894E, Vansbro, Sweden), 3) repeated sprints on field (6*(20+20m)), 4) and the maximal running speed over distances of 10, 20, and 30 m timed by photocells (Globus, Microgate, SARL, Bolzano, Italy). All tests were performed at the same time of day (between 10.00 and 12.00 a.m.) separated by two-day intervals and under identical laboratory conditions (temperature range: 20-24°C; and relative humidity: 76 ± 2%). After the initial evaluation, the subjects were divided into the two groups; the training supplements were undertaken on Tuesdays and Thursdays for 7 weeks, with one performing the RSF program (10 min and 11 sec of training added to the standard soccer training) and the other performing a SWEET training program (30 min added to the standard soccer training). Forty-eight hours after the last training session, the baseline tests were repeated. The incremental test, the repeated sprint ability and the maximal speed were evaluated in this order, with an interval of 48 h between each of the tests.

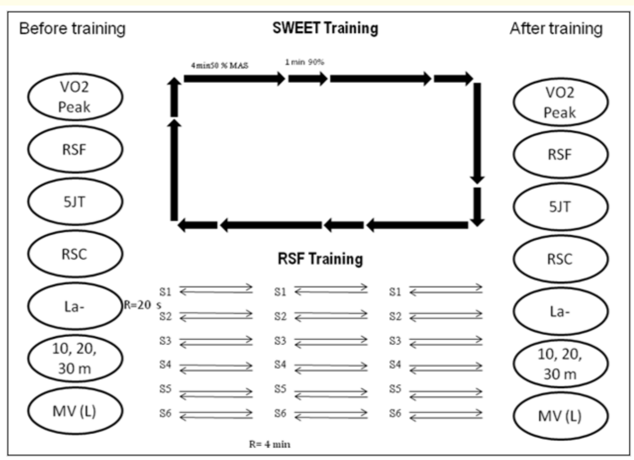

Figure 1: Schematic representation of SWEET and RSF training protocols.

Anthropometric measurements

Anthropometric measurements were made with standard equipment (SiberHegner, Zürich, Switzerland). Muscle volumes were estimated as described by Jones and Pearson [12] and Shephard., *et al*. [13]. Leg length was measured as the distance from the midpoint of a line joining the uppermost leg circumference and the iliac crest, down to the minimum circumference above the ankle. Five leg circumferences were measured at 90° to the limb axis (top of the thigh, mid-thigh, immediately below the patella, maximum calf, and the minimum immediately above the ankle). Biceps, triceps, subscapular, and suprailiac skin folds were measured using a standard caliper (Harpenden/Holtain Calipers, Crosswell, UK). Body density and thus the percentage of body fat were calculated as described by Durnin and Womersley [14]:

Body density = 1.1765−0.0744 (log10 Σ S)

Where ΣS is the sum of the four skinfold readings (in mm).

Body fat = (4.95/D − 4.50)100

Where D is the estimated body density.

Additional skinfold readingwas taken over the front of the thigh and the rear of the calf to assess the thickness of superficial fat over the legs. Femoral intercondylar diameters were measured using standard calipers (SiberHegner, Zürich, Switzerland). The total leg volume was then estimated as:

(ΣC2) L/62.8

Where C2 was the square of the individual circumference readings and L the corresponding limb length.

Fat volume was calculated as:

(ΣC/5)(ΣS/2n)L

Where ΣC is the sum of the five circumferences, Σ*S* is the sum of skinfolds measured over the limb, and n the total number of skinfolds measured over the limb.

Bone volume was calculated as:

$3.14\ R^2 L$

Where R is the average bone radius for the limb, estimated from intercondylar diameters after correction for overlying fat.

Muscle volume was finally calculated as total limb volume − (fat + bone volume).

Incremental maximal exercise test

This test was performed on a motorized treadmill (Cosmed T170, Fridolfing, Germany), with progressive stages, each of 3-min duration. Participants began at a speed of 3.5 km/h, slope. The speed was increased by 1 km/h every 3 min until a speed of 6.5 to 7.5 km/h was attained [15]. Thereafter, the gradient was increased by 2 % every 3 min until an RER of 1 was reached. Finally, the speed was increased every minute until exhaustion. Expired gases were analyzed using a breath-to-breath exercise analysis system (Cosmed, Quark b2, Rome, Italy) and the VO_2 peak was calculated.

Sprint times over distances of 10, 20 and 30m

The maximal speed sprint was evaluated by using three pairs of photocells and reflectors connected with an electronic timer (Microgate, Globus, SARL, Italy). The photocell detectors, positioned at the start, the middle of 10 m, and the end of a 30 m runway were set at the levels of the subjects' knees and times were measured to one hundredth of a second. A standing start was adopted, and participants were urged to run as fast as possible.

Repeated sprints on the playing field (RSF)

Six 20-m shuttle (20 + 20-m with 180° turns) sprints were performed, separated by 20s passive recovery intervals, providing a measure of the ability to perform repeated sprints and to change directions [3]. The speed was evaluated by using a pair of photocells and reflectors connected to an electronic timer (Microgate, Globus, SARL, Bolzano, Italy). Times were measured to one hundredth of a second, measuring from when the athletes left their starting position, touched a line with 20 m distant with a foot and returned to the starting line. Recorded measures were Peak time (PT); total time (TT) and a fatigue index (FI) calculated according to the formula of Fitzsimons., *et al*. [16]:

FI (%) = [(TT / IT x 100) -100]

Where IT = is the ideal time (PT x number of repetitions)

Five jump test (5-JT)

The 5-JT was performed on the grass. Players were wearing soccer boots. Beginning from a standing position, they tried to cover a maximal distance by performing 5 consecutive strides with the feet held together at the start and end of the jumps [17]. After the first four strides, the player had to adjust the last stride to end with the feet together. The 5-JT performance was assessed by tape measure, from the initial front edge of the player's feet to the final rear edge of the feet. In some cases, the person assessing the landing had to focus on the last stride to determine the last foot print on the grass, as players could not always remain in position after landing. Each subject performed 3 trials, with the best of the 3 values used for analysis.

Repeated sprint on cycle ergometer

The repeated sprint on cycle ergometer test used here was adapted from the protocol of Serpiello., *et al*. 2011 "multiple sets of repeated-sprint exercise (RSE)" [6]. Participants initially undertooka warm up protocol of 5 min against a light load of 1 kg at a constant pace of 60 rpm on a cycle ergometer (Monark 894E, Vansbro, Sweden). The repeated sprint on cycle ergometer (RSC) started immediately after 5 min of rest, and it consisted of three sets of 5*5-s sprints with 20 s of passive recovery between sprints and 4 min of passive rest between sets. At each sprint, subjects were allowed loaded pedaling of 5s to reach the maximum cadence and then, they were encouraged to maintain the "all-out" pedaling speed. The resistance level at each sprint was set at 75g per kg of body mass [4]. The ergometer handlebars and seat height were individually adjusted for each subject and two clips with straps used to prevent the feet from slipping of the pedals.

During RSC, peak power output (PPO), mean power output (MPO), fatigue index (FI) and maximal pedalling speed (MPS, rpm) were measured. At rest, and immediately after the 3 min of each set, a finger-tip capillary blood sample was collected from the participants while in a standing position. Samples were analyzed for lactate concentration [La] using Lactate Pro Analyzer (Arkray Inc, Kyoto, Japan).

Training programs

Each day of the RSF training program comprised 3 sets of six sprints of 20 m+20 m (3x [6 x (20 + 20m)]), with 20 s of passive recovery between repetitions (r = 20s), and 4 min of passive recovery between sets (R = 4 min). The SWEET training program comprised bouts of 1 min running at 90 % of maximum aerobic speed (MAS), followed by 4 min at 50% of MAS; this routine was repeated 6 times, giving a total of 30 min exercise. Each training program was introduced immediately after the traditional soccer training warm up, with programs continuing twice a week (Tuesday and Thursday) for 7 weeks. Participants also completed their normal 90 minutes of standard soccer training on the Tuesdays and Thursdays.

Data analysis

Data are expressed as mean ± SD. Normal distribution of all variables was checked using the Kolmogorov-Smirnov test. The performance and physiological responses (pre/post test) of two test training modalities were compared using paired t-tests. Statistical significance was set at $p < 0.05$ throughout. The magnitude of changes was assessed using effect size, with determination of 95% confidence intervals (CI) and percentage changes [18,19]. Effect sizes were classified as follows: <0.2 = trivial, 0.2–0.6 = small, 0.6–1.2 = moderate, 1.2–2.0 large, > 2 = very large [20]. All statistical analyses were carried out using SPSS 20.0 for Windows (SPSS Inc., Chicago).

Results

The test of normality showed that our two groups were homogenous and presented no significant baseline differences for any of the variables studied. Descriptive statistics (mean ± SD), paired t-test, ES, and difference values between groups after training for each comparison are shown in Table 1.

The RSF and SWEET groups significantly improved their maximal running velocities over 10, 20, and 30 m after training ($p < 0.01$, with effect sizes (ES) of 0.77, 1.1 and 1.02 respectively. The RSF group showed larger gains ($p < 0.001$) than the SWEET group ($p < 0.01$). The RSF group also showed significant improvements in the 5-Jump test scores after training ($p < 0.01$), accompanied by increases in mean muscle volume ($p < 0.01$). However, the SWEET group showed no change in either 5-Jump test scores or muscle volumes.

	RSF training group				**SWEET training group**				**Differences between groups after training**	
Variables	Pre-training	Post-training	Change	ES	Pre-training	Post-training	Change	ES	Difference	ES
Total time (s)	46.1 ± 1.9	43.8 ± 2.1 **	-3.1 ± 0.7	1.2	45.4± 0.4	45.24 ± 2.8	-0.19 ± 0.9	0.1	3.82 ± 2.61	1.01
Peak time (s)	7.36 ± 0.3	6.69 ± 0.4 **	-0.67 ± 0.2	1.88	7.16 ± 0.4	7.09 ± 0.4	-0.06 ± 0.1	0.17	0.4 ± 0.1&	1.02
Fatigue index %	4.77 ± 1.8	7 .61 ± 4.6 **	-2.84 ± 4.7	0.05	5.83 ± 3.6	6.24 ± 2.5	-0.04 ± 2.5	0.14	2.8 ± 0.3&	1.08
10-m velocity(s)	1.76 ± 0.1	1.66 ± 0.1 ***	-0.09 ± 0.1	1.17	1.76 ± 0.1	1.72 ± 0.1 **	-0.04 ± 0.1	0.46	0.1 ± 0.1&	0.77
20-m velocity (s)	2.55 ± 0.1	2.45 ± 0.1 ***	-0.09 ± 0.1	0.99	2.56 ± 0.1	2.54 ± 0.1 **	-0.01 ± 0.1	0.21	0.11 ± 0.1&	1.1
30-m velocity (s)	4.3 ± 0.2	4.12 ± 0.1 ***	0.18 ± 0.1	1.12	4.32 ± 0.1	4.26 ± 0.1 **	0.05 ± 0.1	0.5	0.2 ± 0.1&	1.02
5-jump test (m)	11.98 ± 0.7	12.35 ± 0.7**	3.08 ± 1.9	0.55	11.54 ± 0.8	11.70 ± 0.8	1.38 ± 3.0	0.21	0.65 ± 0.09&	0.63
Muscle volume (L)	10.31 ± 0.8	11.13 ± 0.4 **	0.82 ± 0.5	1.34	10.43 ± 0.7	10.71 ± 0.6	0.28 ± 0.2	0,46	0.41 ± 0.63 &	0.9

Table 1: Mean values ± SD of total time, peak time, fatigue index $_{RSA}$ (%) of 6*(20+20m), 10, 20, 30 m sprints, the 5-Jump Test, and muscular volume (L) before and after training.

Performance on the repeated sprint protocol increased significantly only in the RSF group ($p < 0.01$, Table 1). The SWEET group tended to some gains, but these were not statistically significant. Blood lactate concentrations were measured before and after the repeated sprint protocol. Following training the Δ $[Lac^-]$ for both groups in all sets ($p < 0.05$), with the decrease in Δ $[Lac^-]$ being more pronounced for the SWEET than for the RSF group ($p < 0.05$).

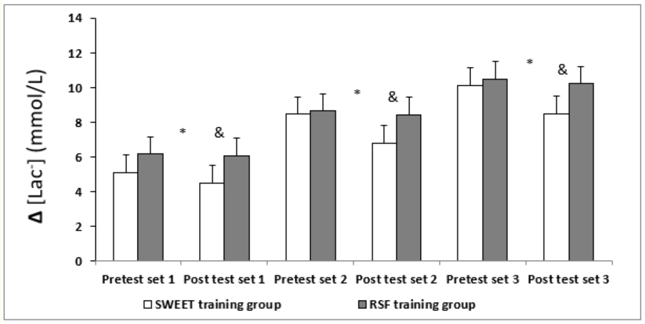

Figure 2: Change in Δ [Lac-] (mmol/L) from pretest to post-test. *Significant difference at $p < 0.05$ from pre-test to post-test within group. &significant differences after training at $p < 0.05$ between groups.

Pre to post changes in repeated sprint performances on ergocycle (RSC) in the two groups are presented in Table 2. The RSF training group showed significant increases in peak power output and mean power ($p < 0.05$) during the three sets. However, no significant changes were observed for the SWEET group in any of these variables. In addition, we found significant differences between groups in peak power and maximal velocity (rpm) during set 1, 2 and 3 after training ($p < 0.05$).

Groups	Variables	Sets	Before training	After training	% change
RSA training group	Peak power (W)	1	885.04 ± 136.99	&&1034.51 ± 118.58 ***	16.88 &&
		2	854.62 ± 140.58	& 962.48 ± 121.33 **	12.62 &
		3	821.62 ± 140.67	&894.96 ± 129.48 *	8.92 &
	Mean power (W)	1	824.21 ± 129.21	873.14 ± 126.06 *	5.93
		2	777.03 ± 100.12	869.73 ± 10.,21**	11.93
		3	727.43 ± 140.29	775,04 ± 97.76 *	6.54
	V max (rpm)	1	165 ± 16.04	&&198 ± 12.26 **	20 &&
		2	159 ± 13.76	&184 ± 22.12 **	15.72 &
		3	153 ± 16.73	&&171 ± 22.14 **	11.76 &&
SWEET training group	Peak power (W)	1	864.33 ± 116.96	905.2 ± 104,62	4.72
		2	853.35 ± 120.56	882.62 ± 102	3.43
		3	796.59 ± 126.15	813,28 ± 88.65	2.09
	Mean power (W)	1	826.69 ± 116.76	867.79 ± 127.75	4.97
		2	770.51 ± 141.37	831.46 ± 83.08	7.91
		3	754.55 ± 144.61	760.34 ± 89.89	2.71
	V max (rpm)	1	161 ± 17.85	170 ± 21.02 **	5.59
		2	159 ± 15.09	165 ± 12.71 *	3.77
		3	149 ± 19.11	152 ± 13.6	2.01
*Student test significantly different at $p < 0.05$, **Student test significantly different at $p < 0.01$.***Student test significantly different at $p < 0.0001$ &Significantly different between groups after training at $p < 0.05$. &&Significantly different between groups after training at $p < 0.01$					

Table 2: Changes in RSC performance before and after training.

Changes in VO_2 peak (%) revealed a significant ($p < 0.0001$) time × group effect of RSF and SWEET groups: (4.4 ± 1.7 % and 4.9 ± 1.9 % respectively), but there was no significant inter-group difference in the response to training.

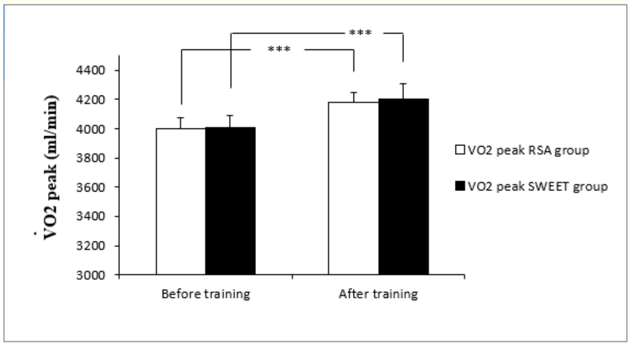

Figure 3: Change in VO2 peak from pre-test to post-test. Significant difference from pretest to posttest within group ($p < 0.0001$).

Discussion

The main finding of this study was that the RSF training supplement was more efficient than the SWEET supplement in terms of boosting muscle volume and enhancing various measures of anaerobic performance [i.e.,(10, 20, or 30 m speed), repeated sprints, and the 5-jump scores)]; however, improvements of aerobic fitness were similar for the two groups.

Sprint and 5-jump test scores

The RSF and SWEET training programs induced similar improvements in anaerobic potential as measured by maximal speeds (10, 20, and 30 m sprints) and aerobic potential as measured by the VO_2 peak on a treadmill. These data point to a major effect of repeated sprints on both aerobic and anaerobic metabolism [21,22]. In agreement with some studies [6,10,23] using a program based on repeated sprint training, we found improvements in court sprint performances. Serpiello., *et al*. [6] used a repeated sprint protocol quite similar to that adopted in our protocol, although the exercise was performed on a non-motorized treadmill (3 sets of 5 × 4-s maximal sprints, with 20 s of passive recovery between repetitions and 4.5 min of passive recovery between sets). After ten repeated-sprint training sessions, they found increases in all indices of performance, particularly acceleration in healthy adults. Dupont., *et al*. [23] compared sprint training (12-15 all-out 40-m runs alternated with 30 seconds of rest) with intermittent runs (12-15 runs lasting 15 seconds at 120% of maximal aerobic speed alternated with 15 seconds of rest). They found that the 40-m sprint time of professional male soccer players was decreased after 10 weeks of sprint training. More recently and using a 10-week program of 40-m repeated sprints, Tonnessen., *et al*. [10] found improvements in the 20 to 40-m speed of elite soccer players. Dawson., *et al*. [24] found improvements in the 40 m times of nine fit males after sprint running training (16 outdoor sprint running training sessions over 6 weeks; in this study, the distances of sprints were 30-80 m at 90-100% maximum speed, with 20 and 40 sprints being performed in each session; these gains were accompanied by increases in the proportion of type II muscle fibres, and gains in endurance, sprint and repeated sprint ability. This suggests that the improvements of 10, 20 and 30 m speed seen in our RSF subjects could reflect their increases of muscle volume.

Our RSF protocol induced significant enhancements in the 5-Jump test scores, but the SWEET group showed no change in either5-Jump test scores or muscle volumes. The sprint training program used by Tønnessen., *et al.* [10] also induced increases in the vertical jump performance of elite soccer players. Our sprint protocol was based on shuttles of 20 m, with direction changes. This type of sprint permits the increase of 5-jump scores via the ability to utilize larger portion of the stored energy in jumping activities [25].

Repeated sprint test

In agreement with the literature, we found that repeated sprint performances (total time, peak time, and fatigue index) were increased significantly only in RSF group [3,10]. Ferrari Bravo [3] also found that the repeated sprint mean time was increased only in those undertaking repeated sprint training. Sprint training program (10 × 40-m sprints) increased repeated sprint performance in well-trained soccer players [10]. The increase of repeated sprint performance does not seem linked to either VO_2 peak improvements or to blood lactate reduction, since the SWEET group also showed gains in these parameters without significant improvement in their repeated sprint performance. Thus, the increase of repeated sprint performance was likely related in part to an improvement in anaerobic metabolism. In addition, the repeated sprints training on the field may have enhanced the ability of the muscles to store elastic energy, which is an important determinant of muscle performance in repeated sprints.

Aerobic potential

Both of our training supplements improved VO_2 peak (by 4.4 ± 1.7 % and 4.9 ± 1.9 % respectively). Since the study of Gimnez., *et al.* 1982 [26], many variants of SWEET protocol have been developed, all combining high intensity exercise of short duration with periods of aerobic exercise, but to the best to our knowledge, there have been no previous studies comparing RSF with SWEET training.

Ferrari Bravo., *et al*. [3] found larger increases in the Yo-Yo Intermittent Recovery Test score of soccer players following 7-weeks of repeated sprint training (3 x 6 maximal shuttle sprints of 40 m) than with a similar period of interval training (4 x 4 min running at 90 - 95 % of HRmax).Mac Dougall., *et al*. [27] argued that a training program based on intense interval training (30-s maximum sprint efforts interspersed by 2-4 min of recovery, 3 times per week on a cycle ergometer for 7 wk) resulted in significant increases in peak power output, total work over 30s, and VO_2 max. In this study, needle biopsies showed that maximal enzyme activities of hexokinase, phosphofructokinase, citrate synthase, succinate dehydrogenase, and malate dehydrogenase were higher after training. The authors concluded that relatively brief but intense sprint training can yield increases of both glycolytic and oxidative enzyme activity, along with gains of maximum short-term power output, and VO_2 max in healthy men. In the same context, Burgomaster., *et al*. (2008) [22] argued that low-volume sprint interval training stimulates rapid improvements in muscle oxidative capacity comparable with those seen following traditional endurance training.

Iaia., *et al*. [28] found that in soccer players, 8-12 weeks of high-intensity running (> 85% HRmax) increased the VO_2 max by 5%-11%) and improved the economy of running by 3% to 7%. They noted a smaller lactate accumulation during submaximal exercise and improvements in the Yo-Yo Intermittent Recovery Test performance. Dupont., *et al*. [23]

101010 also found that high-intensity interval training improved the maximal aerobic speed of professional soccer players. Serpiello., *et al*. [6] reported that repeated sprint exercise improved aerobic fitness, with gains of Yo-Yo Intermittent Recovery Test performance (8%) and a decreased Δ[Lac(-)]/work ratio during sets 1, 2 and 3 of their sprints. In the present study, we also found decreases of blood lactate concentrations in both subject groups, somewhat more pronounced in the SWEET than in the RSF group, reflecting improved aerobic metabolism in both groups. Dawson., *et al*. [24] observed that 6 weeks of short sprint training (30-80 m at 90-100% maximum speed, 20-40 sprints per session) improved the endurance, sprint and repeated sprint ability of fit subjects. Muscle biopsy samples in their subjects showed increases in the proportion of type II muscle fibres in the vastus lateralis following training.

Repeated sprint performances on cycle ergometer

The improvement in power of the lower limbs and Vpeak for the RSF group reflects an enhancement in the ability to utilize the stored elastic energy and indirectly assists in the first phase of force-time curve initiated by the rate of force development in leg extensors within the RSF training group. The improvement could be further explained by findings from other studies where speed, leaping power and strength have been reported to affect each other if an improvement in any one of them occurs [29].

Repeated-sprint training on field and square wave endurance exercise test training produced a reduction in Δ $[Lac^-]$ measured during acute RSC. This could be explained through a greater participation of the aerobic system during RSC, an increased production and/or clearance of lactate [30], or possibly an increase in blood volume. One of the mechanisms responsible for this is the action of the monocarboxylate transporters (MCT), which transport lactate across the muscle cell and mitochondrial membrane. Skeletal muscle MCT and MCT4 protein abundance increased after a training intervention involving multiple 6-s sprints interspersed with 1 min of recovery [31]. It is likely that both an improved oxidative metabolism and an enhanced lactate clearance contributed to the reduction in the Δ $[Lac^-]$ after RSF and SWEET training in the present study.

Conclusion

This study is among the first to investigate differences between repeated sprint training on field (RSF) and Square-Wave Endurance Exercise Test (SWEET) on velocity performances, repeated sprint performances on field, repeated sprint on cycle ergometre and anaerobic and aerobic parameters in soccer players. The present data showed that 7 weeks of repeated sprint training program produced significant improvements in both anaerobic performance (10, 20 and 30 m sprints, 5-Jump Test, and repeated sprints) and aerobic metabolism (VO_2 peak). Thus, repeated sprinting on the playing field seems an effective training tactic for inducing both anaerobic and aerobic training adaptations in soccer players. It is then recommend that soccer trainers integrate such repeated sprinting protocols into their regular training in order to develop speed, the capacity to repeat sprints and aerobic fitness in their players.

Acknowledgments

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