Creatine supplementation nullifies the adverse effect of endurance exercise on the subsequent strength performance

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ABSTRACT

Objective: The objective of this study was to verify if creatine supplementation exerts an ergogenic effect during concurrent exercise. **Methods:** Sixteen female university students were divided into two groups: placebo (**P**) and creatine supplemented (**CRE**). The participants received 20 g of placebo or creatine for five days and 3 g for the following seven days in a double-blind design. Before supplementation, the participants were submitted to a 1-RM test in the leg press followed by maximum repetition test (three sets of repetitions-to-fatigue, performed at 80% of the 1-RM and separated from 150 seconds of recovery – **P** 1st set: 9.0 ± 2.4; 2nd set: 8.9 ± 2.9 and 3rd set: 8.3 ± 3.3 and **CRE** 1st set: 10.2 ± 2.2; 2nd set: 9.8 ± 2.9 e 3rd set: 9.7 ± 3.5 reps). After 12 days of supplementation, the participants were submitted to aerobic test in which they were instructed to cover the maximal distance as possible in 20 min. Subsequently, the participants were submitted to 1-RM test once again followed by the maximum repetition test. **Results:** No differences were observed in the aerobic task performance and in the 1-RM test. After the aerobic test, a decline on the repetition maximum capacity was observed during the last two sets in P (Reps – **P**: 1st set: 7.6 ± 2.6; 2nd set: 4.3 ± 2.9*; $p < 0.01$ and 3rd set: 4.6 ± 2.3*; $p < 0.01$). This reduction was not observed in CRE (Reps – **CRE**: 1st set: 10.9 ± 2.9; 2nd set: 9.5 ± 2.7 and 3rd set: 9.0 ± 3.0). **Conclusions:** There is a hypothesis that the performance of resistance exercise is reduced by a residual fatigue from the previous aerobic exercise bout. One of the peripheral causes of acute fatigue during resistance exercise is related to creatine-phosphate depletion. Probably, the supplementation-induced greater muscle creatine-phosphate content accelerates the recovery and the ATP re-phosphorylation, serving as an additional energetic substrate during concurrent exercise.

Key words: Creatine. Supplementation. Concurrent exercise. Interference.

INTRODUCTION

In the last decades, several studies have investigated the effect of the concurrent training, in which endurance and resistance exercises are performed concurrently at the same training session[1]. Once athletes and individuals physically active adopt this training strategy, there is a great interest in relation to the interference the first activity would exert on the subsequent one.

Results obtained in our laboratory demonstrated that the endurance exercise (70% of the $\dot{V}O_{2max}$ for 45 minutes in treadmill) promotes a reduction on the performance of the subsequent maximum repetition test in the leg press at 45°[2]. Other studies corroborate our findings that the aerobic exercise affects the subsequent strength and power development when endurance exercise is previously performed[1].

In another study, it was observed that the resistance exercise (six series of maximum repetitions in the leg press at 45° with three series at 60% of the 1-RM value and the other three series at 90% of the 1-RM value) did not interfere on the posterior aerobic power performance[3]. These results are also corroborated by other researches that demonstrated that the aerobic power performance does not seem to be influenced by the previous execution of resistance exercises[4-8].

However, the literature presents conflicting results[1]. Some researches suggest the non existence of interference from the concurrent training on the aerobic power or strength performance[9-12]. However, in a study conducted by Nelson *et al.*[13], it was demonstrated that the performance of concurrent training hinders the aerobic power development. This controversy may be related to the adaptation level to the concurrent training stimulus. It seems that individuals adapted to the concurrent training undergo less interference in relation to untrained individuals[3,14]. Other factors also contribute for the discrepancy of results obtained by researches that analyzed concurrent training such as the exercise protocols used and the organization of their variables (intensity, duration and frequency)[15].

Currently, the most consistent data on the concurrent training indicates that this strategy lessens the power and strength gains when compared to the resistance training alone[4-8,16].

There are two hypotheses to explain this harmful interference from the concurrent training. These hypotheses are related to acute or chronic processes[1,15]. The chronic hypothesis consists of the idea that after the concurrent training, the muscle would try to adapt itself to both stimuli. However, this is not possible because the endurance training-induced chronic adaptations are frequently inconsistent with adaptations observed during the resistance training. According to the chronic hypothesis, the combination of these two different stimuli could affect the development of these two physical capacities (aerobic power and strength) due to the fact that both induce to different adaptations[1,4,5].

With relation to the acute hypothesis, it is based on the idea that the former activity would lead to a residual fatigue. This fatigue would hinder the performance of the subsequent activity through alterations on the energetic metabolism (lower substrate availability, acidosis, increase on the ammonia concentration)[1].

Considering that the acute hypothesis is a possible explanation for the interference observed in the concurrent exercise, two studies using carbohydrate supplementation during concurrent exercises were performed[2,3]. In both studies, the carbohydrate intake exerted no ergogenic effect[2,3].

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These results led us to consider that the availability of other energetic substrate would be the limiting factor for the performance of the subsequent resistance exercise. Considering that the creatine-phosphate contributed significantly for the performance of the high-intensity exercise, the objective of this work was to verify the effect of the creatine supplementation on the performance of the concurrent exercise (endurance exercise performed previously to the 1-RM test and the maximum repetition test performed at 80% of the 1-RM value).

METHODOLOGY

Sample

Sixteen female Physical Education students (20.1 ± 1.9 years) from the UniFMU University Center were selected. The practice of strength exercises at least three times a week as well as endurance exercises for at least 30 minutes in alternated or simultaneous days was established as inclusion criterion. Other criterion adopted for the participation in this study was the minimum period of 12 months of previous experience in strength training. The sample selection was performed by means of a questionnaire in which the consumption of other nutritional supplements and controlled substances was evaluated. The experimental protocol was approved by the Ethics Committee in Researches involving human beings (CEPSH) of the Biomedics Sciences Institute – University of São Paulo (Nº 051.00). The experiments were conducted according to specific resolution of the National Health Council (Nº 196/96). All individuals were informed in details on the procedures used and agreed in participating voluntarily in the study, signing a term of free and informed consent and privacy protection.

Determination of 1-RM and maximum repetition capacity

After a quick warm up exercise, the 1-RM value was determined through three increasing attempts in the leg press exercise at 45º[17]. Later, the percentile value equivalent to 80% of the 1-RM value was calculated for the performance of the three maximum repetition sets with intervals of 150 seconds.

Endurance exercise

The exercise protocol adopted consisted of 20 minutes running in delimited track field in which the subjects ran the longest distance as possible in 20 minutes. As the exercise maintained a constant step rhythm during the entire activity, the test started with a command voice "ready, go", with chronometer turned on simultaneously. The test ended with a whistle sound.

Supplementation protocol

The participants were divided into two groups randomly selected. The creatine supplementation (or placebo) was conducted according to double-blind design. In the first phase (overload), 20 grams a day of creatine (or placebo) were administered, being divided into four doses, during five days. During the second phase (maintenance), three grams of creatine (or placebo) were administered during seven days. The group placebo was used as control and followed the same experimental conditions as the group supplemented with creatine; however, this group received only carbohydrate (maltodextrin).

Experimental procedure

Two data collections were performed in distinct days 12 days away from one another. At the beginning of the supplementation protocol, both groups were initially submitted to the 1-RM test and to the maximum repetition test in the leg press at 45º (80% of the 1-RM). Twelve days after supplementation (creatine or placebo), both test (1-RM and maximum repetitions) were once again performed shortly after the 20-minutes running test. Therefore, the objective of this work was to verify the effect of the endurance exercise (running) on the strength development in groups placebo and creatine supplemented for 12 days.

Statistical analysis

The results were analyzed using the analysis of variance (ANOVA – two way) (time factor x supplementation factor) followed by the Tukey test (*GraphPAD* software). The minimum significance level adopted in the present study was of $p < 0.05$. The results are expressed as average and standard deviation.

RESULTS

The value obtained in the 1-RM test presented no alteration between groups placebo and creatine, with or without the previous execution of the endurance exercise (table 1). The 1-RM value/body weight ratio also remained unchanged in relation to groups placebo and creatine at the beginning (*without the previous execution of the endurance exercise*) and at the end of the experiments (*with the execution of the endurance exercise*) (table 1).

TABLE 1
Determination of the body weight (kg), 1-RM value (kg) and the 1-RM value/body weight ratio for leg press exercises at 45º in groups placebo and creatine at the beginning (*without the previous performance of endurance exercises)* and at the end of the experiment (*shortly after the endurance exercise*)

	Placebo (n = 8)			Creatine (n = 8)		
	1-RM (kg)	Weight (kg)	1-RM: Weight	1-RM	Weight (kg)	1-RM: Weight
Initial	180.4 ± 20.1	59.2 ± 4.9	3.0 ± 0.3	191.4 ± 22.5	60.9 ± 5.6	3.2 ± 0.5
Final	179.1 ± 18.3	58.6 ± 4.5	3.1 ± 0.4	189.7 ± 20.2	61.8 ± 5.4	3.1 ± 0.4

Values expressed as average ± standard deviation.

However, in the maximum repetitions test, a decrease on the number of repetitions performed by the group placebo after the performance of the aerobic exercise was observed in the two last sets in relation to the beginning of the experiment (**P**: 1st set: 9.0 ± 2.4; 2nd set: 8.9 ± 2.9 and 3rd set: 8.3 ± 3.3 *vs.* **P**: 1st set: 7.6 ± 2.6; 2nd set: 4.3 ± 2.9*; $p < 0.01$ and 3rd set: 4.6 ± 2.3*; $p < 0.01$) (table 2). This response was not observed in the group creatine (**CRE**: 1st set: 10.2 ± 2.2, 2nd set: 9.8 ± 2.9 and 3rd set: 9.7 ± 3.5 *vs.* **CRE**: 1st set: 10.9 ± 2.9; 2nd set: 9.5 ± 2.7 and 3rd set: 9.0 ± 3.0). At the end of the experiment, after the endurance exercise, the average number of maximum repetitions performed by the group creatine in the last two sets was higher than that of the group placebo (table 2).

TABLE 2
Determination of the number of maximum repetitions performed in leg press at 45º and at 80% of the 1-RM value in groups placebo and creatine at the beginning (*without the previous performance of endurance exercises)* and at the end of the experiment (*shortly after the endurance exercise*)

	Placebo (n = 8)			Creatine (n = 8)		
	1st *set*	2nd *set*	3rd *set*	1st *set*	2nd *set*	3rd *set*
Initial	9.0 ± 2.4	8.9 ± 2.9	8.3 ± 3.3	10.2 ± 2.2	9.8 ± 2.9	9.7 ± 3.5
Final	7.6 ± 2.6	4.3 ± 2.9*	4.6 ± 2.3*	10.9 ± 2.9	9.5 ± 2.7#	9.0 ± 3.0#

Values expressed as average ± standard deviation.
* different from the group placebo at the beginning of the experiment ($p < 0.01$).
# different from the group placebo at the end of the experiment ($p < 0.01$).

Regarding the 20-minutes running test, no difference was observed on the performance of both groups (table 3).

TABLE 3
Evaluation of the distance covered in the 20-minutes running test performed before 1-RM and maximum repetitions tests at the end of the experiment

	Placebo (n = 8)	Creatine (n = 8)
Distance covered (m)	3,846 ± 310	3,759 ± 275

Values expressed as average ± standard deviation.

DISCUSSION

The objective of the present study was to test the effect of the creatine supplementation on the adverse effect of the endurance exercise on the subsequent strength development. As previously observed, the performance of the endurance exercise affected the subsequent strength development[1,2].

This impairment could be explained due to the performance of the resistance exercise in adverse metabolic and energetic condition, in case this exercise is preceded by an endurance exercise[1]. This would occur during strength training performed at the same session and hence characterizing an acute effect. In this context, the muscle would have reduced capacity of developing tension during the performance of the posterior strength training. The possible explanation for this phenomenon was called as acute hypothesis[1,15].

The acute interference hypothesis is supported by the study of Craig *et al.*[6] who verified that the strength development in the lower limbs was impaired due to the performance of an aerobic exercise shortly before the resistance training. In the same study, it was observed that the lower limbs adaptation was not impaired by the previous endurance training. According to the authors, the legs musculature would not recover from the endurance training and would not perform the resistance training at intensity required to promote the desired adaptations.

The mechanisms responsible for the strength and power impairing in the concurrent training are not yet fully identified[1,15,18,19]. A possible candidate is the muscular glycogen depletion, once it is an important energetic substrate for the resistance training[20-22]. However, previous evidences obtained in our laboratory demonstrate that individuals who ingested adequate amounts of carbohydrate before exercise and who were also supplemented with carbohydrate during concurrent exercise could not achieve lessening the harmful effect of the endurance exercise on the posterior resistance exercise[2]. These results, therefore, made us consider the hypothesis that other energetic substrate could contribute for the performance of the concurrent training (aerobic training performed before the resistance training), the creatine-phosphate (CP).

In the present study, the results observed demonstrate that the strategy of ingesting creatine or placebo did not affect the result of the 1-RM test. Recently, in another study conducted in our laboratory[23], we could verify that the creatine supplementation did not change the maximum load supported in supine, checked through the 1-RM test. However, still in this study, we verified that the creatine intake increased the capacity of performing maximum repetitions at 70% of the 1-RM value. These results are in agreement with results found by other researchers[17,24]. Earnest *et al.*[17] did not observe increases on the 1-RM values for supine after creatine supplementation either. As in our study, Earnest *et al.*[17] only verified increases on the capacity of performing maximum repetitions at 70% of the 1-RM value.

Despite the energy absolute production during short-duration maximal effort (~6-8 seconds), as in the case of the 1-RM test, be predominantly supplied by the creatine-phosphate degradation, the intramuscular creatine basal content before supplementation would be able to supply this demand. Consequently, the group submitted to creatine supplementation would not present a better performance in relation to the group placebo[17,23,25].

In relation to the capacity of performing maximum repetitions (80%-1-RM) in the group placebo, the endurance exercise promoted a decrease on this parameter in relation to the initial test, as expected. A possible explanation for the reduction on the number of maximum repetitions is that the endurance exercise would promote a depletion of the energetic substrates, thus generating a residual fatigue (acute interference hypothesis)[1,15]. On the other hand, in the group supplemented with creatine, the capacity of performing maximum repetitions (80%-1-RM) in the leg press at 45° after endurance exercise was maintained.

The fatigue installation in the resistance exercise seems to be multifactorial, presenting as potential causes the CP depletion, the intramuscular acidosis (increase of H^+ ions) and/or the reduction on the muscular glycogen[25]. MacDougall *et al.*[26] observed that the combination between the CP depletion (62% in relation to the rest situation) and the muscular acidosis (21.3 $mmol.kg^{-1}$ of wet weight) was the responsible for the fatigue at the 1st series of maximum repetition at 80% of the 1-RM value. These authors also reported that after three series of maximum repetitions at 80% of the 1-RM value, the incapacity of maintaining the movement pattern seems to be limited by the increase on the H^+ ions concentration[26]. The elaboration of this hypothesis was based on the fact that the CP reduction degree (50% in relation to the rest situation) was smaller than that observed in the 1st series (62% in relation to the rest situation). Reinforcing this hypothesis, the lactate production had been higher at the end of the last series (1st series – 21.3 $mmol.kg^{-1}$ wet weight *vs* 3 series – 27.4 $mmol.kg^{-1}$ wet weight)[26].

Considering that the fatigue at the 1st series may be related with the CP reduction, one may speculate that the higher content of this substrate in the muscle would minimize the CP depletion in the group supplemented with creatine, thus favoring its subsequent re-synthesis for the next series. Furthermore, it is important mentioning the buffering capacity exerted by the ATP-CP system[27]. The immediate re-phosphorylation of ADT into ATP through the CP hydrolysis requires one H^+ ion[27]. As result, this buffering capacity would lessen the harmful effects of the acidosis[25,27,28], such as the inhibition of enzymes involved in the energetic metabolism[25,27] and the reduction on the sensitiveness of the contractile proteins to ions Ca^{++}[28].

Therefore, the increase on the availability of this substrate and its buffering capacity would be responsible for the maintenance of the performance in the subsequent maximum repetitions test in the group submitted to creatine supplementation.

CONCLUSION

According to other results available in literature, the present study demonstrated that the previous performance of endurance exercises affects the subsequent resistance exercise. It was also verified in this study, that the creatine supplementation is able to nullify the adverse effect induced by the endurance exercises on the subsequent performance on the maximum repetitions test at 80% of the 1-RM value. These results suggest that the ATP-CP system contributes significantly for the performance of the concurrent exercise in which the subsequent resistance training is performed at high intensity.

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