ORIGINAL ARTICLE

ENGLISH VERSION

Carbohydrate supplementation fails to revert the deleterious effects of endurance exercise upon subsequent strength performance

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ABSTRACT

Previous studies indicated that endurance exercise might have an adverse effect on subsequent strength performance. The decrease in strength performance might be related to the changes promoted by endurance exercise in energy metabolism. Authors' aim was verify if carbohydrate (CHO) feeding can attenuate the effects of endurance exercise on strength development. To verify that hypothesis, six female university students (164 ± 5.9 cm; 64.9 ± 7.2 kg) with strength training experience were submitted to a $\dot{V}O_{2peak}$ test (44 ± 4.3 ml.min^{-1}) and an 1-RM test in the leg press (186 ± 22.5 kg) followed by a maximum repetitions test (2 sets of leg press exercise performed at 70% of 1-RM value until exhaustion, 1st set 21 ± 2.6 reps and 2nd set 11 ± 1.9 reps) in different days. In a double-blind design, the subjects were submitted to two different trials, receiving placebo (P) or CHO beverages (1 L of P or 6% maltodextrin solutions), 60 min before (500 ml) and during (500 ml) endurance exercise bout. These bouts were performed in a treadmill at 70% of $\dot{V}O_{2peak}$ for 45 minutes. Subsequently, the subjects performed an 1-RM test followed by a maximum repetitions test. No changes were observed in 1-RM test. There was a similar decline in maximum repetitions test (an index of muscular endurance) in both trials (P – 1st set 13 ± 2.9 reps and 2nd set 6 ± 2.1 reps; CHO – 1st set 15 ± 2.5 reps and 2nd set 7 ± 1.7 reps, $p < 0.05$). Previous endurance exercise bout promoted deleterious effect upon muscular endurance task (maximum repetitions test – 70%-1-RM). CHO supplementation was inefficient to revert the effect of endurance exercise upon maximum repetitions test.

Key words: Endurance exercise. Strength exercise. Carbohydrate. Supplementation.

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Received in 14/4/03

2nd version received in 25/9/03

Approved in 27/9/03

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INTRODUCTION

A number of studies showed that endurance exercises performed previously to strength exercises may have prejudicial effects on these, such as impairment of acute performance on specific tests. A possible explanation for such is that an endurance exercise session could promote acute metabolic changes on a subsequent strength training session[1].

In long-duration exercises (21-160 minutes), also known as endurance exercises, the most likely etiology factors of fatigue are thermal stress, dehydration, $\dot{V}O_{2max}$ proportion at exercise, the subject's lactate threshold, the percentage of type I fibers recruited, the biomechanics of running and glycogen content in the body (muscular and hepatic)[2,3]. On the other hand, it is known that activities that last 30-180 seconds are affected by factors such as motivation-determination and the contents of creatine-phosphate and muscular glycogen[2].

Therefore, depletion of glycogen reserves (a variable affected by endurance exercise) could be related to a hazard on strength performance, as it is believed such interference to be related to the metabolism of energy[1]. This idea is supported by the fact that a significant decrease of muscular glycogen affects strength in situations in which the initial reserve of glycogen is reduced through diet or training is enhanced[4]. In addition to the initial glycogen level, considered to be a limiting factor for strength performance, carbohydrates could also affect strength generation by modifying central nervous system functionality through changes of blood glucose[5-7]. Nevertheless, until now, the idea that endurance exercise compromises strength performance due to carbohydrate metabolism is yet to be tested.

Thus, the purpose of this investigation was to check whether carbohydrate intake can lessen endurance exercise effects on the subsequent development of strength during an acute exercise session.

MATERIALS AND METHODS

Sample

Six female university students were selected (164 ± 5.9 cm; 64.9 ± 7.2 kg; 22.4 ± 3.8 years), physically actives ($\dot{V}O_{2peak}$ 44 ± 4.3 ml.min^{-1}) and with at least two years experience in strength exercise. Selection of the sample was made with a questionnaire in which the use of other nutritional supplements and controlled substances was assessed. The experimental protocol was approved by the ethics committee for research on human subjects (CEPSH), of the Biomedical Sciences Institute, University of São Paulo (memo 051.00). According to regulation of the National Health Council (# 196/96), all participants were fully informed on the procedures and volunteered to take part in the study, signing an informed consent and privacy protection form.

Establishing peak $\dot{V}O_2$

All study participants were initially submitted to an ergospirometric test to determine maximum aerobic power. Throughout the test, the exhaled gases were directly collected by an open circuit assessed, breath by breath, by gas analysis device of brand Quintom-QMC. Peak oxygen uptake (peak$\dot{V}O_2$) was the highest oxygen uptake calculated from 30-second averages. The test was performed on a treadmill Quintom/Medtrack – ST 65 with a constant inclination of 2%. A 3-minute warm-up was made on a speed of 5 km.h^{-1}, after which the speed of the treadmill was increased in 1 km.h^{-1} at each minute until voluntary fatigue was reached[8].

Determining 1-RM and maximum repetition capability

After a brief stretching and warm-up, the maximum load (1-RM) was determined by three increasing trials on exercise leg press 45º, with a three-minute interval[9]. Then, 70% of the maximum load (70%-1RM) for performing two maximum-repetition sets with a 90-second interval was calculated. Maximum-repetition capability was determined by exhaustion or inability to keep the pattern of movement. These initial tests (reference values) were carried out three days after the test to establish peak $\dot{V}O_2$.

Protocol for supplementation

The participants received a controlled diet (70% of carbohydrate, 15% of lipids and 15% of proteins) one day before the trials, with either placebo or carbohydrate[10]. Carbohydrate supplementation was carried out on a double-blind fashion. The given supplement was either carbohydrate solution at 6% (60 g maltodextrine.L^{-1}) or a sweet placebo solution, 60 minutes before (500 ml) and during (500 ml) endurance exercise.

Establishing blood glucose level

Monitor *Advantage*® with its stripes was used, according to its instructions for use. Glucose serum levels (mg.dL^{-1}) was established according to the bioamperometry principle, in which glucose is transformed by dehydrogenase glucose in glucolactone. Blood glucose was assessed at four moments: sample 1 – two hours prior the endurance exercise, sample 2 – immediately before endurance exercise, sample 3 – immediately before strength exercise, and sample 4 – at the end of strength exercise.

Experiments

One week after determination of 1-RM at leg press, experiments were carried out in two different occasions, one week apart from each other. Subject selection to receive carbohydrate supplement was made at random. Subjects received supplement (P or CHO) 60 minutes before and during endurance exercise performed at 70% do $\dot{V}O_{2peak}$. At the end of endurance exercise, a maximum load test was carried out to be compared to the 1-RM value previously calculated (initial test). Next, two sets of maximum repetitions at 70% 1-RM with a 90-second interval to compare with the value from the initial test were performed. After seven days, the experiment was repeated, only with the inversion of the supplement offered at the initial test.

Statistical analysis

Statistical analysis was carried out through software GraphPad-Prism™. The results were submitted to variance analysis and, later on, to Tukey's post-test. The significance interval was $p < 0.05$. Results are presented as mean ± standard deviation.

RESULTS

Regardless of carbohydrate or placebo intake, no changes in the results of the 1-RM test carried out immediately after endurance exercise (table 1). As to localized muscular resistance, it was seen a decrease in the number of maximum repetitions at 70%-1RM in both cases (placebo and CHO) compared to the initial test ($p < 0.05$) (table 2). Decrease in capability of performing maximum repetitions (70%-1RM) was similar, with no statistical differences between the placebo and maltodextrine experiments. Serum glucose levels in both experiments was not changed (table 3).

DISCUSSION

A question often raised among those involved in strength training programs is about the influence of performing a long-duration submaximal exercise (endurance) on the subsequent performance of strength. Some studies have already addressed this issue[1,11,12]. They showed a hazardous effect of endurance exercise performed previously to a strength exercise (a compromise in the capability of producing tension). Our intention was to assess whether carbohydrate supplement could lessen or even revert this scenario.

The adjustments from endurance and strength training occur through functional and structural changes typical to each stimulus in different types of muscle fibers[13-16]. Thus, the combination of such stimuli could jeopardize the adjustments, as different mechanisms were activated[11,12]. It is to be mentioned that the literature suggests that adjustments from strength training are compromised due to a prior performance of aerobic training; however the opposite does not seem to be true[17].

According to the literature, the combination of high-intensity aerobic training with a strength training program seems to interfere in the performances of strength and power (this seems to be the variable affected the most)[18]. It is possible for power to be more sensitive to overtraining from the adding of a high-intensity aerobic program and that such interference is related to oxidative stress. Endurance training is likely to compromise adjustments from a performance of strength by changing the pattern of muscle use and/or hypertrophy attenuation.

However, considering the time the studies on the effects of concurrent training (and their results on strength gain) were carried out, it is possible that there is no compromise on the adjustments. The combination of stimuli may actually require more time for the adjustments to occur in the body[18]. As there may be more need to aggregate proteins, a number of simultaneous ultrastructural and enzymatic adjustments may occur.

If it is true that concurrent training actually compromises strength and power performance, this could be related only to the inability of the body to promote adjustments at the time following the stimuli. This means, strength training would be normally performed, but the adjustments would be compromised (post-exercise interference, typical of a chronic process). This theory is called chronic hypothesis. Therefore, according to this hypothesis, the muscle would not manage to adjust itself metabolic or morphologically after stimulation of the concurrent training[12].

On the other hand, the compromise could be explained by performing a strength exercise under a different metabolic condition, if it is preceded by an aerobic exercise[1]. This means, in this case, the lack of adjustment would be related to the inability of properly performing a strength training, due to some adverse conditions induced by endurance exercise. This compromise would take place during strength exercise, therefore typical of an acute effect.

TABLE 1
Establishing maximum load (1-RM) at leg press 45º

Maximum load	1RM (kg)
Initial test (n = 6)	186 ± 22.5
Placebo (n = 6)	191 ± 19.7
CHO (n = 6)	189 ± 23.8

n = number of subjects, data noted as mean ± standard deviation.

TABLE 2
Establishing maximum number of repetitions at 70%-1RM in the leg press 45º

Maximum repetitions (70%-1RM)	1 set	2 set
	(reps)	
Initial test (n = 6)	21 ± 2.6	11 ± 1.9
Placebo (n = 6)	13 ± 2.9*	6 ± 2.1*
CHO (n = 6)	15 ± 2.5*	7 ± 1.7*

n = number of subjects, data noted as mean ± standard deviation.
* p < 0.05 in relation to the initial test.

TABLE 3
Blood glucose levels. Sample 1 – two hours prior to endurance exercise; Sample 2 – immediately before endurance exercise; Sample 3 – immediately after strength exercise; and Sample 4 – at the end of the strength exercise

Blood glucose levels	1	2	3	4
	(mg.dL⁻¹)			
Placebo (n = 6)	92 ± 10.1	89 ± 13.0	98 ± 15.1	87 ± 15.8
CHO (n = 6)	96 ± 13.7	110 ± 16.6	91 ± 9.8	95 ± 9.0

n = number of subjects, data noted as mean ± standard deviation.

In this scenario, the muscle would have its ability to develop tension compromised during strength training performance. This other theory was called acute hypothesis[12]. Acute interference hypothesis is supported by a study by Craig *et al.*[19], who saw that the development of strength in lower limbs was compromised by running immediately before strength training; however, adjustment of upper limbs was not compromised by a previous endurance training. According to these authors, leg muscles would not recover from endurance training and would not perform strength training in the necessary intensity to promote adjustments.

The mechanisms accountable for strength and power compromise in concurrent training have not yet been identified[20,21]. One possibility is depletion of muscle glycogen, as this is an important energetic substrate for strength training[22-24]. Leveritt and Abernethy[11] demonstrated that muscle glycogen depletion by intake restriction and endurance exercise compromise the iso-inertial performance of ducking (however, the isokinetic performance of knee extension was not affected, indicating that the compromise seems to be related to the type of measured strength). Leveritt *et al.*[1] observed that the knee-extension strength was not changed, when assessed between eight and 32 hours after performing a 50-minute exercise on cycle-ergometer at 70-110% of critical power. However, metabolic parameters such as plasma ammonia were significantly higher in relation to those subjects who had their strength assessed without prior endurance exercise (cycle-ergometer).

The results above suggest that impairing strength and power adjustments from intense endurance stimulus may be due to the inability of the subject to properly perform strength exercises after an endurance activity (hypothesis of acute impairment). Considering that the decrease of muscular glycogen during endurance training is a metabolic variable that seems to be involved in the inability, Leveritt and Abernethy[11] point out the importance of carbohydrate intake after endurance exercise to ensure subsequent performance of strength training. It is possible, however, that this strategy is not enough to ensure a proper replacement of carbohydrate reserves. An alternative to Leveritt and Abernethy's proposition[11] is to start carbohydrate replacement before and during the endurance exercise, a possibility not tested so far. Another test is to check whether blood glucose levels are not related to impairment of strength training.

In our study, these factors were investigated. The results show that the strategy of taking carbohydrate or not during endurance exercise did not affect the outcome of the 1-RM test. It is likely that additional recruiting of IIa and IIb fibers during 1-RM test had a role for this parameter not to change. Moreover, the absolute production of energy during maximum and short exertions (~ 6 seconds) is provided basically by degradation of creatine-phosphate, being the production of energy by glycolysis less important [25]. These factors may explain lack of changes in the performance of 1-RM.

In relation to the result of maximum repetitions capability at 70%-1RM, as expected, the endurance exercise promoted a decrease in this parameter, compared to the initial test. A possible explanation for the decrease in number of maximal repetitions is that the selective recruitment of type I fibers seen in endurance exercise would promote reduction of glycogen in these fibers only. During the test of maximum repetitions (to indicate localized muscular resistance), in which there is major dependency on type I fibers, the lower glycogen availability may have affected performance.

Evidences from endurance exercises show that carbohydrate supplementation is enough to promote performance enhancement, and the proposed mechanism for this is maintaining blood glucose levels and decrease of glycogenolysis, particularly in type I fibers[26,27]. Through other studies carried out by Tesch *et al.*[23], MacDougall *et al.*[24], and Haff *et al.*[4], who assessed the use of substracts in strength-only exercises, a positive effect of carbohydrate intake was also to be expected, as the previous endurance activity would have reduced glycogen availability when performing repetitions until fatigue occurred. This hypothesis, however, was not confirmed by our results, as the decrease in the number of maximal repetitions was similar in both experiments (placebo or carbohydrate use). In our study, ergogenic effect from carbohydrate was not seen in the concurrent exercise.

According to Leveritt and Abernethy[11], it is possible that other factors could have caused a reduction in the number of repetitions, when such parameters are assessed after endurance activities. One of these mechanisms suggested by the authors is the subjects being aware that food restriction protocol could affect their performance. In our study, this hypotheses is ruled out, as it was a double-blind investigation. A possibility not tested in our study and pointed out by Millet *et al.*[28] is the muscular fatigue from endurance activity, even though in their study fatigue occurred from a more extenuating activity than in ours.

Even though our observation on the performance is similar to Leveritt's *et al.*[1], differently from them we noted that endurance training does not promote changes in metabolic features (blood glucose) at the strength session that comes after (regardless of the intake or carbohydrate). However, it is to be mentioned that our assessment was made only during the exercise, whereas Leveritt *et al.*[1] assessed possible metabolic changes (concentration of ammonia) for eight to 32 hours after strength exercise.

Thus, we can conclude that an endurance training session (at moderate intensity) carried out prior to a strength exercise affects performance of the later regarding maximum repetition capability. We believe this phenomenon to be related to the acute impairment hypothesis suggested by Leveritt *et al*.[1,12]. Furthermore, we have checked that the intake of a carbohydrate solution (60 g.L^{-1}) before and during endurance exercise was not able to revert the hazardous effect it induced on the subsequent capability of performing repetitions at 70%-1RM until fatigue.

All the authors declared there is not any potential conflict of interests regarding this article.

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