

Original Article (short paper)

Effects of taurine supplementation in elite swimmers performance

Gabriela Batitucci¹, Sara Ivone Barros Morhy Terrazas¹, Mariana Pereira Nóbrega¹, Flávia Giolo de Carvalho², Marcelo Papoti²,
Júlio Sérgio Marchini³, Adelino Sanchez Ramos da Silva², Ellen Cristini de Freitas^{1,2}

¹Universidade Estadual Paulista, UNESP, Faculdade de Ciências Farmacêuticas, Araraquara, SP; ²Universidade de São Paulo, USP, Escola de Educação Física e Esporte de Ribeirão Preto, Ribeirão Preto, SP, Brazil; ³Universidade de São Paulo, USP, Faculdade de Medicina de Ribeirão Preto, Ribeirão Preto, SP, Brazil

Abstract — Aim: Taurine is considered a semi-essential amino acid characterized by having various physiological functions in the body that modulate mechanisms of action involved in the muscle contraction process, increased energy expenditure, insulin signaling pathway, carbohydrate metabolism, and scavenging free radicals. These functions are crucial for aerobic exercise performance; thus, taurine supplementation may benefit athletes' performance. The objective of this study was to evaluate the effects of taurine supplementation on the resting energy expenditure and physical performance of swimming athletes. **Methods:** In a double-blind study, 14 male swimmers were randomized into two groups: the taurine group (n = 7) and the placebo group (n = 7), which received 3 g per day of taurine or placebo in capsules during 8 weeks. Resting energy expenditure, plasma taurine, physical performance, anthropometry, dietary consumption were measured and an incremental test was performed to determine their maximal front crawl swimming performances before and after the 8-week period. **Results:** The levels of serum taurine (p < 0.0001) and lactate (p = 0.0130) showed a significant increase in the taurine group; however, the other variables were not different. No changes were observed in the resting energy expenditure, mean speed performed, and the anaerobic threshold of the swimmers post-supplementation period. **Conclusion:** Supplementation of taurine increased plasma concentrations of this amino acid, but did not lead to significant changes in food intake, rest energy expenditure, and athletes' performance. However, the supplemented group presented a higher lactate production, suggesting a possible positive effect of taurine on the anaerobic lactic metabolism.

Keywords: anaerobic lactic metabolism, energy expenditure, swim.

Introduction

Taurine (2-aminoethanesulfonic acid) is a non-essential amino acid found in abundance in mammalian cells, which is synthesized from other sulfur-containing amino acids such as methionine and cysteine. Although taurine can be obtained by endogenous synthesis, there are reports in the literature showing the endogenous production is insufficient for attending the body requirement of taurine. This non-essential amino participates in numerous biological and physiological functions like regulation of calcium homeostasis in both skeletal muscle and cardiac tissue^{1,2}, increases muscle force³ and insulin sensitivity⁴, improves energy expenditure⁵ and lipid metabolism⁶ and prevents oxidative stress in athletes⁷. Therefore, taurine must be obtained by food intake and can be found mainly in fish and seafood². This amino acid does not participate in the process of protein synthesis².

Among the functions related to taurine is the regulation of intracellular calcium levels (Ca²⁺), membrane stabilizing^{2,8}, antioxidant^{7,8} and anti-inflammatory processes^{9,10}. Taurine can modulate glucose metabolism potentiating the hepatic and muscular insulin signaling pathways^{4,11}. Also, this amino acid modulates the use of lipids, stimulating the expression of genes related to the production of the following enzymes: lipoprotein lipase, acyl-CoA oxidase, acyl-CoA synthase, and acyl-CoA dehydrogenase, which are involved in the metabolism of lipid substrates⁵.

Due to the several effects attributed to the action of taurine in the body, some investigations tried to understand the relationship between this nutrient and physical exercise. According to Bakker and Berg¹², taurine can increase the transport of calcium

to myofibrillar contractile proteins, optimizing skeletal muscle function, with consequent benefits to athletic performance. Acute supplementation of 6 g/day of taurine for seven days significantly increased the time to exhaustion, maximum workload, and maximal oxygen uptake (VO₂ max) on a cycle ergometer, and reduced the oxidative stress markers¹³. Yatabe, Miyakawa, Miyazaki, Matsuzaki, Ochiai¹⁴ evaluated the taurine concentrations in the skeletal muscles of rats and their time to exhaustion after endurance running. The authors found that 0.5 g/kg/day of taurine increased physical strength in the supplemented group.

In swimming, the contribution of the aerobic metabolism to a maximal effort of 400 m may range from 25 to 83% of total energy and can be influenced by maximal oxygen uptake, metabolic thresholds and peak speed performed^{15,16}. Thus, the use of taurine supplementation may oppose the possible overproduction of reactive oxygen species (ROS). Since other investigations described nutritional inadequacies in competitive swimmers that result in losses of recovery time and performance^{17,18}, some attention must be given to the provision of adequate energy intake of both macronutrients and micronutrients¹⁹.

Considering taurine supplementation has potential effects on energy metabolism and muscle contraction strength, we hypothesize that its use as an ergogenic resource will benefit swimmers' performance, especially those performing efforts of 400 m. Thus, the primary aim of the present investigation was to evaluate the effects of taurine supplementation on the resting energy expenditure and physical performance of swimmers.

Methods

Participants

The volunteers participating in the present study were 14 male swimmers with 18-25 years of age, the weight of 78.6 ± 5.8 kg, the height of 180.0 ± 4 cm, and a body mass index (BMI) of 24.1 ± 0.6 kg/m². All volunteers were from the elite competitive swim team of Ribeirão Preto city. These athletes regularly trained two to three hours per day during a particular training period and were competitive swimmers with a minimum of 3 years of experience at regional and/or national competition level. Each participant gave a written consent before the start of the study. The inclusion criterion was based on their participation for at least two consecutive years in national competitions. Also, they were not using any medication at the time of the research. The present study was approved by the Human Subject Committee of the Faculty of Pharmaceutical Sciences, Food and Nutrition Department / Food and Nutrition Postgraduate Program- São Paulo State University (protocol n° 00526312.9.0000.5426).

Trial design

A double-blind and randomized study was conducted. The subjects were divided randomly into two groups: the placebo group (n = 7) and the taurine group (n = 7). The taurine group received 3g of taurine per day^{7,20}, while the placebo group received 3g of starch flour, which was identical in appearance to taurine capsules.

After a fasting period of 8h, each volunteer was to the University Hospital of Ribeirão Preto to measure resting energy expenditure by indirect calorimetry, plasma taurine and anthropometric measurements. Also, guidelines were given to complete the three-day food register. These evaluations were performed before and after eight weeks of placebo or taurine supplementation.

Supplementation protocol

The participants were instructed to intake 3 grams of pure taurine^{7,20} or placebo, which refers to 3 capsules containing 1g of the supplement, every day in the morning before breakfast, during an eight-week period. The taurine powder was obtained from Ajinomoto (Aminoethylsulfonic Acid, Ajinomoto R, São Paulo, SP) and the capsules were manipulated by the Department of Industrial Pharmacy of the School of Medicine of Ribeirão Preto, University of São Paulo. Swimmers were instructed to avoid taurine food sources such as fish, seafood, and energy drinks during the study protocol.

Nutritional assessments

Dietary intake was assessed using three-day dietary records. The records were filled by the volunteers on 2 weekdays and 1 weekend day. The software DietPro 5.1 (A.S. Sistemas, Viçosa, MG, Brazil) was used to quantify the intake of macronutrients and total energy of athletes.

Measurement of resting energy expenditure

The resting energy expenditure (REE) was determined by indirect calorimetry. The subjects were instructed to breathe immediately into a face mask (Hans Rudolph, Kansas City, MO, USA) connected to a breath-by-breath gas analyses system Medics Calorimeter® (SensorMedics Corporation, Yorba Linda, California, USA). After a fasting period of 8h, the athletes were evaluated during the 30-minute test¹⁸. The values with variations higher than 10% were not used. Also, the average of the values of oxygen uptake (VO₂) and carbon dioxide elimination (VCO₂) was used to calculate energy expenditure according to Weir's formula²¹.

Plasma taurine assay

The concentrations of plasma taurine were determined by high-performance liquid chromatography (Shimadzu model LC 10AD) using a Shimadzu Model RF-535 fluorescence detector. Taurine 99 % was used as standard (Sigma-Aldrich, St. Louis, MO, USA)²².

Performance test protocol

After 15 min of warm-up (i.e., 500m of low and moderate intensity), the swimmers randomly performed three 400-m front-crawl submaximal efforts with 3 min of passive recovery in between and in intensities corresponding to 85, 90, and 100% of the maximum velocity obtained by the athletes for this swimming distance²³. It is important to point out the maximal velocity for the 400-m swimming distance was measured before and after the 8-week period. The motion-analysis software Kinovea™ (version 0.8.15, available for download at <http://www.kinovea.org>) was used to analyze performance (time and velocity). The tests were performed in a 25-m swimming pool with a water temperature of $25 \pm 1^\circ\text{C}$.

Blood samples were obtained from the earlobes in 25 µL heparinized capillary tubes 1min after the end of each effort. Also, after the last effort of 400 m, blood samples were also taken after 3 and 5min to measure peak blood lactate concentrations²³. Blood lactate concentrations were assayed by a lactate analyzer (YSI 2300 Sport, Yellow Spring Instruments, Yellow Springs, Ohio). The swimming intensity corresponding to the 4.0 mM blood lactate concentration was considered as the anaerobic threshold²⁴ and was obtained by the exponential interpolation of the lactatemia vs. swimming intensity curve.

Statistical analyses

Shapiro-Wilk and Levene's tests were applied to assess normality and homogeneity, respectively. Two-way repeated measures analysis of variance followed by Sidak post hoc test were conducted to compare changes within and between groups (Placebo versus Taurine). In cases of nonparametric distribution,

Friedman test was applied. For data with heterogeneous variances, Welch test was conducted. The level of significance was set at $p < 0.05$ in all analyses and data were expressed as mean \pm standard deviation and as confidence intervals graphics.

Results

The plasma taurine concentrations were not different between the studied groups at baseline. After the 8-week period, the taurine

group showed a significant increase in plasma taurine (Taurine group pre: 104.75 ± 88.33 nmol/L; Taurine group post: 3983.48 ± 768.87 nmol/L, $p < 0.0001$). Also, compared to the placebo group, the taurine group showed a significant increase of plasma taurine (Placebo group pre: 49.91 ± 8.1 nmol/L; Placebo group post: 174.00 ± 120.29 nmol/L).

Figure 1 shows the parameters assessed by the three-day dietary records. The intake of calories and macronutrients (carbohydrates, proteins, and lipids) was similar between the groups, before and after the period of taurine supplementation.

Figure 1. Evaluation of food intake before (Pre) and after (Post) 8 weeks of placebo or taurine supplementation (n = 14).

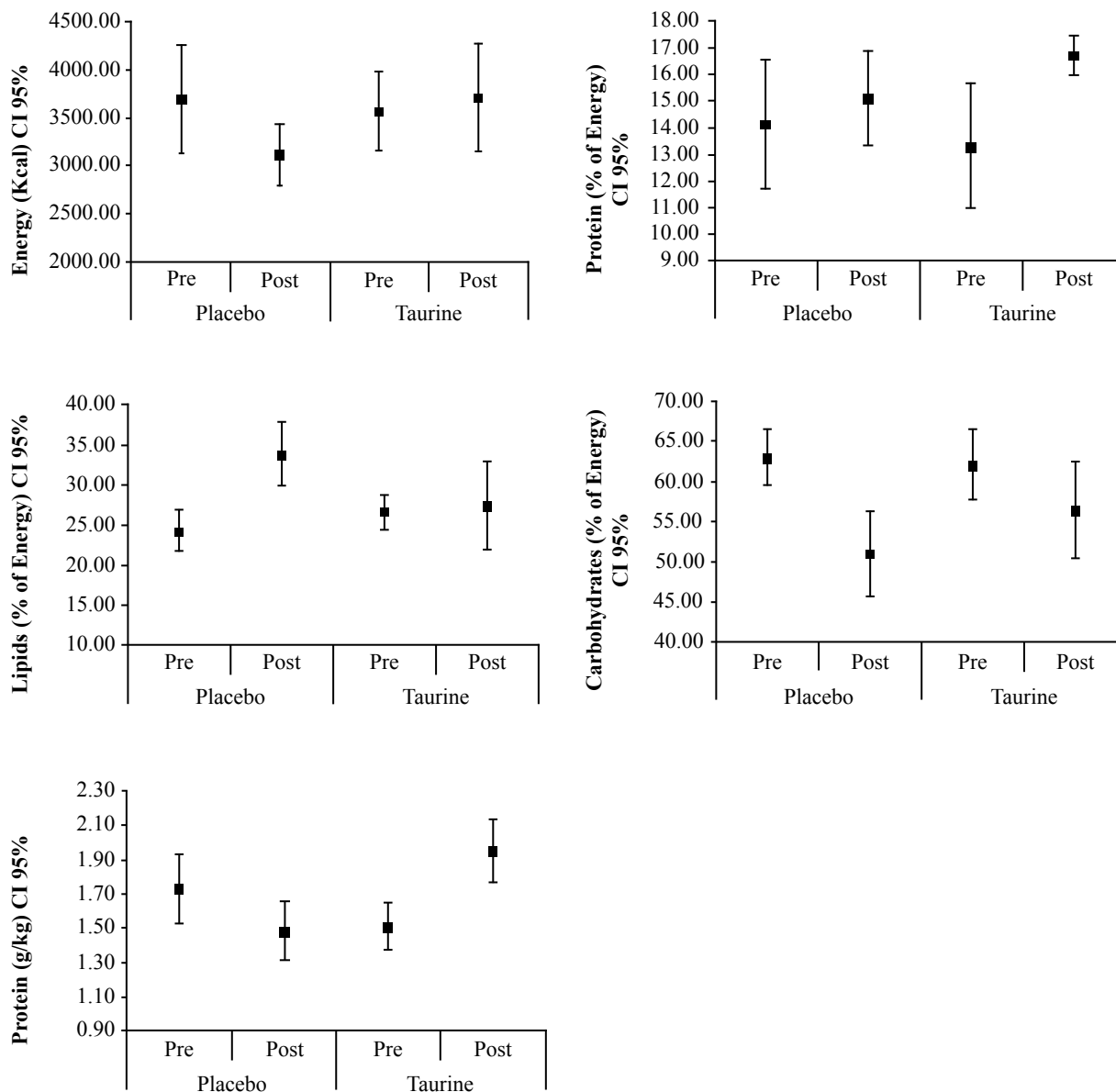


Figure 2 shows the values obtained by the indirect calorimetry before and after the intervention period. No significant differences were found between the groups and periods studied.

Regarding blood lactate concentrations, the taurine group increased all values after the supplementation period. First

effort of 400m: $F_{(1,12)} = 8.161$, $p < 0.05$; Second effort of 400m: $F_{(1,12)} = 12.007$, $p < 0.05$; Third effort of 400m: $F_{(1,12)} = 8.423$, $p < 0.05$; 3 min after the third effort of 400m: $F_{(1,12)} = 49.211$, $p < 0.05$; 5 min after the third effort of 400m: $F_{(1,12)} = 34.669$, $p < 0.05$) (Figure 3).

Figure 2. Evaluation of REE, VO₂, VCO₂ and QR before (Pre) and after (Post) 8 weeks of placebo or taurine supplementation (n = 14).

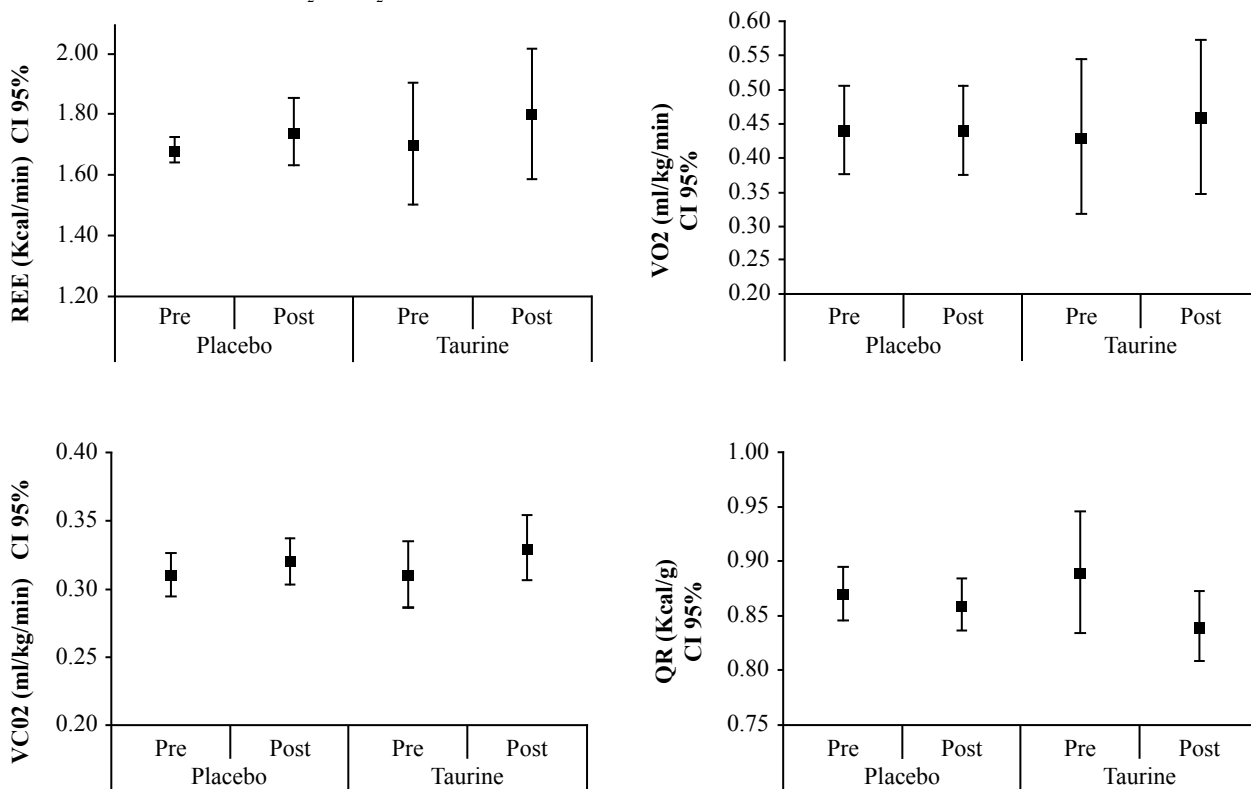


Figure 3. Evaluation of blood lactate concentrations (mmol/L) before (Pre) and after (Post) 8 weeks of placebo or taurine supplementation (n = 14). * Statistical difference in relation to “Pre Taurine” at p ≤ 0.05.

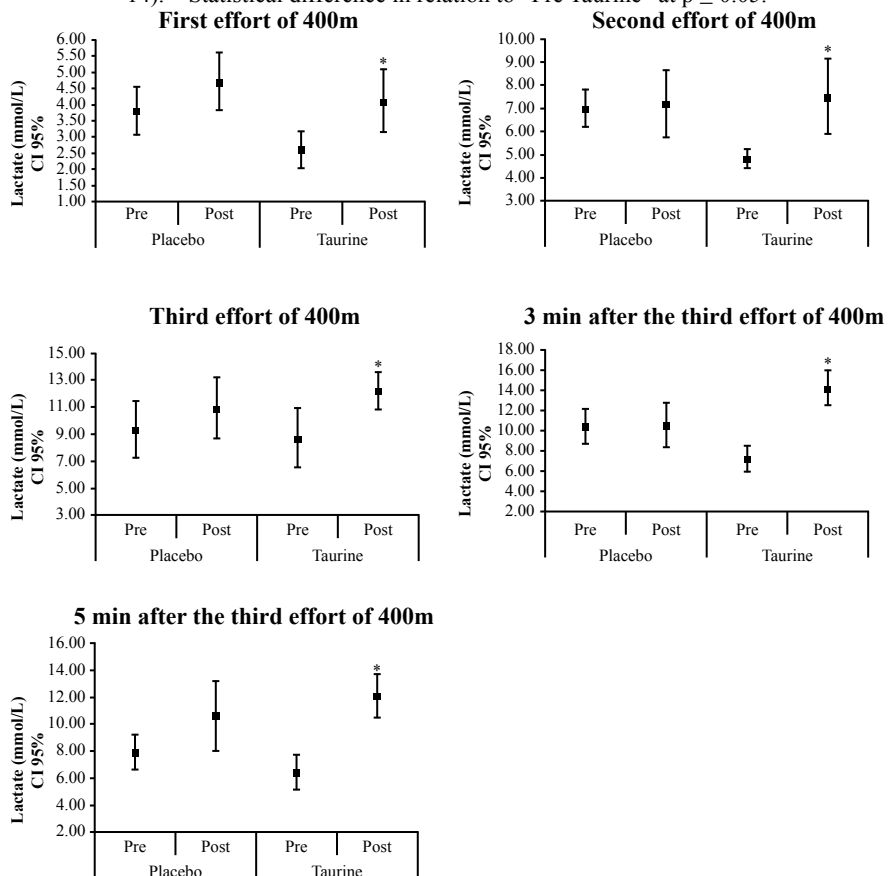
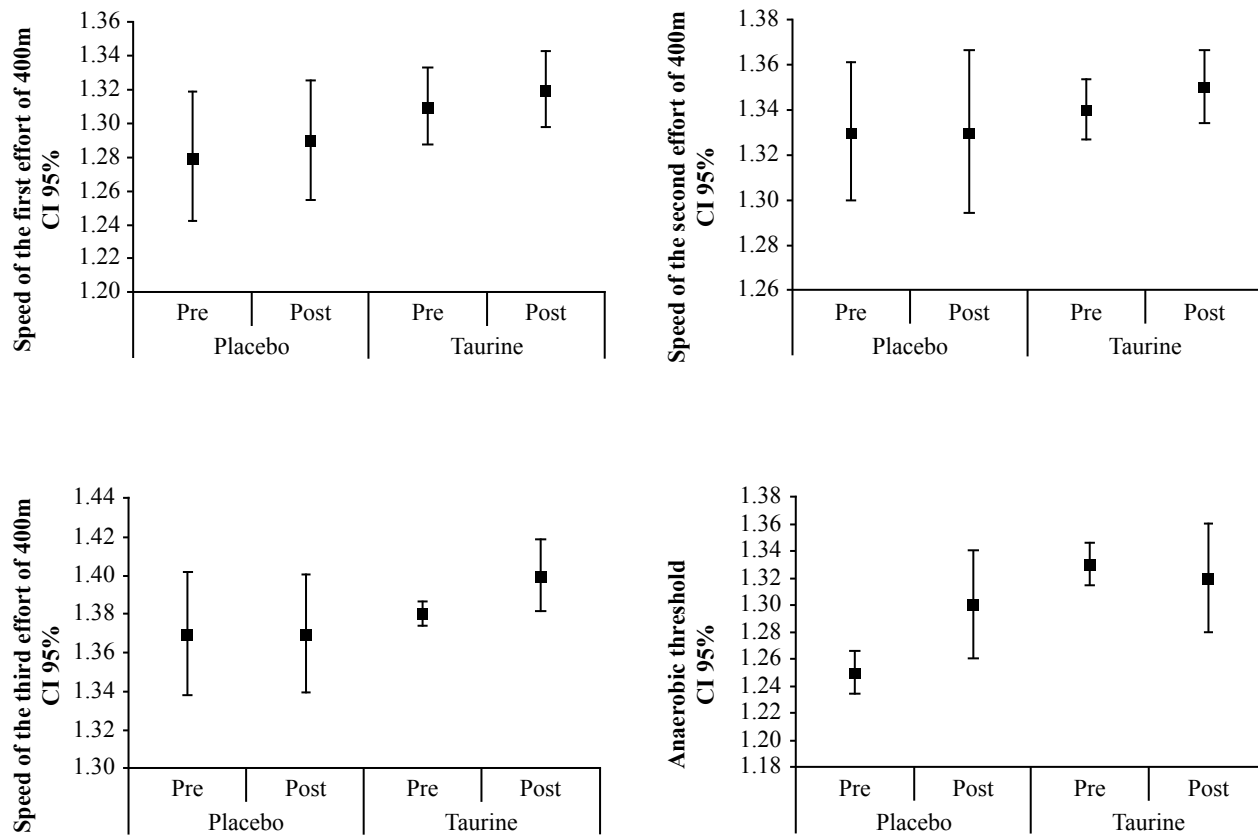


Figure 4 shows the mean speed achieved in each effort of 400 m and the anaerobic threshold of the swimmers. No

significant changes were observed before and after the supplementation period.

Figure 4. Evaluation of mean speeds (m/s) before (Pre) and after (Post) 8 weeks of placebo or taurine supplementation (n = 14).



Discussion

In this study, we examined the effects of eight weeks of taurine supplementation on energy consumption, resting energy expenditure and swimmers' performance. The levels of serum taurine and lactate showed a significant increase in the taurine group; however, the other variables were not statistically significant. No changes were observed in the resting energy expenditure, the mean speed achieved in each effort of 400 m, and the anaerobic threshold of the swimmers post-supplementation period.

The plasma taurine concentrations were not different between groups at baseline. However, eight weeks of supplementation of 3g of taurine increased its plasma concentration ($p < 0.0001$) in 22.89 times compared to the placebo group, which evidenced the effectiveness of the current supplementation protocol. Similar results were found by Galloway, Talanian, Shoveller, Heigenhauser, Spriet²⁵ that used an acute supplementation of 5g of taurine in physically active subjects and detected an increase of approximately 16 times in the plasma taurine concentration compared to the baseline condition. According to Bakker and Berg²⁶, the content of taurine in muscle cells can modulate contractile muscle activity. Therefore, the increase of plasma taurine may be beneficial for the athlete, because can promote the maintenance of muscular integrity.

Adequate energy consumption is essential to maintain the performance, body composition, and health of athletes (American College of Sports Medicine Joint Position Statement)²⁷. Herein, energy intake ranged from 3120 to 3720 Kcal/day, and we did not verify significant differences in total calories and macronutrients consumed between the groups or between the evaluated time periods. Since we did not observe significant changes in body mass, we consider that the energy intake was sufficient to deal with the energy requirements imposed by the total energy expenditure of the athletes. Furthermore, their energy intake attended the nutritional recommendations for athletes suggested by American College of Sports Nutrition²⁷, which refers to 45 kcal/kg of body weight.

Regarding the effects of taurine supplementation on athletes' performance, Balshaw, Bampouras Barry, Sparks²⁸ observed that the acute use of 1g of taurine in runners improved their time trial performances. However, their oxygen uptake and blood lactate concentrations were not influenced by this dose. The authors considered that the probability that their performance results were associated with the action of taurine was 99.3%, although it was noted that the mechanism of taurine action has not yet been elucidated.

In the current investigation, the mean speeds of the three efforts of 400 m and the anaerobic threshold were not affected

by the chronic use of 3g of taurine. However, after the eight weeks of intervention, the taurine group increased the blood lactate concentrations measured after the three efforts of 400 m as well as those measured at the third and fifth minute after the third effort of 400 m. These results suggest that taurine supplementation stimulated the use of the anaerobic lactic metabolism during the efforts of 400 m. Also, despite the increased lactate production, our results showed that the taurine supplemented athletes did not decrease the speed performed even when the lactate production was higher than the placebo group.

Also, Beyranvand, Khalafi, Roshan, Choobineh, Parsa, Piranfar²⁹ evaluated the effects of 1.5 g supplementation for two weeks in seven patients with cardiac insufficiency. The authors observed that the application of an exercise capacity test performed before and after taurine supplementation resulted in a greater ability to perform the exercise, including an increase in time and distance when compared to the control group. Their results suggest that taurine optimized the performance of the test by increasing the tolerance to the effort.

It is well established in the literature that the physiological adaptations of the athlete are highly specific to the nature of the training³⁰. In practical terms, the difference of 0.027 m/s found between the speed attained at baseline and after taurine supplementation could be crucial in athletic performance during competition. In fact, in the last Absolute Brazilian Swimming Championships - Maria Lenk Trophy-2016, the difference in mean speed between the first and second place in the 400 m competition was 0.007 m/s³¹.

Considering that all participants underwent the same training program in the current study, we can hypothesize that the statistical difference observed in the concentration of lactate and the slight alteration in average speed may be associated with taurine supplementation. However, more studies are needed to evaluate the effects of chronic supplementation of taurine on swimmer's performance to elucidate the mechanisms associated with taurine and increased lactate production as well as the viability of its consumption for enhancing the training capacity of athletes.

Conclusions

The results of this study showed that supplementation of taurine during the eight-week period in elite swimmers did not promote significant changes in rest energy expenditure and 400 m performance; however, there were observed higher levels of blood lactate after all efforts without impairing speed performance. Thus, taurine supplementation may contribute to the anaerobic lactic metabolism. As a practical application, taurine supplementation may allow the performance of training sessions that emphasize the anaerobic lactic metabolism development.

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Corresponding Author

Ellen Cristini de Freitas
School of Physical Education and Sports of Ribeirão Preto, University of Sao Paulo, EEFERP/USP. Exercise Physiology and Metabolism Laboratory.
Bandeirantes Avenue, 3900 - Monte Alegre. Ribeirão Preto , São Paulo, Brazil.
Email: ellenfreitas@usp.br

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