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The Effect of High-Doses of Taurine Ingestion on Time to Exhaustion Running Performance

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ORİGİNAL ARTICLE

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Abstract

The study aimed to investigate the effect of acutely consuming high-dose isolated 6 g of taurine 90 min before incremental treadmill-running time to exhaustion (TTE) performance on maximal oxygen uptake (VO_2max), maximal heart rate (HRmax), TTE, and ratings of perceived exertion (RPE). A total of ten well-trained, competitive male endurance (biathlon) athletes participated in this study. A double-blind, randomized crossover design was used in the study and consisted of three separate testing sessions. During the second and third sessions, 90 min before the exercise protocols, participants consumed ~500 ml of a sugar-free lemonade drink with either 6 g of taurine or nothing added (placebo). The incremental treadmill-running TTE performance started at $6km \cdot h^{-1,}$ and the participants warmed up for 6 minutes at this constant speed. After a warm-up, the treadmill's speed was increased by 0.016km/h per second, and the slope of the treadmill was increased by 0.5% for each 60 seconds. Oxygen uptake (VO_2) and HR were measured while the participant was running on the treadmill. RPE was measured immediately after each trial using the Borg Scale (6-20 points). As a result, the acute ingestion of 6 g of taurine 90 min before incremental treadmill-running TTE performance did not enhance TTE, HRmax, and RPE but did result in a non-significant slight change in VO2max (2%).

Keywords: Ergogenic Aid, Maximal Heart Rate, Maximal Oxygen Uptake, Taurine, Time to Exhaustion

Akut Yüksek Doz Taurin Takviyesinin Tükenme Zamanına Kadar Yapılan Koşu Performansına Etkisi

Öz

Bu çalışmanın amacı tükenme zamanına kadar yapılan artan şiddetli koşu performansından 90 dakika önce akut olarak tüketilen yüksek doz izole taurin takviyesinin (6 g), maksimal oksijen alımı (VO_2max), maksimal kalp atım hızı (HRmax), tükenme zamanı (TTE) ve algılanan zorluk derecesi (AZD) üzerindeki etkisini araştırmaktı. Çalışmaya 10 antrenmanlı, yarışmacı, dayanıklılık (biatlon) sporcusu katılmıştır. Çalışmada çift-kör randomize çapraz geçişli çalışma dizaynı kullanılmıştır. Katılımcılara egzersiz protokollerinden 90 dk önce ~500 ml şekersiz limonata ile karıştırılmış 6 g taurin (Hardline Nutrition; 100% pure) ya da hiçbir şey eklenmeden şekersiz limonata (plasebo) takviyesi verilmiştir. Artan şiddetli koşu protokolü $6km \cdot h^{-1}$ hızla başlamıştır ve katılımcılar bu sabit hızda 6 dakika ısındıktan sonra, koşu bandının hızı saniyede 0.016 km/h, eğimi ise dakikada %0,5 artmıştır. Katılımcıların oksijen tüketimi (VO_2) ve kalp atım hızı (HR) değerleri koşu bandı protokolleri süresince kaydedilmiştir. AZD her denemeden sonra Borg skalası (6-20 puan) ile ölçülmüştür. Bu çalışmanın sonucunda, tükenme zamanına kadar yapılan artan şiddetli koşu performansından 90 dakika önce akut olarak tüketilen 6 gr izole taurin takviyesinin HRmax, TTE ve RPE değerlerinde plasebo müdahalesine kıyasla istatiksel olarak anlamlı fark oluşturmadığı saptanmıştır. VO_2max değerinde ise istatiksel olarak anlamsız ancak %2 gelişim sağlandığı görülmüştür.

Anahtar Kelimeler: Ergojenik Yardım, Kalp Atım Hızı, Maksimum Oksijen Alımı, Taurin, Tükenme Zamanı

Introduction

Taurine, a sulfur-containing ß-amino acid, is the most plentiful free amino acid in mammalian tissues (Huxtable, 1992) and is considered a semi-essential nutrient in humans (Gaull, 1986). The intracellular concentration of taurine is relatively high in many organs, such as the brain, myocardium, liver, kidney, and skeletal muscle (Jacobsen and Smith, 1968). The distribution of taurine in skeletal muscle shows that there is more taurine in oxidative skeletal tissue (~15-20 μmol/g) than in glycolytic muscle tissue (~1-3 μmol/g). Taurine's preferential distribution in oxidative tissue suggests that it may be essential for mitochondrial activity (Hansen et al., 2006) and aerobic performance (Ward et al., 1999). Due to taurine's widespread distribution, it has been postulated that it is involved in various metabolic processes, including those supporting endurance exercise performance. Even though some possible mechanisms exist, the precise mechanism underpinning how oral taurine supplementation may affect human endurance performance remains speculative. The possible mechanisms suggested in the studies are increased Ca^{2+} release into interstitial muscle space (Dutka et al., 2014), antioxidant defence to stress responses (Hansen et al., 2006), and enhanced lipolysis, thereby reducing glycolytic contributions (Carvalho et al., 2020; Rutherford et al., 2010). It is considered that one of these mechanisms, or a combination of them, can improve endurance performance.

Taurine is currently claimed as practical nutritional support and is one of the main contents in energy drinks. Many commercialized "energy" drinks, with many manufacturers claiming it has plenty of ergogenic effects with relatively low doses (~1–2 g) of taurine per serving (Rutherford et al., 2010; Wójcik et al., 2010). However, scientific evidence to support these claims is lacking. Furthermore, many previous studies have administered exogenous taurine before exercise as part of a commercially available energy drink containing other active ingredients such as caffeine, carbohydrate, and glucuronolactone. Combining various performance-enhancing stimulants and substances makes it difficult to identify specific responses to isolated taurine. Considering the fact that taurine supplementation is one of the main ingredients in energy drinks and the mentioned ergogenic effects, the lack of studies examining the ergogenic effects of isolated taurine supplementation is quite surprising (Waldron et al., 2018). Therefore, there is still no consensus regarding the effects of isolated taurine supplementation on performance. At the same time, questions such as dosage for use, acute or regular use, and whether it should be found in plasma or muscle tissue for enhancing performance still await answers.

A recent meta-analysis study based on the findings of a very limited number of studies reported that a single dose of taurine was as effective as regular use on endurance performance. According to this result, they reported that athletes might see the potential ergogenic benefits of taurine without using it regularly or approaching the tolerable limit per day (10 g/day) (Waldron et

al., 2018). However, only a few studies examined the effect of isolated taurine on endurance performance in athletes and used relatively low doses (similar to energy drinks -1/1.66 g). The results of these studies show that pre-exercise taurine consumption does not improve or produce slight changes in aerobic performance markers in athletes (Balshaw et al., 2013; Kammerer et al., 2014; Rutherford et al., 2010; Ward et al., 2016; Warnock et al., 2017). To our knowledge, only one study has investigated the effect of a single-dose relatively higher amount of isolated taurine on aerobic performance markers (accumulated oxygen consumption and EPOC) (Milioni et al., 2016).

In this context, the main aim of the current study was to investigate the effect of acutely consuming high-doses isolated 6 g of taurine 90 min before incremental treadmill-running TTE performance on the maximum rate of oxygen consumption (VO_2max), maximum heart rate (HRmax), ratings of perceived exertion (RPE), and TTE. It was hypothesized that 6 g of taurine ingestion 90 min before the test protocol would enhance VO_2max, HRmax, TTE, and RPE values compared to placebo during the incremental treadmill-running TTE performance.

Materials and Methods

Participants

A total of ten well-trained, competitive male endurance (biathlon) athletes (age:21,2±1,3 years; height:179,7±1,6 cm; body weight:68,8±2,5 kg; BMI: 21,4±,56) participated in this study. One participant dropped out for personal reasons; nine completed all performance tests and were included in the analysis. G* Power software version 3.1. (Heinrich Hein University, Düsseldorf, Germany) was used to calculate an a priori sample size of 9, which was sufficient to identify differences between conditions with a statistical power of .80. The inclusion criterion is based on their participation in national competitions for at least three years. The use of any supplement was determined as an exclusion criterion from the study for eliminating the combined effect of supplements.

Experimental Protocol

A repeated measure, randomized, double-blind, crossover design was used in this study. Participants had three separate visits to the laboratory, the first being familiarizing themselves with the protocol. The first trial was followed by two experimental trials in which participants received 6 g of taurine or a placebo 90 minutes before the exercise protocol. Each test was administered at an interval of 5 days. The interval of five days was chosen to limit the effects of fatigue and possible changes in training status. Each laboratory session was performed at the same time of the day to minimize the possible consequences of the circadian variation (Souissi et al., 2010). Tests were performed at 20–22 °C laboratory temperatures with 38–40% humidity. VO_2 and HR were measured throughout each incremental treadmill-running TTE performance, which was performed 90 minutes

after the oral ingestion of the supplements. Respiratory gas responses were measured with the breath-by-breath automatic portable gas analysis system (Cosmed K5, Italy) while running on the treadmill (H/p/cosmos Saturn, Germany). HR was measured with a telemetric (Garmin, USA) system integrated with the Cosmed K5 system, which can measure at one-second intervals. RPE was measured immediately after each trial using the Borg Scale (6-20 points). Before each trial, participants were instructed to abstain from food for the previous 3 h and follow their usual dietary strategy. The test procedure is presented in Figure 1.

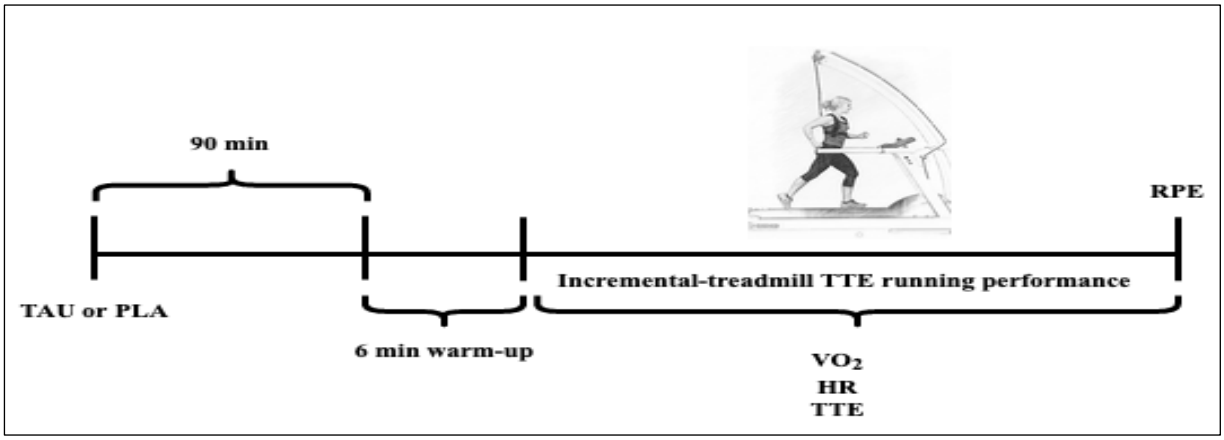


Figure 1. Test Protocol

Incremental Treadmill-Running Time to Exhaustion Test Protocol and Measurement of the Maximal Oxygen Uptake

The incremental treadmill-running TTE performance started at 6km·h$^{-1,}$ and the participant warmed-up for 6 minutes at this constant speed. After 6 minutes of warm-up, the treadmill's speed was increased by 0.016km/h per second, and the slope of the treadmill was increased by 0.5% for each 60 seconds. VO_2max was measured with the breath-by-breath automatic portable gas analysis system (Cosmed K5, Italy) while the participants ran on the treadmill (H/p/cosmos Saturn, Germany). The portable metabolic gas analyzer was calibrated before each test using a sample of known gases (5.0% CO_2 and 16.0% O_2). Suppose at least three of the following criteria were observed and accepted as an indication of reaching the VO_2max capacity. The test was terminated: (*i)*despite the increase in workload, VO_2 stabilization in the last two stages (≤150 mL·kg^{-1}·min^{-1}); *(ii)* respiratory quotient ≥1.15; HRmax>85% of predicted HRmax; *(iii)* no increase in HR despite the increasing workload; *(iv)*marking RPE 17 and above in Borg's scale (6-20). VO_2max is the highest average VO_2 value achieved during the last 30 seconds of each trial.

Placebo and Taurine Supplementation

Supplements were in powder form, dosed at analytical balance (Radwag 220 R.2 plus), and consumed by participants with ~500 ml of lemonade without sugar (Uludağ, Bursa). Lemonade, a low-calorie drink (4 kcal - 0.0 g protein -0.7 g carbohydrates / 0.0 g fat / 100 ml), was used to mask the potential flavor that taurine might have provided, and the containers were opaque so as not to allow the participants to identify the content. The drinks consist of either 6 g of taurine (Hardline Nutrition; 100% pure) or nothing added (placebo). Carbohydrate based drink was chosen as a placebo supplement because an acute intake of 30-60 grams is required for carbohydrates to affect performance (Baker et al., 2015). All trials started 90 min after ingestion. This pre-ingestion period was used to elicit peak plasma taurine concentrations at study initiation (~1-2.5h) (Galloway et al., 2008; Ghandforoush-Sattari et al., 2010).

Statistical Analysis

IBM SPSS Statistic 25.0 package program was used for statistical analysis. Initially, all variables were tested for normal distribution using the Kolmogorov-Smirnov test, and it was determined that the data showed normal distribution. The paired samples t-test was used for comparison between taurine and placebo trials. A statistical significance level was accepted as $p<0.05$. The formula "[(post – pre) / pre x 100]" was used in the percentage change calculations.

Ethics

The current research has been conducted within the "Directive on the Ethics of Scientific Research and Publication in Higher Education" framework. Ethical approval was obtained from the Gazi University Ethics Committee for the current study, numbered 2022-893, which was conducted in accordance with the 1964 Helsinki declaration. The study details were explained to the participants face to face, and if they agreed to participate, they were asked to sign the informed consent form prepared by the researchers.

Findings

Table 1 presents the descriptive statistics and analyses of the physiological variables measured in endurance athletes during both incremental treadmill-running TTE performances. There were no statistically significant differences in VO_2max ($p=.449$), HRmax ($p=.505$), and RPE ($p=.641$) between acute placebo and taurine supplementation trials (Table 1). However, VO_2max values were slightly better in the taurine condition compared to the placebo (%2).

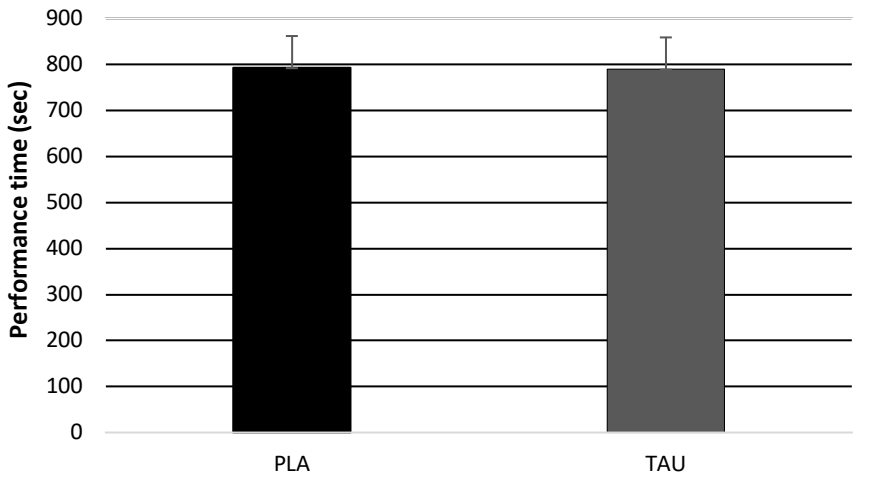
Similarly, there was no difference in the TTE performance between placebo (13,13±1,9 min) and taurine (13,10±1,9 min) trials (t=-0,622, p=,551) (Figure 2). However, there was no clear pattern in TTE, 5 participants performed longer duration during the placebo trial, and 4 participants performed longer duration during the taurine trial. However, one of them was slightly better than the placebo trial.

Table 1

Comparison of Physiological Responses between PLA and TAU Trials

Variables	PLA	TAU	%	t	p
	Mean ± SD	Mean ± SD			
VO_2 (ml/min)	3681.66 ± 526.0	3764.53 ± 562.12	2.25	-0.886	0.402
VCO_2 (ml/min)	4132.59 ± 695.53	4165.61 ± 680.21	0.80	-0.274	0.791
VO_2max (ml/min/kg)	53.46 ± 4.70	54.57 ± 4.26	2.08	-0.795	0.449
RQ	1.12 ± 0.06	1.11 ± 0.10	-1.19	0.47	0.651
Speed (km/h)	10.10 ± 1.94	10.55 ± 1.75	4.45	-1.058	0.321
HRmax (bpm)	194.33 ± 7.23	195.33 ± 6.02	0.51	-0.697	0.505
RPE	15.44 ± 1.42	15.11 ± 1.76	-	0.485	0.641

PLA: Placebo; TAU: Taurine; VO_2 = Oxygen consumption; VCO_2 =Carbon dioxide production; RQ= Respiratory Quotient (VCO_2/VO_2); HRmax= Maximal heart rate (bpm), RPE: Ratings of perceived exertion



Values are Mean ± Standard deviation; PLA: Placebo; TAU: Taurine;

Figure 2. Effect of taurine and placebo ingestion on total treadmill-running time to exhaustion running performance.

Discussion

This study provides novel data for the literature regarding the effect of acute single-dose isolated taurine ingestion on human aerobic exercise performance. The main aim of the study was to investigate the effect of acutely consuming isolated 6 g of taurine 90 min before an incremental

treadmill-running TTE performance on VO_2max, TTE, HRmax, and RPE. In partial support of our hypothesis, we found that isolated taurine, supplementation may improve performance during the time to-exhaustion running performance compared to placebo by increasing VO_2max (Table 1).

The isolated ingestion of 6 g of taurine did not provide a statistically significant difference in the subjects' VO_2max, but it did increase it by 2% compared to the placebo condition. In agreement with this study, previous studies using a single dose of isolated taurine (1-1.66-6 g of taurine) also found a non-significant slight change in VO_2max in different forms of exercise (Kammerer et al., 2014; Milioni et al., 2016; Ward et al., 2016).

Time to exhaustion did not improve using taurine supplementation compared to placebo in well-trained biathlon athletes. In line with this study, Kammerer et al., in their research, used a relatively low dose (1 g) of taurine and did not report improvement in TTE in healthy male soldiers (Kammerer et al., 2014). Similar to this current study, Milioni et al. found that 6 g of taurine ingestion 90 min before high-intensity running performance did not provide a statistically significant difference. However, time-to-exhaustion was improved by 2.9% in recreationally trained males (Milioni et al., 2016).

It is known that the ingestion of isolated taurine does not increase HR or blood pressure but may have inotropic effects on cardiac musculature (Bichler et al., 2006; Doerner et al., 2015), particularly when Ca^{2+} concentration is reduced, as observed during exhaustive exercise (Huxtable, 1992). If taurine supplementation increases myocardial contractility and diastolic filling time per cardiac cycle, lower HR might be expected during incremental treadmill-running TTE performance. In the present study, the isolated taurine ingestion did not affect HRmax during the incremental treadmill-running TTE performance. In support of our findings, Rutherford et al., Ward et al., Warnock et al., and Kammerer et al. in their study reported that the use of a single dose of acute taurine did not change HR values compared to placebo condition (Kammerer et al., 2014; Rutherford et al., 2010; Ward et al., 2016; Warnock et al., 2017). RPE value also did not show a statistically significant difference between trials.

The possible reason for the lack of difference in VO_2max, TTE, and HRmax might be related to the bioavailability of taurine in skeletal muscle tissue. Galloway et al. stated that acute taurine ingestion only increases plasma content, not muscle content, and even the use of acute taurine at high doses do not ensure the bioavailability of taurine in muscle cells. Also, Matsuzaki et al. found that after exercise, regardless of duration, taurine concentration was decreased in all skeletal muscles but remained unchanged in the plasma (Matsuzaki et al., 2002). If acute taurine supplementation provides an increase in plasma taurine and does not change after exercise, it may not be an effective strategy

for enhancing performance as well as Galloway et al. in their study showed that seven days of regular use of taurine did not change skeletal muscle taurine content (Galloway et al., 2008). However, Balshaw et al. in their study verified improvements in 3km time trial performance in well-trained athletes after 1 g of acute taurine ingestion, and some other studies show regular use of taurine (6 g/day for 7 days) provides substantial improvement in VO_2max, exercise time, distance covered, time to exhaustion but the population they worked with was the elderly heart failure patients (Ahmadian et al., 2017; Beyranvand et al., 2011) or healthy sedentary people (Zhang et al., 2004).

Conclusion and Recommendations

In this study, the deficiencies observed in previous studies were tried to be eliminated, such as using relatively low doses of taurine supplementation and improper timing for the pre-exercise consumption period to elicit peak plasma. The lack of muscle tissue analysis to examine intracellular taurine levels after a single dose of high taurine supplementation and the insufficient number of well-trained participants are a limitation of the study. In conclusion, the acute ingestion of 6 g of taurine 90 min before incremental treadmill-running TTE performance did not enhance TTE, HRmax, and RPE but did result in a non-significant slight change in VO2max (2%). Furthermore, the lack of difference in VO_2max, HRmax, TTE, and RPE supports previous research. Future studies should consider the analysis of muscle tissue after acute single-dose isolated taurine supplementation.

Ethical Approval

Ethics Review Board: Gazi University, Commission of Ethics

Date of Ethics Assessment Document: 21.06.2022

Issue Number of the Ethics Evaluation Document: / 2022-893

Author's Contribution:

The processes related to the introduction and method part of the research were carried out by the first and second authors, and the authors carried out the processes related to the findings, discussion, and conclusion part with equal contribution.

Conflict of Interest

The authors declare no conflict of interest.

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