Effects of Taurine Supplementation on Vascular Endothelial Function at Rest and After Resistance Exercise

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Abstract High-intensity resistance exercise has been shown to increase arterial stiffness and reduce vascular endothelial function. Taurine supplementation has a favorable effect on maintaining vascular function. We had previously reported that taurine supplementation attenuated increases in resistance exercise–induced arterial stiffness. In the present study, we further investigate the effects of taurine supplementation on vascular endothelial function at rest and after resistance exercise.

Twenty-nine healthy men were recruited and randomly assigned to either the placebo supplement group (n = 14) or the taurine supplement group (n = 15) in a double-blinded manner. Subjects were required to ingest 6 g of either a placebo or the taurine supplement for 2 weeks prior to and 3 days following the exercise. Two weeks after the commencement of supplementation, the subjects were asked to perform 2 sets of 20 repetitive unilateral maximal-effort resistance exercise of the elbow flexors on a Biodex isokinetic dynamometer, with each contraction lasting 3 s, with 1 repetition performed every 9 s and 4 min rest in between sets. We evaluated the changes in brachial artery flow-mediated dilation (FMD) in the non-exercised arm as an index of vascular endothelial function. Relative and absolute FMDs were measured prior to supplementation, before exercise, and 24, 48, and 96 h after exercise.

Two weeks of taurine supplementation significantly increased both relative and absolute FMDs. Baseline diameter significantly increased at 96 h following the exercise in both groups. However, there was no change in the peak diameter. Consequently, both relative and absolute FMDs were significantly reduced at 96 h after the exercise in both groups. Taurine supplementation does not affect resistance exercise–induced reduction in FMD.

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Two weeks of taurine supplementation (6 g/day) significantly increased vascular endothelial function at rest; however, taurine supplementation did not improve resistance exercise–induced reduction in FMD.

Keywords FMD · Resistance exercise · Vascular endothelial function

1 Introduction

Central large arteries play a buffering role in lowering the blood flow and pressure; that is, increasing arterial stiffness can reduce the buffering action and lead to increasing blood pressure. Increased arterial stiffness has been identified as an independent risk factor for future cardiovascular disease (Najjar et al. 2005).

Increased arterial stiffness may be associated with reduced vascular endothelial function. Dysfunction of the vascular endothelium is one of the earliest events in cardiovascular disease (Ross 1993). Regular aerobic exercise has been known to reduce arterial stiffness (Tanaka et al. 2000) and promote improvement in vascular endothelial function (Pugh et al. 2014; Birk et al. 2012). In contrast, although resistance exercise training also has been shown to reduce arterial stiffness, it has been reported in previous studies that acute high-intensity resistance exercise could reduce vascular endothelial function assessed by brachial artery flow-mediated dilation (FMD) response (Choi et al. 2016; Stacy et al. 2013).

Nutritional strategies might minimize these detrimental effects of resistance exercise. Taurine (2-aminoethanesulfonic acid) is the most abundant semi-essential amino acid. Taurine can be synthesized in several mammalian tissues, including the skeletal muscle, but it is mainly acquired from diet, such as meat and seafood. Previous studies have shown a protective effect of taurine against endothelial dysfunction. Taurine treatment reverses diabetes-induced vascular endothelial dysfunction in rodents (Wang et al. 2008; Ikubo et al. 2011) and humans (Moloney et al. 2010). Further, we had previously reported that taurine supplementation attenuates resistance exercise–induced arterial stiffness by reducing circulating oxidative markers (Ra et al. 2016). In addition, taurine supplementation could attenuate muscle damage symptoms following high-intensity resistance exercise (Ra et al. 2015; da Silva et al. 2014; Silva et al. 2011; Zhang et al. 2004).

From previous evidence, we hypothesized that taurine supplementation may limit resistance exercise–induced reduction in vascular endothelial function. In the present study, we investigated the possible effects of taurine on vascular endothelial function at rest and after performing resistance exercise.

2 Methods

2.1 Participants and Supplement Protocol

The present study was a double-blind, randomized, placebo-controlled trial that was conducted in accordance with the principles of the Declaration of Helsinki. A total of 29 healthy young men (age, 20–33 years: BMI, 21.7 ± 0.3 m/kg^2) participated in the present study. None of the participants had any regular physical activity for at least 1 year prior to commencing the study. All the participants were normotensive and non-obese, and none of them was on any medication nor were they smokers. None of the participants was taking taurine or any other nutritional supplement prior to enrollment. The present study was approved by the Ethical Committee of the University of Tsukuba. Written informed consent was obtained from all the subjects prior to their participation in the study.

Participants in the taurine group were given 2 g of taurine powder and those in the placebo group acted as the controls and were given the same amount of lactose powder The participants had to orally ingest each supplement after every meal (thrice a day) for a total of 18 days (14 days supplementation prior to exercise day and 4 days following the initiation of exercise).

2.2 Experimental Procedures

All the participants assembled at the laboratory in the morning after fasting overnight. They had been asked to refrain from caffeine and alcohol consumption for at least 12 h, and intense exercise for at least 48 h prior to entering the study. The participants were made to rest in the supine position for 20 min in a quiet place. Brachial vascular endothelial function was assessed for each of the participants while they were in the supine position. During the study, we measured brachial vascular endothelial function on five different days: prior to starting supplementation (Pre), immediately before exercising (BEx, day 15), and 24, 48, and 96 h after exercise (day 16, 17, and 19).

2.3 Resistance Exercise

Following the 2 weeks of supplementation (on day 15), participants performed 40 maximal eccentric unilateral contractions of the elbow flexor, as previously reported (Ra et al. 2015, 2016). This resistance exercise was performed with the non-dominant arm. Each contraction was held for 3 s and repeated every 9 s, and consisted of maximal contraction through a range of motion from 90 to 180° of elbow flexion.

2.4 Assessment of Vascular Endothelial Function

Vascular endothelial function was assessed by endothelium-dependent FMD. Brachial artery FMD was assessed in the non-exercised arm using a novel stereotactic probe-holding device equipped with an edge-tracking system for 2D imaging and pulsed Doppler flow velocimeter for automatic measurement (UNEXEF; Unex Co. Ltd., Nagoya, Japan) as previously described (Choi et al. 2016). In the present study, both relative and absolute FMDs were calculated as percentage and absolute changes in the arterial diameter divided by the baseline diameter at maximal dilation after the cuff deflation (after 5 min inflation). Namely, relative FMD (%) = ([peak diameter – baseline mean diameter]/baseline mean diameter) × 100; absolute FMD (mm) = peak diameter – baseline mean diameter.

2.5 Statistical Analysis

Values are expressed as mean ± SE. Changes in measurements were analyzed for effects of time and supplement in a two-way ANOVA, and post hoc analysis was performed using the Bonferroni method. All statistical analysis was performed using GraphPad Prism 6 (GraphPad Software, San Diego, CA) with statistical significance set at $p < 0.05$.

3 Results

3.1 Effects of the 2-Week Taurine Supplementation on Vascular Endothelial Function at Rest

Prior to starting supplementation (Pre), there were no statistically significant differences between the placebo and the taurine group in both relative and absolute FMDs. Both relative and absolute FMD significantly increased following the 2-week taurine supplementation (Fig. 1).

3.2 Effects of Taurine Supplementation on Vascular Endothelial Function After Performing Resistance Exercise

There were no significant interactions in any variables illustrated in Fig. 2. Although mean peak arterial diameters in both groups were not changed, mean baseline diameters in both groups significantly increased on 96 h after exercise compared with

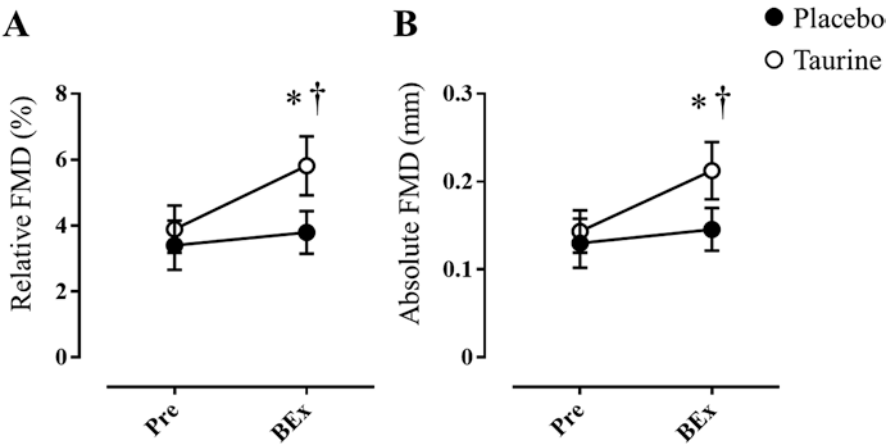

Fig. 1 Changes in (**a**) relative and (**b**) absolute FMDs by 2 weeks placebo or taurine supplementation. Two-way ANOVA revealed significant interaction (time∗supplement) in both relative and absolute FMD change. ∗$p < 0.05$ shows the significant difference between two times point in taurine group. †$p < 0.05$ shows the significant between-group difference on BEx (day 15)

BEx (Fig. 2a). In addition, both relative and absolute FMD values gradually decreased and significant differences were found on 96 h compared with BEx, respectively (Fig. 2c, d).

4 Discussion

It has been reported that taurine supplementation significantly improves both endothelium-dependent and -independent vascular function in pre-hypertensive (Sun et al. 2016) and type I diabetes patients (Moloney et al. 2010). In the present study, we confirmed that 2 weeks taurine supplementation (6 g/day) significantly increased brachial artery FMD value in healthy young men; it was found to be mainly dependent on increasing peak arterial diameter. Taurine supplementation may contribute to nitric oxide (NO) production and/or NO bioavailability due to increasing share stress. However, this relationship is not clear as there was no analysis performed of either NO concentration in the blood stream or its availability. Altogether, taurine supplementation can be a good nutritional strategy for maintaining vascular endothelial health even in healthy young populations.

We have already reported that the exercise-induced decrease in vascular endothelial function is associated with increasing central arterial stiffness (Choi et al. 2016). In addition, we previously confirmed that taurine supplementation in young men could attenuate exercise-induced arterial stiffening (Ra et al. 2016). However, in the present study, we did not observe the protective effect of taurine supplementation on reduction in exercise-induced vascular endothelial function. In the present study, reductions in both relative and absolute FMDs were mostly dependent on gradually

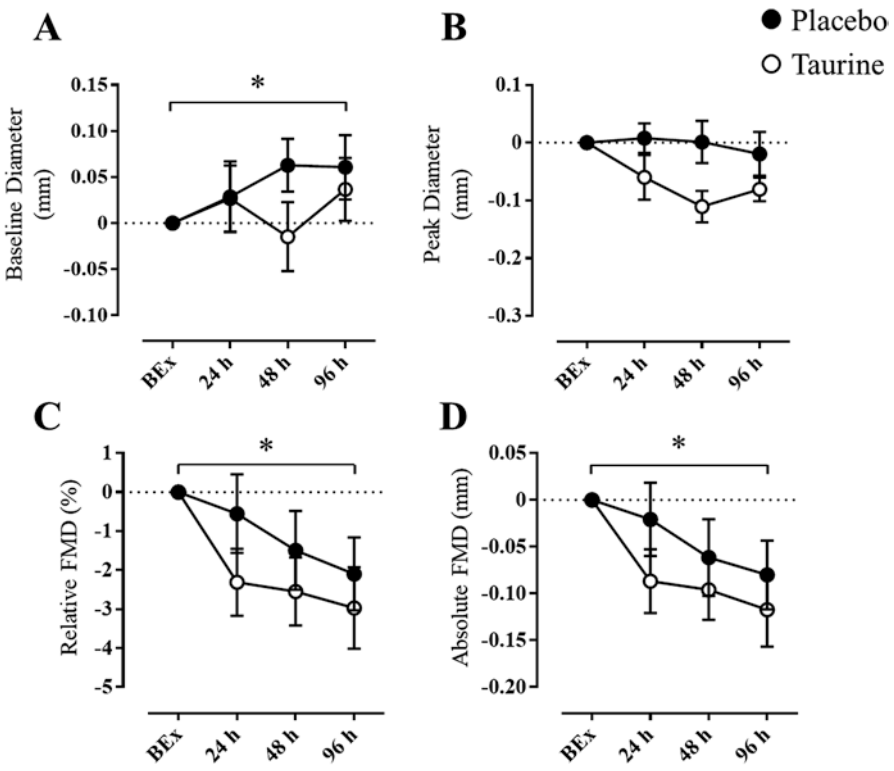

Fig. 2 Changes in (**a**) baseline diameter, (**b**) peak diameter, (**c**) relative FMD, and (**d**) absolute FMD after resistance exercise expressed as changes from BEx. There were no significant interactions in any variables. Significant time effects were found in (**a–d**) $*p < 0.05$ shows significant difference at 96 h compared with BEx ($p < 0.05$) in both group

increasing baseline arterial diameter (Fig. 2a). Skeletal muscle tissue damage due to high-intensity eccentric exercise has been shown to increase oxygen saturation (Ahmadi et al. 2008) and blood volume (Kano et al. 2005) in the muscle. We would like to focus attention on the effects of taurine supplementation on vascular endothelial function between resting state and after high-intensity resistance exercise.

The reduction in endothelial-dependent FMD value which we observed might indicate disruption of endothelial cells or the vascular smooth muscle cells, and it might lead to decreasing blood flow to the damaged muscle during vascular dilation. Severe eccentric types of resistance exercise can impair local microvascular function (Kano et al. 2005) and vasodilator response of the skeletal muscle (Heap et al. 2006). A reduction in vascular endothelial function after eccentric exercise associated with reduced share stress to endothelial cells (Stacy et al. 2013), increased central arterial stiffness (Choi et al. 2016), and skeletal muscle tissue damage (Barnes et al. 2010; Stacy et al. 2013). Taurine supplementation failed to prevent exercise-induced muscle damage symptoms (Ra et al. 2015, 2016). Collectively, the present results suggest that taurine supplementation improves vascular endothelial

function at rest but not after performing resistance exercise. Future research examining the precise mechanisms associated with taurine supplementation and the vascular endothelial health is warranted to elucidate our findings.

5 Conclusion

In summary, 2 weeks taurine supplementation (6 g/day) significantly increased vascular endothelial function at rest; however, taurine supplementation did not improve resistance exercise–induced reduction in endothelium-dependent FMD.

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