



The Combined Effect of Taurine and Omega-3 Supplementation on Delayed Onset Muscle Soreness in High-Intensity Eccentric Exercise

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Abstract

Background: Eccentric exercise makes more tensions in active muscle fibers, resulting in muscle damage and delayed pain. Therefore, Delayed-Onset Muscle Soreness (DOMS) is a common result of severe eccentric contractions. This study aimed to clarify the combined effect of taurine and omega-3 supplementation on DOMS and muscle damage after high-intensity eccentric exercise in young untrained men.

Methods: Forty-eight young untrained males were assigned to four groups (taurine+omega-3 [combined], taurine, omega-3, and one placebo group) and given 1,500 mg taurine and 1,500 mg omega-3 or 1,500 mg taurine or 1,500 mg omega-3 or placebo twice a day respectively. Each group received its supplements for twenty-eight days. DOMS and muscle damage in the lower body developed using a leg press with a weight equivalent to 70% of 1RM (One-Repetition Maximum). Lactate dehydrogenase (LDH), Creatine kinase (CK) and perceived muscle soreness measures were repeated before, immediately, 24, 48, and 72 hr after eccentric activity. $p < 0.05$ was considered to be statistically significant.

Results: In the combined group, there was no increase in CK and LDH in immediate time and 72 hr after the exercise, respectively, compared to the period before the workout. At 24 and 48 hr after the training, there was a significant decrease in muscle pain perception in all groups compared to placebo ($p < 0.05$).

Conclusion: A combination of 1500 mg taurine and 1500 mg omega-3, two times a day, for four weeks can reduce the levels of CK and LDH enzymes as some indicators of muscle damage. It also attenuates exercise-induced DOMS and muscle damage.

Keywords: Dietary supplementations, Fatty acids, Omega-3, Taurine, Muscle soreness

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Introduction

Eccentric exercise causes more tension in active muscle fibers than concentric or isometric (constant length) contractions, which leads to muscle damage and delayed pain. Consequentially, Delayed-Onset Muscle Soreness (DOMS) and muscle weakness are typically the outcomes of intense eccentric contractions.

Mechanical stresses exerted by active muscles in eccentric contractions cause sarcoma-induced muscle damage and sarcomere structure (1). In addition, mechanical forces have the potential to disrupt skeletal muscle fibers. This type of damage induces pro-inflammatory responses and post-exercise recoveries, which ultimately results in Delayed-Onset Muscle Soreness (DOMS) (2,3).

DOMS is recognized as a common muscle discomfort occurring after unfamiliar exercises, especially when a person is repeatedly exposed to high eccentric muscle contractions or unaccustomed exercise. It increases within the first 24 *hr* post-exercise and rises to peak between 24 to 48 *hr*. The main DOMS symptoms are stiff, aching, and painful muscles, reduced muscle power, and biochemical symptoms such as increased CK and LDH.

The level of muscle pain experienced following training depends on the intensity, duration, repetition, and type of physical activity (4-6). This injury affects not only one's athletic performance but also one's daily activities (7).

Numerous strategies have been proposed to help alleviate the negative consequences of DOMS, including stretching, massage, cryotherapy, ultrasound, homeopathy, and Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) such as aspirin, ibuprofen, and acetaminophen (8,9), as well as nutritional and supplementation strategies such as vitamin C, E, L-carnitine, *etc.* (10). Dietary and supplementation strategies have been examined for their ability to alleviate symptoms of DOMS.

Numerous studies have focused on the use of such therapeutic compounds to prevent or ameliorate DOMS and exercise- and physical activity-related injuries (7,9).

Taurine (2-aminoethanesulfonic acid), which is abundant in skeletal muscle, has been reported to have many physiological and pharmacological

actions, including membrane stabilization, anti-oxidation, osmoregulation, modulation of ion flux, and control of Ca²⁺ homeostasis, and several metabolic effects related to improved glucose tolerance, insulin sensitivity, and substrate uptake, storage, and oxidation in addition to playing roles as a neurotransmitter and neuromodulator (11,12). Lociano *et al* reported that taurine supplementation (50 mg/kg/day) in healthy men after a period of eccentric activity could significantly reduce CK and LDH compared to the placebo (13). Conversely, Galan *et al* in 2018 found no effect of prolonged taurine use (3 g/day for eight weeks) on serum levels of CK and LDH (14).

Fish oils are an excellent source of omega-3 Polyunsaturated Fatty Acids (n3 PUFAs). Omega-3 polyunsaturated fatty acids (n3 PUFA) are thought to have powerful anti-inflammatory effects due to their ability to inhibit the synthesis and release pro-inflammatory Arachidonic Acid (AA) and Prostaglandins (PGs) (15).

It has been suggested that omega-3 PUFA may prove a viable strategy to attenuate muscle inflammation and improve functional recovery following high-intensity exercise (16). One of the connections between omega-3 PUFA and muscle inflammation is via down-regulation of pro-inflammatory cytokines, such as TNF- α and IL-6, reduced production of AA and Reactive Oxygen Species (ROS), consequently resulting in a decrease in the inflammatory response (17). Therefore, it is believed that consuming omega-3 fatty acids will result in an anti-inflammatory reaction to exercise, decreasing DOMS (18,19).

Several studies reported the positive effect of omega-3 fatty acids on DOMS. Tartibian *et al* demonstrated that 1.8 g of omega-3 fatty acid ingestion by healthy males (n=45) reduced pro-inflammatory factors following eccentric exercise (20). Lembke *et al* reported that 2.7 g of omega-3 fatty acids ingestion for 30 days could reduce DOMS and C-Reactive Protein (CRP) following eccentric contractions compared to sunflower oil ingestion (21). Similar studies demonstrated that omega-3 fatty acid consumption reduced the symptoms of DOMS. There was a decrease in DOMS after eccentric exercise in a group of 27 males who consumed 1.8 g of omega-3 fatty acids (19). In addition, DOMS after eccentric

exercise was significantly reduced in three males and eight females who consumed 3 g of omega-3 fatty acid for seven days (18).

However, a 2013 study by Gray *et al* indicated that supplementation with three grams of fish oil daily for six weeks showed no significant difference in serum CK levels and muscle damage caused by a period of eccentric activity compared to placebo (22). One way to enhance the health benefits of nutrients is to supplement them at the same time, which can effectively mitigate the damage exercise causes.

In Ra *et al*'s study, simultaneous intake of omega-3 with taurine significantly decreased serum levels of CK and LDH compared to placebo group and groups receiving these nutrients alone (23). Also, the Philpott *et al* study in 2017 demonstrated that adding fish oil to a sports drink containing whey protein, leucine, and carbohydrate significantly reduced serum CK levels in the intervention group compared to other groups and placebo (24).

According to the above, regarding the presence of contradictory results, and the lack of research on the simultaneous effects of omega-3 and taurine

supplements in the prevention of DOMS, it is likely that this combination of supplements can reduce the severity of inflammatory responses by enhancing each other's efficacy. Consequently, it significantly reduces muscle damage and enhances performance. The findings of this research may be used to reduce muscular damage induced by exercise in those who are just beginning to exercise.

Materials and Methods

Subjects

This semi-experimental clinical trial was approved by the ethics committee of the Sport Science Research Institute (SSRI; IR.SSRC.REC.1399.022). This study was registered in Iranian Registry of clinical trial (IRCT number: IRCT20200327046871N1). Among the volunteers referred to the Iranian Football Rehabilitation and Medical Evaluation Center (IFMARK), 48 untrained young men were selected as subjects based on inclusion criteria (Figure 1). Inclusion criteria were normal weight ($24.9 > \text{BMI} > 18.5$) and following a general Iranian dietary pattern. Moreover, exclusion criteria included

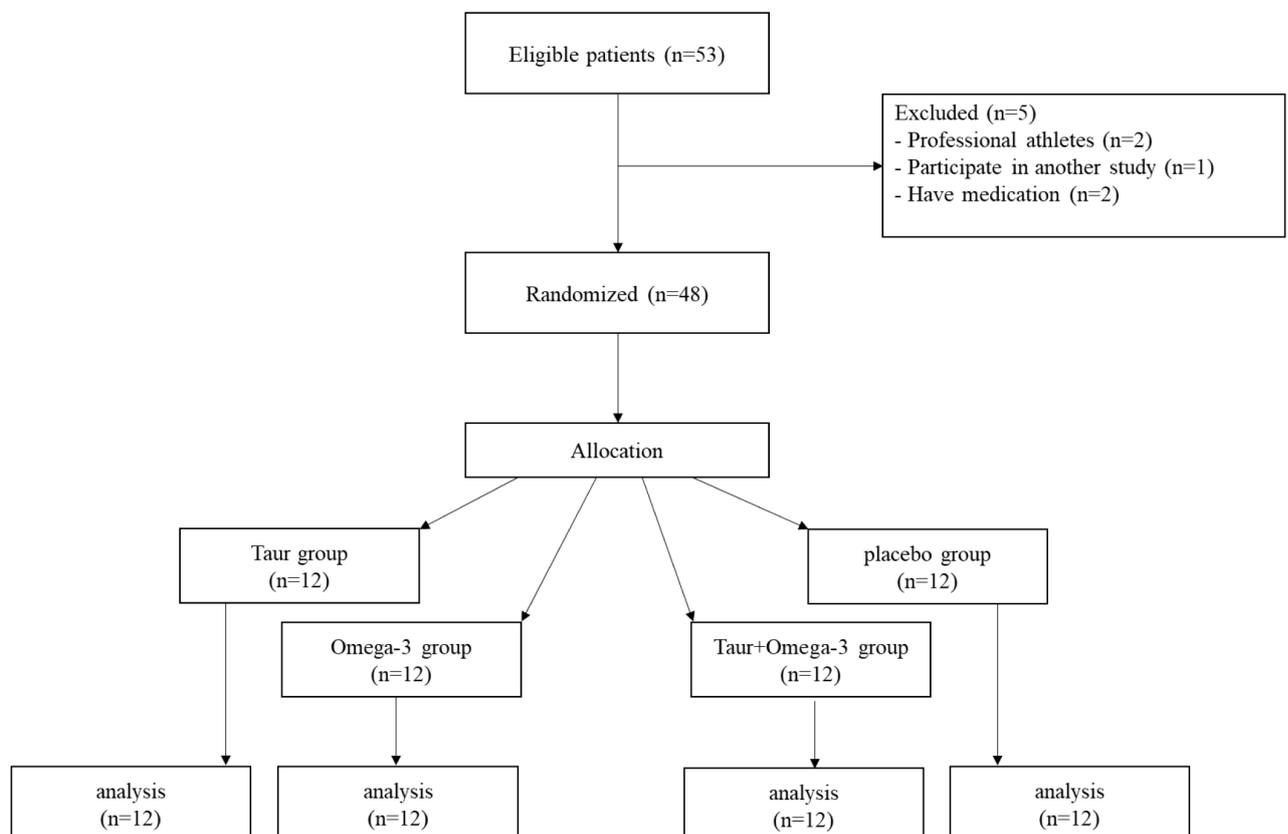


Figure 1. Consort flow-diagram of the study.

a history of sports activities, taking nutritional supplements, medication, and painkillers, following a specific diet. If each of the mentioned criteria was not met during the intervention period, the subjects were excluded from the study. After informing the subjects about the benefits and possible risks of the study, they received an informed consent form to participate in the study. In the informed consent form, details and possible risks of exercise were described in detail. Subjects were assured that personal information was confidential and they were allowed to be excluded at each stage of the study and they were also informed about the study aims, procedures, and risks before signing an informed consent form.

Anthropometric measurements

The weight was measured using the Seca 881 digital weighing scale to the nearest 0.1 kg without shoes while wearing minimal clothes. Height was measured to the nearest 1 mm without shoes, with shoulders in a normal position. The fat percentage of the subjects was measured by the Bioelectrical Impedance Analysis (BIA) and by in Body 270.

One-repetition maximum (1RM)

In the training session, the knee joint bending motion record was recorded, and a maximum repetition (1RM) was obtained through the following formula (25):

$W = \text{Weight Lifted (Kg)}$

$R = \text{Repetitions Complete}$

Supplementation

The 48 participants who met the criteria were randomly assigned to four groups. Each group received their respective supplements for a total of twenty-eight days. Thus, the Taurine+Omega-3 group (Taur+ ω 3) got [1,500 mg taurine+1,500 mg Omega-3 (EPA=1000 mg, DHA=500 mg)] twice daily, the Taurine group (Taur) received [1,500 mg taurine] twice a day, the Omega-3 group (ω -3) received 1,500 mg omega-3 [EPA = 1000 mg, DHA = 500 mg] twice a day, and the placebo group (PLA) received 1,500 mg of maltodextrin twice a day. Eight hours before beginning the eccentric activity, the final supplement dosage was taken. The supplements were supplied by the Karen Iran Pharmaceutical Company.

Muscle damaging protocol

Similar to LaRoche D statement (26), DOMS and muscle damage in the lower body developed using a leg press with a weight equivalent to 70% of 1RM. After participants were instructed on the technique, they conducted a warm-up consisting of two sets of eight repetitions at maximum intensity. Then performed three sets of fifteen with 70% 1RM eccentric knee extension. Positive movement was implemented by an examiner, where the leg raised to a to a zero-degree knee angle and the negative movement (eccentric contraction) was performed by the subjects. There was a three-minute break between each turn.

Blood sampling and analysis

Blood indices (LDH and CK), as well as perceived muscle soreness measures were repeated before, immediately, 24, 48, and 72 hr (five times overall, including four times after eccentric activity and one time before it).

Laboratory measures included the activity of LDH and CK enzymes. Serum samples were prepared by drawing 5 ml of blood from the antecubital vein in a sitting position. After 20 min of coagulation at laboratory temperature, the samples were immediately centrifuged for 10 min at 3000 rpm. Serum CK was determined using a colorimetric assay based on Jaffe reaction with the sensitivity of 1 U/L and the Coefficient of Variation (CV) of 1.6% (Colorimetric Kit, Pars Azmoon Co., Tehran, Iran). LDH activity was measured using enzymatic colorimetry with the sensitivity of 5 U/L and CV of 1.2% (Colorimetric Kit, Pars Azmoon Co., Tehran, Iran). Both CK and LDH are stated as units per liter.

Statistical analysis

Changes in measurements were tested for effects of time and group in a two-way repeated-measures analysis of variance (ANOVA). If a significant F value was obtained, then post hoc analysis was performed using the Bonferroni method with statistical significance set at $p < 0.05$. The data were analyzed by Intention-To-Treat (ITT) method. All the values were expressed as mean \pm SD. All statistical analyses were carried out using SPSS version 22.0 (IBM Inc., Armonk, New York, USA).

Results

Anthropometric and physiological characteristics of the subjects were obtained in the first testing session (Table 1). There were no significant baseline differences among the groups.

Changes in creatine kinase (CK)

The CK levels for five groups are shown in figure 2. Creatine kinase levels increased significantly in all groups at 24, 48, and 72 hr after the test compared with the pre-test.

However, immediately after the test, there was no significant increase compared to the pre-test in the group that received Taurine alone and the Taurine and Omega 3 group. However, in the omega-3 group alone, creatine kinase levels increased significantly at the time immediately after the test compared to

the pre-test ($p=0.02$). None of the groups showed a significant difference in creatine kinase levels directly after the test compared to the placebo group, although the Taurine and Omega-3 group demonstrated a significant difference between 24 ($p<0.001$), 48 ($p<0.001$), and 72 hr ($p<0.001$) post-test and placebo. This reduction was significant in the taurine group only at 24 ($p=0.031$) and 48 hr ($p=0.046$) and in the omega-3 group only at 48 hr ($p=0.013$) post-test compared to the placebo. Moreover, a significant decrease was found in the concurrent group compared to the groups receiving supplements alone, just at 24 and 72 hr after the test ($p<0.05$).

There was no significant difference in reducing creatine kinase levels between groups that received omega-3 and taurine alone at either measurement time.

Table 1. Anthropometric and physiological characteristics of the subjects

	Taur (n=12)	Omega-3 (n=12)	Taur+omega-3 (n=12)	PLA (n=12)	p-value
Age (year)	20.83±1.69	22.16±2.28	21.33±1.43	22.41±1.88	0.306
Weight (kg)	71.65±4.01	71.84±3.97	70.31±3.57	71.77±4.93	0.53
Height (m)	1.72±0.03	1.73±0.03	1.72±0.03	1.73±0.05	0.84
Fat percent	19.31±1.55	18.85±1.75	19.35±1.87	19.2±1.59	0.45
BMI (kg/m ²)	24.05±1.48	23.75±1.17	23.67±1.35	23.6±0.9	0.759

All values are shown as mean± SD. Tau: Taurine, PLA: Placebo; BMI (Body Mass Index)

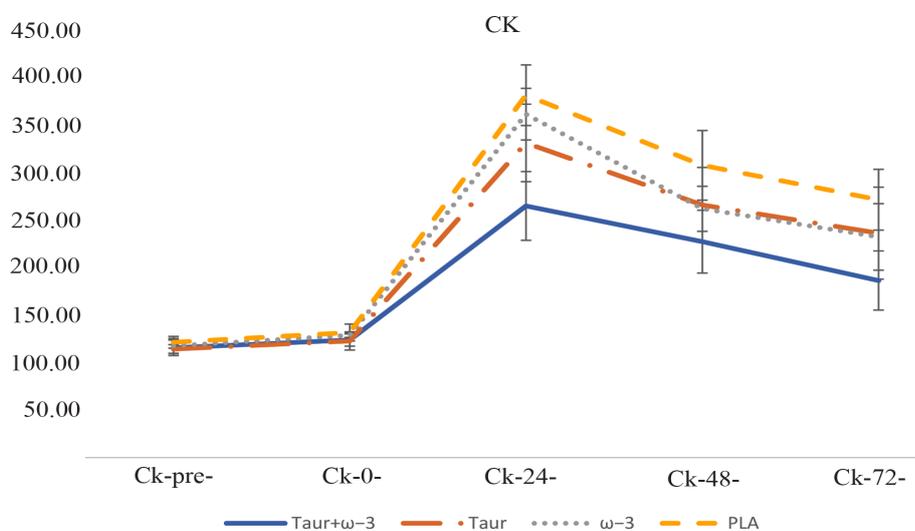


Figure 2. Comparison of serum creatine kinase (CK) changes at different times before and after the resistance exercise. A significant difference between the Taurine and Omega 3 group (Tau + ω -3) and the placebo group ($p<0.05$).

Changes in lactate dehydrogenase

The LDH levels for different times are shown in figure 3. Lactate dehydrogenase levels increased significantly in all groups immediately ($p < 0.001$), 24 ($p < 0.001$) and 48 *hr* ($p < 0.001$) compared to the pre-exercise value. But in the omega-3 alone and Taurine and Omega 3 groups, there was no significant difference between 72 *hr* and pre-test time.

Compared to the pre-test, there was a significant increase in serum lactate dehydrogenase in the taurine group at 72 *hr* ($p < 0.001$).

Taurine and Omega 3 group showed a significant reduction in lactate dehydrogenase compared to the placebo group only 24 *hr* after the test ($p = 0.016$). At other times of measurement, no such difference was found. Moreover, none of the other groups differed significantly at any of the times. In addition, there was no significant difference in the lactate dehydrogenase reduction between the groups.

Changes in muscle pain perception

The muscle pain perception levels for five time points are illustrated in figure 4. The perception of muscle pain increased in all groups immediately, 24, 48, and 72 *hr* compared to the pre-test value ($p < 0.05$). None of the groups indicated a significant difference in the perception of muscle pain immediately and 72 *hr* after the test, while at 24 and 48 *hr* after the test, there was a significant decrease in the taurine group ($p_{24-h} = 0.003$) ($p_{48-h} = 0.049$) and Taurine and Omega 3 group ($p_{24-h} < 0.001$) ($p_{48-h} = 0.001$) compared to the placebo group. In either of the measurement times, omega-3 supplementation did not significantly decrease the perception of muscle pain. Simultaneous use of taurine and omega-3 significantly reduced muscle pain at 48 ($p = 0.014$) and 72 *hr* ($p = 0.047$) after the test relative to omega-3 intake alone, but not when taurine was used alone. When the effects of taurine and omega-3 were compared separately, there was no

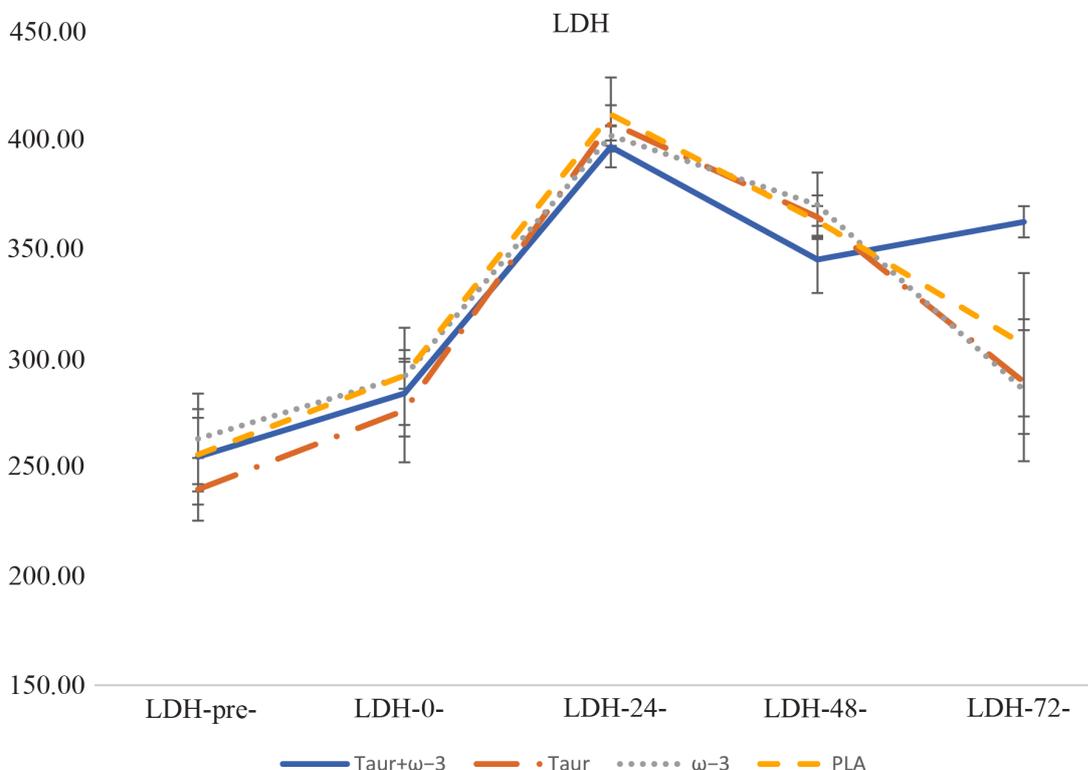


Figure 3. Comparison of serum lactate dehydrogenase (LDH) changes at different times before and after the resistance exercise. A significant difference between the Taurine and Omega 3 group (Tau + ω-3) and the placebo group ($p < 0.05$).

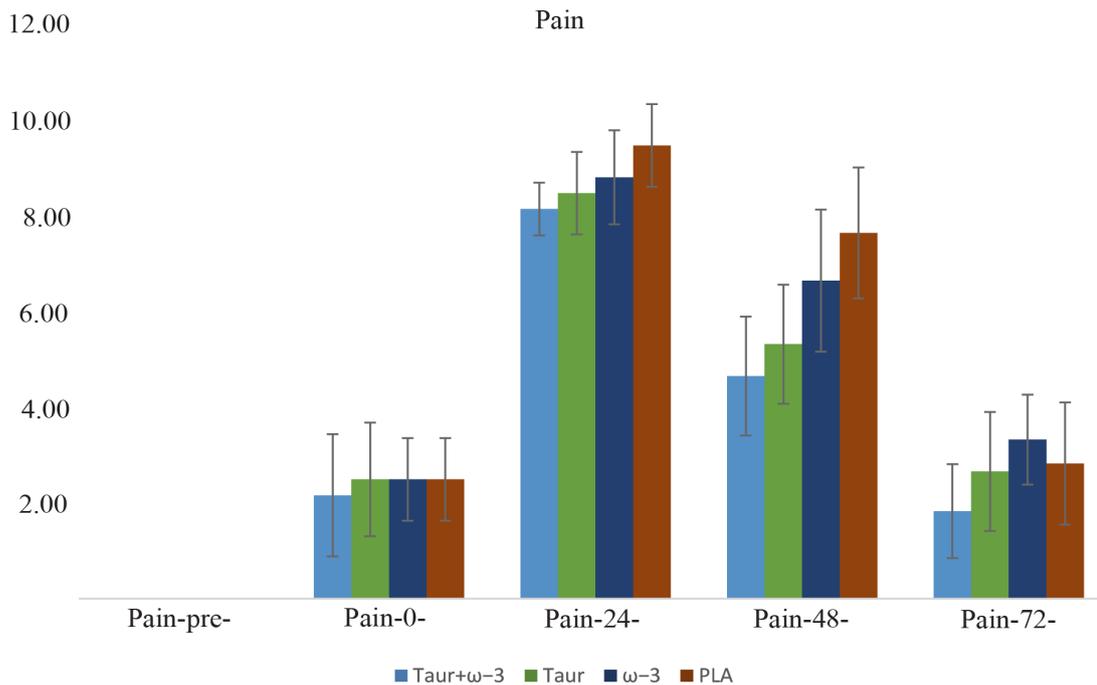


Figure 4. Comparison changes in muscle pain perception at different times before and after the resistance exercise. A significant difference between the Taurine and Omega 3 group (Tau + ω-3) and the placebo group ($p < 0.05$).

significant difference in reducing pain perception.

Discussion

Delayed Onset Muscle Soreness is one of the common symptoms of exercise-induced muscle damage associated with increased serum CK and LDH enzymes (27-29). Increased oxygen consumption during and after eccentric exercise and the production of free radicals is one of the major causes of delayed onset muscle soreness, and that antioxidant supplementation may decrease these effects (30, 31). Our results represented that simultaneous supplementation of omega-3 and taurine could lower CK and LDH in post-exercise. Taurine and omega-3 supplements alone significantly reduced CK levels in 24 hr and 48 hr post-exercise, respectively (Figure 2). Perception of muscle pain was also considerably reduced in the taurine and omega-3 supplement groups simultaneously and in the taurine group alone. Taurine (2-aminoethanesulfonic acid) is a fundamental amino acid in skeletal muscle that plays a key role in calcium homeostasis, osmotic regulation, and antioxidant capacity against stress responses (32). It has been shown that in the post-exercise, the level of taurine in skeletal muscle decreases, which

is parallel to the increase in glycolytic enzymes such as lactate dehydrogenase and creatine kinase (33). The results showed that the group receiving taurine supplementation had a significant decrease in serum CK at the post-exercise, while serum LDH levels were not significantly different from the placebo group. The various studies are in line with our results; for instance, Silva *et al* suggested that taurine supplementation (50 mg/kg) for 21 days (14 days before and seven days after eccentric exercise) in healthy men could reduce CK and LDH levels (13). Another study showed that 2 gr/day of taurine ingestion by young men for two weeks before and three days after high-intensity eccentric exercise could effectively reduce DMOS by decreasing CK (34). In contrast, a study by Galan *et al* reported that 3 g of taurine ingestion by male athletes for eight weeks had no significant effect on CK and LDH (35). Possible reasons for reducing DOMS by taurine may be related to the antioxidant capacity and protective effect of taurine on cell membranes, which reduces CK leakage following muscle damage.

Omega-3 fatty acids are essential fatty acids that contain eicosanoids such as Eicosapentaenoic Acid (EPA) and Docosahexaenoic acid (DHA), as

previous studies have shown that omega-3 intake can increase EPA and DHA levels which in turn decreased synthesis of other eicosanoids associated with increased inflammation (15,18,35). The present study showed that simultaneous supplementation of omega-3 and taurine could reduce CK and LDH post-exercise. In addition, the group receiving omega-3 supplementation had a significant decrease in serum CK the post-exercise, while serum LDH levels were not significantly different from the placebo group. Numerous studies have examined the effect of omega-3 supplements on DMOS. For instance, a survey by Jakeman *et al* demonstrated that high-dose omega-3 fish oil supplementation in male athletes significantly reduced exercise-induced muscle damage (36). Another study reported that 1.8 g of omega-3 fatty acid ingestion before exercise significantly reduced serum creatine kinase concentration compared with placebo (20). A possible reason for reducing DOMS may be related to the antioxidant and anti-inflammatory properties of omega-3 fatty acids. On the other hand, Gray *et al* represented that 1.3 g of omega-3 fatty acid ingestion for six weeks had no significant effect on serum CK and muscle damage due to a period of extrovert activity (13).

In addition to muscle damage, DOMS causes aching pain in the affected muscle due to strenuous exercise in beginners, which reduces physical function and even disrupts a person's daily activities (37). The present study stated concomitant use of omega-3 and taurine supplementation decreased Pain Assessment Scale (PAS) to perceive muscle pain. The results also showed that taurine supplementation alone could reduce the perception of muscle pain, while omega-3 supplementation did not have significant effects. In support of our results, previous studies have suggested that muscle taurine levels play a role in muscle cramps and muscle soreness that occur during and after exercise (33), as Yoshihisa *et al* showed that maintaining taurine concentrations in skeletal muscle might play a role in improved maximal performance on exercise (38). Contrary to our results, the study by Tartibian *et al* indicated that ingestion of 1.8 g/

day omega-3 for 30 days before and after exercise significantly reduced muscle pain in untrained men (19). The pain assessment index in this study was different from ours, which could be a possible reason for the conflicting results.

This is the first clinical trial study to examine the simultaneous omega-3 and taurine supplementation of DOMS in athletes. The intervention period and dosage of supplements in the present study were shorter than in previous studies and show that concurrent load supplementation of omega-3 and taurine supplements with a synergistic effect on antioxidant and inflammatory processes can affect DOMS.

Conclusion

This study showed that supplementation of the combined omega-3 and taurine supplements in untrained men for 28 days before performing extrovert resistance activity could reduce the levels of creatine kinase and lactate dehydrogenase enzymes as some indicators of muscle damage. It also decreased the perception of muscle pain caused by exercise.

Ethics

This trial was registered in Iranian Registry of Clinical Trials with ID number of RCT20200327046871N2.

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The taurine and omega-3 supplements are provided by Karen Nutrition Company. The Karen Company had no role in the design of the study, collection, analysis, and interpretation of the data and writing the manuscript.

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Conflict of Interest

This study was performed by financial support from Karen Nutrition Company and the authors declare that they have no conflict of interest.

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