The Effects of a Novel Taurine-L-Malic Acid Complex on Indices of Recovery after an Exercise Protocol Inducing Delayed-Onset Muscle Soreness

Original Research

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Abstract

Introduction: The purpose of this investigation was to determine the effects of a novel dietary supplement (Maltor™) on indices of muscle recovery after a delayed-onset muscle soreness (DOMS) protocol.

Methods: In a double-blind, placebo-controlled, crossover trial, subjects consumed the treatment (i.e., 5 g. Maltor™ – a complex of taurine and L-malic acid in an approximately 2:1 ratio) and placebo (i.e.,1 g of sodium citrate and 4 g of maltodextrin) daily over 14 days. Subjects were instructed to consume the treatment or placebo for 14 days. After 14 days of consumption, subjects performed a DOMS protocol based on their 1-RM. Inflammatory markers, arm circumference, strength, subjective and objective measures of pain were assessed 24hr, 48hr and 72hrs after DOMS protocol.

Results: A statistically significant difference was found for the assessment of pain threshold via the pressure algometer (p=0.5). Subjects in the treatment group exhibited a higher pain threshold two days post-DOMS (i.e., delta score data). We found no significant differences between groups for arm circumference, 1-RM (p=0.66), pain assessed by VAS (0.94), or arm circumference (p=0.91) between the groups. Furthermore, there were no significant differences between groups for Interleukin-6 (p=0.85) and C-reactive protein (p=0.48), key markers of inflammation.

Conclusions: Based on this preliminary investigation, two weeks of consuming taurine-L-malic acid complex may diminish delayed-onset muscle soreness in exercise-trained males as assessed by an algometer (i.e., assessment of pain threshold).

Key Words: pain, amino acid, supplements

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Introduction

Delayed onset muscle soreness (DOMS) is characterized by exercise-induced muscle pain or soreness that manifests 24-48 hours after physical activity. DOMS primarily arises from microscopic tears in muscle fibers, particularly as a result of eccentric exercises[1]. These eccentric movements induce mechanical stress and fatigue within the muscle fibers[1-3]. The strain on the sarcomere during eccentric exercises triggers an inflammatory response, leading to the

accumulation of cytokines that amplify the perception of pain[4]. The most prominent symptom of DOMS is muscle soreness/tenderness, which may interfere with range of motion or activities of daily living[1-4]. Other symptoms include elevated creatine kinase levels, heightened cytokine response, joint stiffness, and reduced muscular strength[4]. The onset of DOMS typically occurs within 6-12 hours following eccentric exercise and progressively intensifies, reaching peak pain levels between the 48 to 72-hour mark[1].

Reducing Delayed Onset Muscle Soreness (DOMS) can be challenging due to the exact etiology being unknown. Studies have investigated the effects of various modalities and nutritional supplements on mitigating symptoms of DOMS[5,6]. Due to the oxidative stress associated with muscle damage, antioxidants may prove to be a beneficial supplement for enhancing recovery from exercise-induced muscle damage. One such ingredient is a sulfur-containing amino acid called L-Taurine. Taurine is found naturally in various tissues of the human body and in some foods[7]. Taurine is present in high concentrations in skeletal muscles, which may contribute to its role in muscle recovery and performance[7,8]. It is theorized that taurine aids in recovery from exercise-induced muscle damage because it inhibits the production of pro-inflammatory cytokines and reduces oxidative stress[9,10].

L-malic acid is an organic compound found in various fruits. L-malic acid plays an important role in energy production since it is a key intermediate in the Krebs cycle. The conversion of malate into oxaloacetate generates NADH[11]. NADH plays a critical role in the energy production of cells by facilitating the transfer of electrons during cellular respiration, leading to the generation of ATP[11]. Thus, L-malic acid may indirectly improve sports performance through energy production. Malic acid is used in a variety of industries, including food and pharmaceuticals. It is regularly added to foods and beverages to enhance flavor and is used in the medical industry to increase the absorption of drugs[12].

The negative effects of DOMS, mainly muscle soreness and stiffness, can be detrimental to training and athletic performance. Supplementation may attenuate DOMS and enhance recovery. The purpose of this investigation was to determine the effects of a dietary supplement (Maltor™) on indices of muscle recovery after a delayed-onset muscle soreness (DOMS) protocol. The authors hypothesize the dietary supplement will lessen the inflammatory response, leading to improved recovery.

Scientific Methods

Experimental Protocol

In a double-blind, placebo-controlled, crossover trial, subjects consumed the treatment (i.e., 5 g. Maltor™ – a patent pending complex of taurine and L- malic acid in an approximately 2:1 ratio) and placebo (i.e.,1 g of sodium citrate and 4 g of maltodextrin) daily over a 14-day period. Subjects were instructed to consume the treatment or placebo for 14 days. After 14 days of consumption, subjects were assessed for 1-RM (repetition maximum) strength of the elbow flexors. Based on their 1-RM strength, subjects completed the DOMS protocol. After the DOMS protocol, subjects performed an additional 1-RM with the elbow flexors. Muscle circumference, self-reported ratings of soreness questionnaire, and assessment of soreness via Algometer were assessed. All participants underwent an informed consent process in accordance with the Declaration of Helsinki and an approved IRB protocol submitted to the institutional review board of Keiser University.

Subjects

Seventeen trained males volunteered for this investigation. All participants were healthy, exercise-trained (minimum of one year of regular physical activity), and between the ages of 18-65 years of age. Body composition was assessed using a multi-frequency bioelectrical impedance device (InBody® 270). Study participants stood on the platform of the device barefoot with the soles of their feet on the electrodes and then grasped the handles of the unit with their thumb and fingers to maintain direct contact with the electrodes. They stood still for ~1 minute while keeping their elbows fully extended and their shoulder joint abducted to about a 30-degree angle.

Delayed Onset Muscle Soreness Protocol

Subjects performed DOMS protocol with the non-dominant arm. Subjects were instructed to place their elbow on the pad of the exercise bench with their shoulders flexed at 45 degrees. Subjects held a dumbbell weighing 60% of their 1RM for one second at a 90-degree angle before lowering it slowly for three seconds. Once the elbow was completely extended, the investigator manually returned the subject's arm to a 90-degree flexion position. Subjects completed 75 repetitions with their non-dominant arm using this method. Protocol was ended if subjects were unable to complete repetitions with proper form.

Assessment of self-reported ratings of soreness
To assess subjective ratings of soreness and to determine level of soreness, subjects were instructed to complete, subjects rated their soreness using a number scale. The numeric rating ranged from 0 to 10. Zero (0) indicated none or no soreness, 5 indicated moderate soreness, and 10 indicated severe soreness. Subjects completed this assessment on each visit to the laboratory.

Assessment of Soreness with an Algometer
An algometer is a device that measures the pressure-pain threshold[9]. Subjects were instructed to place their arm fully extended, with palm-facing up on a table. Next, the investigator pressed the blunt end of the instrument slowly and systematically into the distal portion of the elbow flexor muscles (i.e., biceps brachii). Once the subject expressed feeling intolerable pain, the pressure on the instrument was recorded.

Muscle Circumference
Mid-arm circumference was measured midway between the acromion and elbow crease while subjects were standing with the arm relaxed.

Inflammatory Markers (IL-6 and CRP)
Saliva samples were obtained from each participant via passive drool. The samples were collected in 1.5 mL polypropylene microcentrifuge tubes and kept on ice until the session was complete. Following the session, the samples were stored in a freezer at -20°C until assayed. Saliva samples were run in duplicates. Both CRP and IL-6 were quantified via a human enzyme immunoassay kit according to the manufacturer's instructions (Salimetrics, Carlsbad, CA, USA). The functional sensitivity of the Salivary CRP ELISA Assay kit (Generation II) is 19.44 pg/mL when the sample is diluted two-fold. The functional sensitivity of the salivary IL-6 ELISA is 2.08 pg/mL.

Statistical Analysis
All data are expressed as the mean ± standard deviation. An independent samples t-test was used to determine differences between groups with regard to the delta score. When comparing the pre vs posttest values, a paired samples t-test was utilized. A p-value of $P \leq 0.05$ was used to determine significance. GraphPad Prism 10 (Boston, MA) was used for the statistical analysis.

Results
Subjects
Subject characteristics are shown in Table 1. All subjects were young, healthy males who trained on a regular basis. Two subjects dropped out of the study, whereas 15 subjects completed the study.

Table 1. Subject characteristics

Characteristic	Subject Average
Height cm	178±7
Weight kg	87.0±18.7
Lean mass kg	71.6±13.6
Fat mass kg	15.4±6.2
% Body fat	17.2±4.5
Total body water liters	52.4±9.9
Total number of years of training	13.1±9.4
Average hours of weight training per week	6.1±4.1
Average hours of aerobic exercise per week	3.1±2.0
Other exercises per week	1.3±2.1

Data are expressed as the mean ± standard deviation. N=15

Indices of Recovery
A statistically significant difference was found for the assessment of pain threshold via the pressure algometer (p=0.053). Subjects in the treatment group exhibited a higher pain threshold two days post-DOMS (Figure 1). We did not find any significant differences between groups for 1-RM (p=0.669), pain assessed by VAS (p=0.936), or arm circumference (p=0.913) between the groups. Furthermore, there were no significant differences between groups for Interleukin-6 (p=0.855)and C-reactive protein (p=0.478), key markers of inflammation (Figures 2-6).

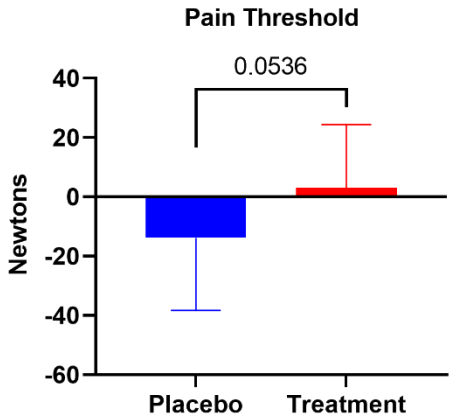


Figure 1. Change in pain threshold pre-DOMS and two days post-DOMS. The data is expressed as the mean and standard deviation.

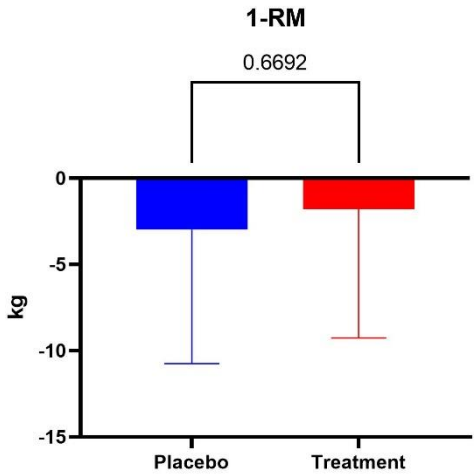


Figure 2. Change in 1-RM pre-DOMS and two days post-DOMS. The data is expressed as the mean and standard deviation.

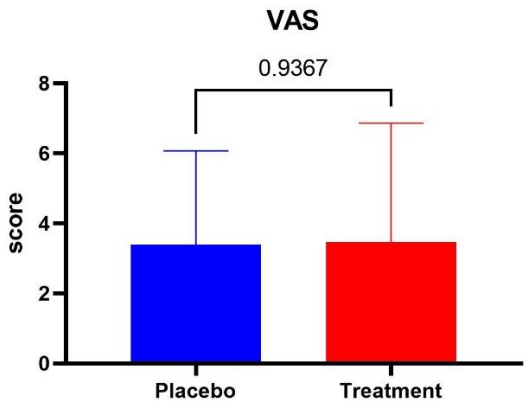


Figure 3. Change in pain perception pre-DOMS and two days post-DOMS. The data is expressed as the mean and standard deviation.

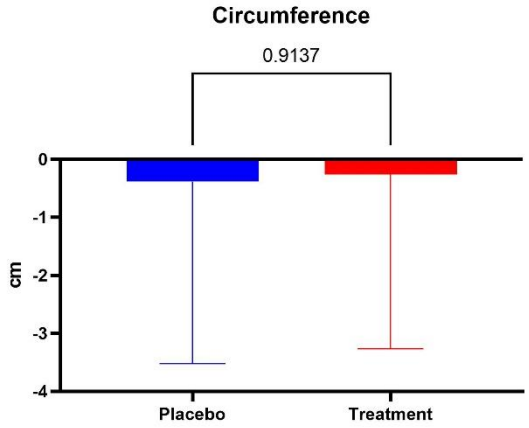
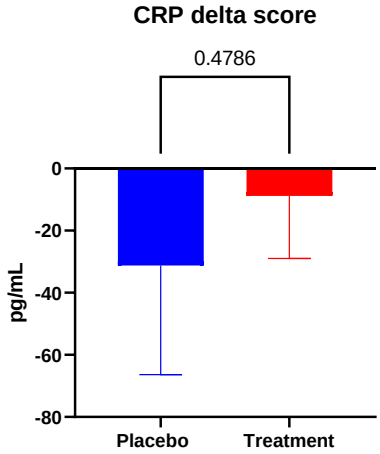
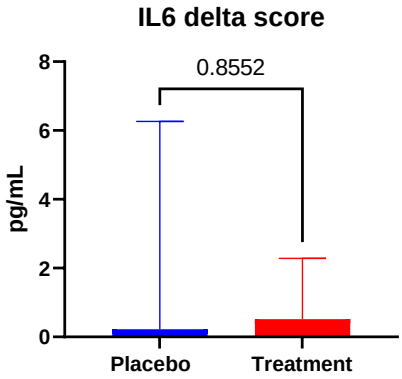


Figure 4. Change in arm circumference pre-DOMS and two days post-DOMS. The data is expressed as the mean and standard deviation.



The values are the change in CRP post (day 2 and 3 combined) vs. day 1 (baseline)

Figure 5. Change in C-reactive protein. The data is expressed as the mean and standard deviation.



The values are the change in Interleukin-6 post (day 2 and 3 combined) vs. day 1 (baseline)

Figure 6. Change in IL-6. The data is expressed as the mean and standard deviation.

Discussion

This study investigated the effects of 14 days of supplementation with a taurine-L-malic acid complex on indices of recovery following exercise-induced muscle damage. The major findings of the current investigation are that this supplement may have a favorable effect on the perception of pain. A statistically significant difference was found for the assessment of pain threshold via the pressure algometer two days after completing the DOMS protocol. No improvements were found between the groups in 1-RM, pain assessed by VAS, inflammatory markers, or arm circumference.

The present study is the first study with a taurine-malic acid complex; however previous studies have been conducted with taurine alone or in combination with other ingredients. Previous studies suggest using taurine-containing supplements attenuates the damage induced by eccentric exercise[8,13]. Ra et. al.[13] compared the use of BCAAs, Taurine, or BCAAs with taurine in DOMS-related symptoms[13]. Similar to this study's findings, self-reported pain using a VAS did not improve in the group receiving taurine. A significant difference in pain was reported in the group receiving BCAAs combined with taurine on the 2nd day[13]. Interestingly, Ra et al. reported an increase in plasma taurine levels following supplementation. The current study did not evaluate plasma levels of taurine. Another study evaluated the effects of taurine supplementation on muscle damage and exercise performance in male subjects. Creatine kinase, a marker of muscle damage, was unaffected by taurine supplementation; however, peak force was greater in the taurine group compared to placebo 48h post-DOMS protocol[8]. This study suggests taurine does not affect muscle damage but can improve recovery performance. The authors theorize taurine's anti-inflammatory effects may be responsible for the improvement in force production[8]. These findings differ from the current study, which did not see improvements in performance; however, comparison to the present study is difficult due to the different performance metrics being assessed. De Silva et al.[14] evaluated the effectiveness of taurine supplementation on muscle performance for 21 days. The authors reported less self-reported muscle soreness in subjects consuming a taurine-containing supplement compared to placebo. Immediately following the DOMS-inducing protocol, muscle strength was assessed. Similar to the findings of this study, no differences in strength between groups were reported.

Intense or prolonged exercise causes microscopic damage to muscle fibers, resulting in the release of pro-inflammatory cytokines, such as interleukin-6 (IL-6), as well as anti-inflammatory cytokines, such as interleukin-1β to repair damaged tissue[14-16]. This process can contribute to soreness and inflammation. Previous studies have evaluated the effect of taurine on inflammatory markers[9,16,17]. Wang et al.[17] reported a decrease in IL-6 post-exercise following the acute ingestion of a taurine-containing energy drink. It is important to note that the duration of supplementation and exercise type differed from the current study. Da Silva et al.[16] reported an increase in inflammatory cytokines IL-1β, TNF, and IL-10 following eccentric exercise in both the placebo and taurine supplementation group[16]. Despite the nonreduction of inflammatory markers, improvements in oxidative stress were reported. The authors suggest taurine is involved in other roles related to muscle damage, irrespective of its effects on inflammation[16]. These results are in line with the current study, which did not report decreases in IL-1β, although the current study did not measure oxidative stress. Despite the lack of change in inflammatory markers, subjects reported decreased pain via the algometer, suggesting that a taurine-L-malic acid complex may be effective at reducing discomfort associated with DOMS.

L-malic acid is the natural isomeric (L) form of malic acid. It is a Krebs cycle intermediate[18], and citrulline malate, which is a 2:1 ratio of citrulline to malic acid, is used to boost sports performance[19]. L-malic acid can promote energy production (from the burning of pyruvic acid) which may help fight off muscle fatigue (counteracting the buildup of lactic acid)[19,20]. L-malate is an intermediate in the process of metabolism; it plays an important role in generating mitochondria ATP both under aerobic and hypoxic conditions. It can be absorbed and enter the mitochondria through cell membrane and promote to produce energy in mitochondria. Moreover, L-malate is a component of the malate aspartate shuttle and is of importance in transporting NADH from cytosol to mitochondria for energy production. L-malic acid is an intermediate metabolite of Krebs cycle, it is directly involved in mitochondrial energy metabolism; and it is also part of the malate-aspartate shuttle[21]. For these reasons the combination of taurine and L-malic acid in a patent pending complex could potentially provide a synergistic effect for reducing discomfort associated with DOMS.

Conclusions

Two weeks of consuming a taurine-L-malic acid complex may diminish delayed-onset muscle soreness in exercise-trained males as assessed by an algometer (i.e., assessment of pain threshold). However, there were no differences in the recovery of maximal strength, pain as assessed by VAS, as well as measures of inflammation (i.e., CRP and IL-6). It should be noted that these data are preliminary and reflect a very limited sample size.

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References

1. Hotfiel T, Freiwald J, Hoppe MW, et al. Advances in Delayed-Onset Muscle Soreness (DOMS): Part I: Pathogenesis and Diagnostics. *Sportverletz Sportschaden*. Dec 2018;32(4):243-250. Delayed Onset Muscle Soreness - Teil I: Pathogenese und Diagnostik. doi:10.1055/a-0753-1884
2. Faulkner JA, Brooks SV, Opiteck JA. Injury to skeletal muscle fibers during contractions: conditions of occurrence and prevention. *Phys Ther*. Dec 1993;73(12):911-21. doi:10.1093/ptj/73.12.911
3. MacIntyre DL, Reid WD, Lyster DM, McKenzie DC. Different effects of strenuous eccentric exercise on the accumulation of neutrophils in muscle in women and men. *Eur J Appl Physiol*. Jan 2000;81(1-2):47-53. doi:10.1007/PL00013796
4. Lewis PB, Ruby D, Bush-Joseph CA. Muscle soreness and delayed-onset muscle soreness. *Clin Sports Med*. Apr 2012;31(2):255-62. doi:10.1016/j.csm.2011.09.009
5. Kim J, Lee J. A review of nutritional intervention on delayed onset muscle soreness. Part I. *J Exerc Rehabil*. Dec 2014;10(6):349-56. doi:10.12965/jer.140179
6. Cheung K, Hume P, Maxwell L. Delayed onset muscle soreness : treatment strategies and performance factors. *Sports Med*. 2003;33(2):145-64. doi:10.2165/00007256-200333020-00005
7. Schaffer SW, Jong CJ, Ramila KC, Azuma J. Physiological roles of taurine in heart and muscle. *J Biomed Sci*. Aug 24 2010;17 Suppl 1(Suppl 1):S2. doi:10.1186/1423-0127-17-s1-s2
8. McLeay Y, Stannard S, Barnes M. The Effect of Taurine on the Recovery from Eccentric Exercise-Induced Muscle Damage in Males. *Antioxidants (Basel)*. Oct 17 2017;6(4)doi:10.3390/antiox6040079
9. Kontny E, Szczepańska K, Kowalczewski J, et al. The mechanism of taurine chloramine inhibition of cytokine (interleukin-6, interleukin-8) production by rheumatoid arthritis fibroblast-like synoviocytes. *Arthritis Rheum*. Oct 2000;43(10):2169-77. doi:10.1002/1529-0131(200010)43:10<2169::Aid-anr4>3.0.Co;2-#
10. Schaffer S, Kim HW. Effects and Mechanisms of Taurine as a Therapeutic Agent. *Biomol Ther (Seoul)*. May 1 2018;26(3):225-241. doi:10.4062/biomolther.2017.251
11. Haddad A, Mohiuddin SS. Biochemistry, Citric Acid Cycle. *StatPearls*. 2024.
12. Wei Z, Xu Y, Xu Q, Cao W, Huang H, Liu H. Microbial Biosynthesis of L-Malic Acid and Related Metabolic Engineering Strategies: Advances and Prospects. *Front Bioeng Biotechnol*. 2021;9:765685. doi:10.3389/fbioe.2021.765685
13. Ra SG, Miyazaki T, Ishikura K, et al. Additional effects of taurine on the benefits of BCAA intake for the delayed-onset muscle soreness and muscle damage induced by high-intensity eccentric exercise. *Adv Exp Med Biol*. 2013;776:179-87. doi:10.1007/978-1-4614-6093-0_18
14. Cerqueira É, Marinho DA, Neiva HP, Lourenço O. Inflammatory Effects of High and Moderate Intensity Exercise-A Systematic Review. *Front Physiol*. 2019;10:1550. doi:10.3389/fphys.2019.01550
15. Docherty S, Harley R, McAuley JJ, et al. The effect of exercise on cytokines: implications for musculoskeletal health: a narrative review. *BMC Sports Science, Medicine and Rehabilitation*. 2022/01/06 2022;14(1):5. doi:10.1186/s13102-022-00397-2
16. da Silva LA, Tromm CB, Bom KF, et al. Effects of taurine supplementation following eccentric exercise in young adults. *Appl Physiol Nutr Metab*. Jan 2014;39(1):101-4. doi:10.1139/apnm-2012-0229
17. Wang Y, Xu T, Zhao H, Gu C, Li Z. Effect of taurine in muscle damage markers and inflammatory cytokines in running exercise. Original Research. *Frontiers in Physiology*. 2022-September-13 2022;13doi:10.3389/fphys.2022.1008060
18. Krebs HA, Salvin E, Johnson WA. The formation of citric and alpha-ketoglutaric acids in the mammalian body. *Biochem J*. Jan 1938;32(1):113-7. doi:10.1042/bj0320113
19. Gough LA, Sparks SA, McNaughton LR, et al. A critical review of citrulline malate supplementation and exercise performance. *Eur J Appl Physiol*. Dec 2021;121(12):3283-3295. doi:10.1007/s00421-021-04774-6
20. Abraham GE, Flechas JD. Management of Fibromyalgia: Rationale for the Use of Magnesium and Malic Acid. *Journal of Nutritional Medicine*. 1992/01/01 1992;3(1):49-59. doi:10.3109/13590849208997961
21. Borst P. The malate-aspartate shuttle (Borst cycle): How it started and developed into a major metabolic pathway. *IUBMB Life*. Nov 2020;72(11):2241-2259. doi:10.1002/iub.2367