New aspects of cellular adaptation in physical activity: A delayed muscle pain approach

Mahdieh Nassiri Ovanaki[1], Mehran Ghahramani[2*]

1. Department of Exercise Physiology, Central Tehran Branch, Islamic Azad University,Tehran, Iran
2. Department of Exercise Physiology, Gilan-E-Gharb Branch, Islamic Azad University, Gilan-E-Gharb, Iran

***Corresponding author:** Tel: +98 9188342771 Fax: +98 8343227555
Address: Department of Exercise Physiology, Gilan-E-Gharb Branch, Islamic Azad University, Gilan-E-Gharb, Iran
E-mail: Mehran.physiology@gmail.com
Received; 18/08/2019 revised; 25/10/2019 accepted; 5/11/2019

Abstract

The purpose of the present study was to investigate the context of new aspects of cellular adaptation in physical activity with a focus on delayed pain approach, the nature and types of pain, several preventive and non-pharmacological approaches to delayed onset muscle soreness (DOMS) and to achieve a desirable conclusion and provide more relevant information from previous research. In this study, articles were searched in specialized databases and 30 related articles were selected based on inclusion and exclusion criteria, and cellular adaptation in physical activity with a focus on delayed muscle pain approach was investigated. Mechanical and metabolic stress is the cause of injury during participation in an unfamiliar activity. Mechanical and metabolic stress may trigger pathological responses to activity-induced muscle damage. The suggested cause of metabolic muscle injury has been the inadequate production of mitochondrial ATP, ischemia, hypoxia and changes in ion concentration. The present study showed that physical activity is, in general, among the methods that can be effective in the prevention and treatment of delayed muscle soreness including: massage, cryotherapy, hydrotherapy, use of nonsteroidal anti-inflammatory drugs, antioxidant use, warm-up and cool-down, stretching movements before and after the activity, avoiding new and unfamiliar activities, starting activities gradually and lightly .Resistance activity causes muscle damage by increasing creatine kinase enzymes, lactate dehydrogenase. Accordingly, resistance training, especially extracorporeal contraction, produces oxygen-free radicals and lipid peroxidation, eventually leading to muscle tissue damage and subsequent inflammatory processes.

Keywords: Physical activity, Delayed onset muscle soreness, Cellular adaptation

Introduction

One of the muscle injuries that has been involving sports physiologists for years is delayed onset muscle soreness (DOMS), being called delayed because it does not occur immediately after physical activity, but from hours to days after a session of intense physical activity. Many people who do not exercise physically experience some form of delayed onset muscle soreness. Evidence shows that a significant number of beginner athletes, who are just starting out, are simply avoiding physical activity because of this soreness or discomfort, or at least are looking for conditions that they will no longer experience it.

The phenomenon of DOMS not only prevents athletes from participating in exercise programs, but also acts as a deterrent to the display of exercise skills. Concerns among sports coaches, physiologists, and other sports medicine

Copyright © 2020 Journal of Basic Research in Medical Science. This is an open access article distributed under the terms of the Creative Commons Attribution 4.0International License(https://creativecommons.org/licenses/by-nc/4.0/)which permits copy and redistribute the material, in any medium or format, provided the original work is properly cited.

[Downloaded from demo.medilam.ac.ir on 2026-11-15]

practitioners are about the existence of soreness and most likely performance-attenuating factors, and in particular the increased risk of injury to athletes due to reduced strength from DOMS, and hence they are interested in preventing or minimizing the effects of DOMS on the shortest time possible.

An effective and beneficial treatment for DOMS will enhance athletic performance and accelerate the return of non-athletes to daily living activities.

Sports coaches and physiotherapists have recommended different therapeutic approaches for the treatment of the skeletal muscles involved, but there is limited evidence to prove the effectiveness of some strategies; also there is little research with contradictory results to compare the effectiveness of different therapeutic plans and determine which are more effective and more practical in a shorter time. Of course, one method of relieving soreness is being sedentary, but because the athlete must reach his or her highest capacity in terms of strength, range of motion and feeling no pain in the least amount of time, specialists are looking for methods to eliminate these unwanted side effects that are faster than inactive rest. Thus, the necessity of identifying and applying the most appropriate method for the specific purposes of each exercise seems essential (1).

The nature of Muscle Soreness

Muscle soreness may be experienced by everyone after doing physical activity. Muscle pain or muscle soreness is an unpleasant condition in the muscle that is associated with feelings of pain, stiffness, weakness and cramping in the muscles involved.

Existing reports suggest that soreness occurs after heavy, unusual activity associated with extrovert contractions, thus among activities that possess the aforementioned specificity we can note walking and running downhill (2, 3), specific plyometric exercises (2,3) and extrovert contractions during weight training (1-3).

Types of Muscle Soreness

There are generally two types of muscle soreness known: a) acute muscle soreness b) delayed-onset muscle soreness.

A) Acute muscle soreness: This type of muscle soreness occurs during and immediately after physical activity and may be due to decreased blood flow to the active muscles (local anemia) (4-6).

Another look at the etiology of acute muscle soreness suggests that the soreness may be due to the accumulation of metabolic end products such as H+ or lactic acid and tissue swelling, which results from fluid transfer from the blood plasma into the tissues. This is the same as feeling of muscle bulking that athletes experience after endurance or strength training; in general, soreness and contusion usually develop within minutes or hours of exercise, which is why they are called acute contusion (1,4-6).

Characteristics of Pains that Occur During or Immediately After Physical Activity

It occurs during introvert contractions and the same length (2,3). Blockage of the bloodstream causes pain and intensifies pain (4-6). With the cessation of exercise and normalization of blood flow, the pain subsides rapidly. Chemicals released from muscle contraction stimulate the free ends of type VI nerve fibers that cause pain. The

[Downloaded from demo.medilam.ac.ir on 2026-11-15]

more energy consumed to do the task, the greater the pain from it. Pain is most likely caused by substances such as acids (lactate or pyruvate), ions, proteins, and hormones that are associated with muscle contraction (4-6).

Summary of the Mechanisms of Pain Created During Physical Activity

Prostaglandins and substance P increase the sensitivity of pain receptors but do not directly cause pain. The severity of pain is not related to the extent of tissue damage but to the severity and speed of tissue injury. Mechanisms of pain creation in tissue injury: release of bradykinin or proteolytic enzymes. Mechanisms of ischemic pain: lactate production, bradykinin or proteolytic enzymes. Mechanism of pain in muscle spasms. Direct pressure on the receivers. Muscle ischemia due to pressure on the vessels and increased energy consumption by the muscle. Slow pain is one of the most important mechanisms of incremental levels of brain awakening by stimulating the reticular formation of the brainstem. This is why sleeping is difficult for the person who is in pain.

Delayed Onset Muscle Soreness

Another type of muscle soreness that is felt one or two days after a session of intense physical activity is called delayed onset muscle soreness, because the pain does not occur immediately after training (1, 5). The objective symptoms of delayed onset muscle soreness (DOMS) can be examined in two parts:

A) Functional (overt) symptoms, including: feeling pain, swelling and restriction of movement and reduction of joint range of motion and loss of muscle strength.

B) Biochemical or laboratory (covert) symptoms, including: release of enzymes (creatine kinase, lactate dehydrogenase) (7) increase in myoglobin, hydroxyproline, white blood cells, macrophages and monocytes (7) change in the plasma level and calcium and increase in prostaglandins and changes in catecholamines and cortisol hormone.

Theories of delayed onset muscle soreness comprised of lactic acid theory, muscle contusion theory, torn tissue theory or construction damage theory (6), connective tissue theory (7), enzyme diffusion theory, tissue fluid theory, theory of free radicals, theory of waste overproduction (7), and theory of inflammation.

Location of Delayed Onset Muscle Soreness

Any overused skeletal muscle may develop DOMS, for example after a long run downhill (2), the person will feel pain in the hip and knee flexor and extensor muscles. Intense activity (especially extrovert activity) causes injury or trauma to the muscle, junction of the muscle and tendon or both, where tenderness and pain are often felt in the distal part of the muscle at the tendon junction and then spread throughout the muscle (9). Actually, damage to the lower one-thirds of the muscle (far from the trunk) is most likely due to the fact that the order of placement of the fibers relative to the longitudinal axis in this area is the highest angle, that is, the muscle has the highest tension. As such, the fibers' risk of injury to mechanical shock is increased (1,8).

Prevention and Treatment of Delayed Onset Muscle Soreness

Physical activity

[Downloaded from demo.medilam.ac.ir on 2026-11-15]

The general hypothesis that muscle soreness is reduced by physical activity has been studied for several years. Sub-maximal introvert activity does not cause tissue damage and produces much less intramuscular pressure than extrovert muscle activity, whereas extrovert muscle activity increases pressure and adds to the movement of intravascular fluid into the interstitial space of trained muscle fibers. Slow active movement is most likely to be the most effective method of reducing swelling and excretion of fluid accumulated in the injured site due to increased range of motion and putting pressure on the site of injury. Although some studies disagree with introvert therapy as a treatment, it has been reported, following sub-maximal introvert activity, to induce a decrease in DOMS, and an increase in muscle function. Overall, researchers have provided evidence that show high-speed voluntary muscle contraction reduces DOMS and related symptoms and delays the return of muscle function to its original state.

So far, the most effective treatment for DOMS is the preceding extravert exercise on the same muscle group. Performing one bout of extravert exercise provides a muscle adaptation that makes it more resistant to post-exercise injury (1,8,11). Bennett et al. (2005), examining the effect of yoga training on DOMS, stated that performing yoga training before extravert exercise decreased DOMS compared to the individual who did yoga training 24 hours after extravert exercise (10).

Dietary supplements

Carbohydrate diet, Vitamin C (4,5), betahydroxy beta methyl butyrate (HMB) and alpha-ketoisocaproic acid (KIC), vitamin E (7,12).

Stretching

Researchers examined the effect of stretching before and after physical activity on DOMS and obtained different results. Falkner et al. stated that the cause of DOMS is muscle cramps and stretching relieves cramps. But recent evidence does not support the theory of muscle cramping, and it is generally believed that muscle damage is a direct and indirect cause of muscle pain (9).

It is also believed that stretching after physical activity can cause the accumulated excess fluid to disperse due to muscle injury and reduce pain, but later research has shown that the peak time of swelling (5 days after physical activity) is not in line with the peak time of cramping (2 - 3 days after physical activity), so such a conclusion cannot be valid.

Electromyographic findings indicate a decrease in the electrical activity of the muscle during slow and static stretching, which may be another reason for demonstrating muscle relaxation after stretching (1,8). Static stretching is preferable to throwing stretching for the following reasons: less muscle tissue vulnerability, less energy requirement, and avoiding fatigue or muscle pain and relieving it (9).

Massage

The effect of exercise massage on DOMS return to baseline has been investigated by several researchers. In all studies except one, massage was administered immediately, 24 or 48 hours after physical activity. Russian sports therapists advocated the effectiveness of massage 1 to 3 hours after intense physical activity, although its logical and scientific reason has not been established.

[Downloaded from demo.medilam.ac.ir on 2026-11-15]

Smith et al. suggested that a significant decrease in DOMS following a three-hour massage after extravert activity may be due to neutrophils activity by mechanical massage or an increase in serum cortisol (13). Glick et al. examined the effect of massage on DOMS and swelling and restore of muscle function and expressed that finger massage for 10 minutes restores muscle function to its original state. Researchers have also suggested using Swiss-based massage for DOMS treatment and stated that massage increases blood flow and lymph and reduces blood lactate levels compared to passive rest (1,8).

The results of research show that the mechanical effect of massage on muscle soreness is due to degradation of metabolic waste and sediment, increase of local circulation and decrease of pain. In addition, massage significantly reduces the amount of blood lactate compared to passive rest, but its effect on improving flexibility is low. In addition, using alcoholic compounds can increase the effect of massage. Massage with hot water pressure increases the release of proteins from the muscle tissue into the bloodstream and helps maintain neuromuscular function. On the other hand, light exercise with muscles with DOMS is more likely to improve muscle blood flow and temporarily reduce DOMS more effectively than massage (1,8,14-17).

Cryotherapy

When damage and swelling occur, the blood circulation of the site is disrupted and the healing process is delayed due to insufficient oxygen supply. By reducing local metabolism and the damaged organ need for oxygen, cryotherapy blocks the process of degradation due to lack of oxygen, and also reduces the speed of pain message to the sensory cortex by reducing the nerve impulse flow in the sensory nerves. Substances that are released as a result of inflammation cause pain, and the muscle becomes contused. Ice as an anti-inflammatory agent reduces muscle contraction and eliminates tension. The cold also reduces the activity of the Golgi tendon organs, which are inhibitors of receptors, and anesthetizes pain receptors. Following acute tissue lesions, the use of cold has been suggested to reduce inflammation and muscle cramps. Cryotherapy is effective in improving soft tissue damage because of its ability to reduce the response to circulation, inflammation, edema and intravascular pressure. Ice massage causes the greatest decrease in intramuscular temperature compared to other cryotherapy treatments (1,8).

Transcutaneous Electrical Nerve Stimulation (TENS or TNS)

There is a new method to relieve pain which is called T.N.S. In most cases the flow frequency is between 50 and 150 Hz, the flow intensity is between 12 and 30 mA and the excitation time is about 100 to 500 microseconds. A group of researchers believe that the use of T.N.S stimuli secretes a set of chemical or morphine-like chemicals, such as serotonin, endorphin and enkephalin, which have analgesic properties (8). The effects of low frequency TENS on delayed contusion were studied by Gyulik et al 30-minute treatment of two beats per second at 300 μs had a significant decrease in pain sensation and a significant increase in range of motion (7,8,18).

Herbal Treatment

[Downloaded from demo.medilam.ac.ir on 2026-11-15]

The use of herbal remedies, especially *Arnica Montana*, goes back to the 16th century. Arnica Montana, commonly known as the mountain pearl, is a plant of which 271 medicines with 33 different uses are made. Using this drug can relieve pain and treat rheumatism, soft tissue trauma, muscle fatigue, inflammation, venous insufficiency, infection and heart disease. Arnica Montana can be used in oils, sublingual tablets and tinctures. The effects of Arnica Montana tablets on blood enzymes and muscle soreness of marathon runners were investigated. There was no significant difference in blood enzyme levels of Arnica Montana and control groups, but muscle pain was decreased in the Arnica Montana group.

Another study of subjects with coronary artery failure revealed the efficacy of topical use of Arnica Montana. The effect of Arnica Montana tablets and oils on DOMS was similar to NSAIDs. It appears that m any studies are needed on the beneficial effects of this herbal medicine, especially in the setting of inflammation and trauma of soft tissue (5).

Heat and water Treatment Instruments

Hot water showers, steam baths, regular baths, local baths, the use of dry heat such as optical heat and saunas, increasing temperatures using exothermic means are methods that are mentioned in limited sources and little is known about their effects. The only research carried out in this area dates back to 1988. Elsewhere, in a study, 56 German male students reported that cold jacuzzi at temperatures between 12.8 and 18.3° C for 20 minutes after extravert exercise was more effective than hot jacuzzi and mixed treatment. Researchers also suggest that hot jacuzzi (35 to 45° C) not only does not improve the symptoms of DOMS but also exacerbates it (5).

Discussion

Exercise and sport participation are an important factor in reducing the risk of many diseases and physical problems such as cardiovascular disease, hypertension and obesity. In addition, they are effective in treating many mental disorders such as anxiety and depression as well as increasing self-confidence and self-esteem. Exercise affects the body and mind, and physical and psychological factors subsequently affect exercise and athletic performance. Muscle soreness is one of the problems that athletes face and is often associated with a decrease in exercise performance and causes the athlete to find a way to get rid of the pain. The percentage of muscle soreness depends on various factors such as level of competition, duration and intensity of activity, age and individual differences (7,21).

It is believed that excessive stretching of the sarcomeres reduces a person's voluntary and muscular strength (22). This issue confirms the effect of the performed methods (especially stretching movements) on the Golgi tendon organ and connective tissue and the result that the decrease in muscle strength is due to the decrease in deep receptor function in post-eccentric contraction days and has a negative effect on nerve function (7).

It has been stated that warming can reduce the adhesion of muscle tissues and due to its mechanical function, it can affect the amount of initial damage. Warming can reduce the adhesion of muscle tissues and be effective in the amount of initial damage due to its mechanical function. Increased

[Downloaded from demo.medilam.ac.ir on 2026-11-15]

blood flow may be able to limit inflammatory responses and thus be able to limit the effects of secondary damage after eccentric activity. However, an increase in muscle temperature has been reported to be the most important factor yet Lu and Herbert consider the observed effect to be weak. Consistent with the results the above aforementioned studies, High and Holi did not observe a difference in the rate of peak pain that is also consistent with the results of Law et al., (23,24).

Conclusion

Although the muscles of the body tend to adapt to repeat an unfamiliar activity (2,3,8,19,20), the pain and contusion after the first bout of exercise is undeniable and may prevent athletes from participating in training programs or be a deterrent to his sporting skills.

Introducing existing strategies for the prevention and treatment of delayed onset muscle soreness, including pharmacological and non-pharmacological treatments of DOMS, can help coaches and athletes to overcome this problem and improve the performance of both beginner and professional athletes.

Acknowledgments

We appreciate those colleagues and researchers helped us with this article.

References

1. Gulick DT, Kimura IF, Sitler M, Paolone A, Kelly JD. Various treatment techniques on signs and symptoms of delayed onset muscle soreness. J Athl Train. 1996;31(2):145-52.
2. Armstrong RB. Initial events in exercise-induced muscular injury. Med Sci Sports Exerc. 1990;22(4):429-35.
3. Armstrong RB, Warren GL. Intermittent high intensity exercise: preparation, stresses and damage limitation. London, Spon.1993; P: 275-85.
4. Fox and Matthew. Physiology of Exercise (Asghar Khaledan, Translator). Tehran, Tehran University Press. 2005. (Persian)
5. Sanadegol H. Exercise Physiology. Publications of the National Olympic Committee Volume I, 1993. (Persian)
6. Wilmore Jack H, Castiel David L. Physiology of Exercise and Physical Activity. Translation. Innovative Publications. 2000. (Persian)
7. william D, Mc ardle, Frank. L, Katch. Victor. L. Katch. Essentials of Exercise Physiology. Lippincott Williams & Wilkins, 2006 - 753 Seiten
8. Heiss R, Lutter C, Freiwald J, Hoppe MW, Grim C, Poettgen K, et al. Advances in Delayed-Onset Muscle Soreness (DOMS) - Part II: Treatment and Prevention. Sportverletz Sportschaden. 2019;33(1):21-29. English. doi: 10.1055/a-0810-3516.
9. Faulkner JA, Brooks SV, Opiteck JA. Injury to skeletal muscle fibers during contractions: conditions of occurrence and prevention. Phys Ther. 1993;73(12): 911-21. doi: 10.1093/ptj/73.12.911.
10. Bennett M, Best TM, Babul S, Taunton J, Lepawsky M. Hyperbaric oxygen therapy for delayed onset muscle soreness and closed soft tissue injury. Cochrane Database Syst Rev. 2005;(4):CD004713. doi: 10.1002/14651858.CD004713.pub2.
11. Dariusz B, Beata O, Sylwia S, Jakub G A, Dariusz B. Influence of Physical Activity on Reduction of Delayed Onset Muscle Soreness. Central Eur J Sport Sci Med. 2015;12(4) 83-90. doi:10.18276/cej.2015.4-09.
12. Jouris KB, McDaniel JL, Weiss EP. The Effect of Omega-3 Fatty Acid Supplementation on the Inflammatory

[Downloaded from demo.medilam.ac.ir on 2026-11-15]

Response to eccentric strength exercise. J Sports Sci Med. 2011;10(3):432-8.
13. Smith LL, George RT, Chenier TC, McCammon MR, Houmard JA, Israel RG, ET AL. Do over-the-counter analgesics reduce delayed onset muscle soreness and serum creatine kinase values? Sport Med Train Rehabil. 1995;6(2):81-8. doi: 10.1080/15438629509512039.
14. Arroyo-Morales M, Olea N, Martínez MM, Hidalgo-Lozano A, Ruiz-Rodríguez C, Díaz-Rodríguez L. Psychophysiological effects of massage-myofascial release after exercise: a randomized sham-control study. J Altern Complement Med. 2008;14(10):1223-9. doi: 10.1089/acm.2008.0253.
15. Donaldson SJ, Ronan KR. The effects of sports participation on young adolescents' emotional well-being. Adolescence. 2006;41(162):369-89.
16. Thomas, M. Robin H, Aaron W. Effectiveness of Sport Massage for Recovery of Skeletal Mudcle from Strenuos Exercise. Clin J Sport Med; 2008; 18(2):446-460. doi:10.1097/JSM.0b013e31818837a1.
17. Woodman N, Tim. H, Lew M. The Relative Impact of Cognitive Anxiety and Self Confidence upon Sport performance: A Meta Analisis. J Sport Sci. 2003: 21(4):433-57. doi: 10.1080/0264041031000101809.
18. David B. Exercise induced Muscle Damage and Inflammatory. J Sci Med Sport: 1994: 26(3);85-99.
19. Guzel NV, Hazar S, Erbas D. Effects of Different Resistance Exercise Protocols on Nitric oxide, Lipid Peroxidation and Creatine Kinase Activity in Sedentary Males. J Sport Sc Med. 2007; 6(4):417-22.
20. Atashak S, Baturak K. The Effect of BCAA Supplementation on Serum C Reactive Protein and Creatine Kinase After Acute Resistance Exercise in Soccer Players. Ann Biol Rese. 2012; 3(1):150-7.
21. Scott K, Powers, Edward T, Howley. Exercise Physiology Theory and Application to Fitness and Performance. Fourth Edition, By MC Grow Hill Companies; 2001.
22. Clarkson PM, Hubal MJ. Exercise-induced muscle damage in humans. Am J Phys Med Rehabil. 2002;81(11 Suppl): S52-69. doi: 10.1097/00002060-200211001-00007.
23. Law RY, Herbert RD. Warm-up reduces delayed onset muscle soreness but cool-down does not: a randomized controlled trial. Aust J Physiother. 2007;53(2):91-5. doi: 10.1016/s0004-9514(07)70041-7.
24. High DM, Howley ET, Franks BD. The effects of static stretching and warm-up on prevention of delayed-onset muscle soreness. Res Q Exerc Sport. 1989;60(4):357-61. doi: 10.1080/02701367.1989.10607463.

[Downloaded from demo.medilam.ac.ir on 2026-11-15]