Mechanical Tissue Damage:
Implications for Performance and Prescription
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The Source of Mechanical Muscle Damage

The leading cause of muscle damage related to exercise stems from mechanical factors. Muscle tension, and active strain on lengthened fibers during *eccentric* contractions produce direct trauma to the muscle tissue (12). This differs greatly from the proposed oxidative stress placed on muscle tissue with pro-longed, intense endurance exercise. As it is known, dynamic muscle function in acyclical, impact sport occurs as a sequence of active eccentric muscle actions followed by active concentric muscle actions known as the stretch-shortening cycle (SSC) (1). Since eccentric contractions contribute to the SSC, it is not a surprising phenomenon that muscle damage occurs during prolonged or intense exercise such as distance running, plyometrics and resistance training (1). These activities are commonplace in training programs for most athletes.

The hypothesis that attempts to explain the physiology behind eccentric-based mechanical muscle damage is that fewer motor units are recruited to handle the same load and force per cross-sectional area of muscle. This demonstrates that eccentric work requires fewer muscle fibers to do the same amount of concentric work, and that less energy is required to perform the eccentric work. Tension per unit of active muscle mass is also greater, which results in more damage to the muscle. At the cellular level, Z-line streaming, which is explained as "disorganization of the area that joins the repeating contractile elements of the myofibrils together" and myofibrillar disruption are direct manifestations that muscle damage has occurred (12). Furthermore, calcium homeostasis and excitiati on-contraction coupling are impaired and examination of eccentrically damaged muscle shows damage to the sarcolemma, T-tubules, myofibrils and the cyoskeleton (12). All of these structural changes to the muscle fiber are actually present as soon as 5-15 minutes post exercise.

The Impact of Muscle Damage on Performance

It is common and normal to experience pain and muscle stiffness with a new training program. This phenomenon, as we all know, is known as delayed onset of muscle soreness, or DOMS, and is associated with muscle fiber injury. DOMS is most prevalent at the beginning of the sporting season or a new training program when athletes are returning to training following a period of reduced or varied activity (2).

Following exercise, for approximately 8 hours, muscles are generally pain free (1). DOMS begins the first 24-48 hours after exercise and peaks between 24 and 72 hours (3,4,5). All discomfort usually subsides within 96 hours (1). Along with the soreness, comes other related symptoms such as prolonged muscle weakness, a decreased range of motion and muscle protein leakage into the blood plasma.

There is evidence, in the literature, that neuromuscular functions can be impaired by muscle soreness. Kinematic analysis of gait mechanics following DOMS has revealed reductions in range of motion about the ankle, knee and hip joints (2). These changes could be due to a reduced range of motion in the quadricep muscle group and a subsequent reduction of shock absorption capability of the lower body (2). Since eccentric contractions are vital for shock absorption or braking in the direction of gravity, altered gait patterns can have negative effects on shock absorption abilities of the lower extremities. Muscle injury may also lead to altered recruitment patterns or changes in the temporal sequencing of muscle activation (2). Findings of altered neuromuscular control such as time to peak EMG and time to peak contraction velocity have been researched and were found to persist for up to 5 days (2).

Absolute reductions in strength and power have also been documented by numerous researchers (2). The duration of strength reduction, most notable after eccentric contractions, was found to be 8-10 days following the training session. Conversely, concentric strength recovered more rapidly, only taking 4 days (2) Many researchers have unfortunately failed to collect repeated strength data on back to back days which has important implications for the athlete who may be at risk for injury as they suffer through a deficit in a muscle group while they continue to train (2).

DOMS is certainly a "subclinical" injury (2). However, sometimes athletes are required to practice and train during periods of intense muscle soreness. These effects can raise questions about whether or not to work through the pain or rest and recover. The following risk factors should be noted during this time (2):

1. DOMS can reduce the cushioning effect during landings and running. To compensate, increased shock absorption will occur at other joints causing unaccustomed strain.
2. Changes in co-ordination may also lead to unaccustomed strain to be placed on muscles, ligaments and tendons during functional activity - motor unit recruitment patterns may be altered and in this vulnerable state, training may worsen present damage (8).
3. A decrease in force output in a muscle group or to fibers of a muscle may lead to compensatory recruitment from uninjured areas leading to altered agonist/antagonist ratios and increased stress on compensating muscle groups - Reductions in jumping performance, after exercise-induced muscle damage, lasted up to 4 days (1).
4. An inaccurate perception of impairment or a reduction in DOMS may also cause an individual to return to high intensity activity before the muscle has adequately recovered.
5. An elevated physiological response to endurance exercise has been reported after muscle damaging exercise where breathing frequency, respiratory exchange ratio, heart rate and RPE were all significantly higher two days after eccentric exercise when compared with concentric exercise (1).

Managing Muscle Damage

Pain serves a critical purpose. It acts as a reminder to the athlete that impairment to the muscle still exists. The sensation of soreness comprises muscle tenderness, pain on palpation and mechanical stiffness that results in pain when the muscle is stretched or activated (8). The tenderness often is described as localized in the distal portion of the muscle in the region of the musculotendinous junction. Tenderness within this region could be due to the fact that muscle pain receptors are most concentrated in the region of the tendon and connective tissue in the muscle. Angles of the fibers to the long axis of the muscle are greatest in the region of musculotendinous junction, increasing the susceptibility of the fibers to mechanical trauma. In severe DOMS, the pain is generalized throughout most of the muscle belly.

It has been suggested that 3 training sessions per muscle group per week is a minimum frequency for gaining muscle size and strength (10,11). Therefore, if this training frequency is followed, some training sessions may be performed when the muscles are still experiencing delayed onset of muscle soreness (DOMS) from the previous session. Generally speaking, if exercise-induced muscle damage occurs, it can be harmful for the tissue to receive another damaging stressor again *early* in the recovery process (10,11). However, if the initial damage is induced via eccentric based activity like plyometric training this may not be the case. Previous studies have shown that performing repeated bouts of eccentric exercise 3 and 6 days (72 -144 hours) after the initial bout did not result in further damage or retard the recovery process (10,11).

Currently no studies have examined muscle damage and soreness induced in a practical situation where more than 3 training sessions are adhered to per week, with some separated by less than 24 hours of recovery. Also, no studies have used highly trained subjects when measuring repeated bouts of eccentric exercise and the effects on DOMS.

Nonsteroidal anti-inflammatory drugs (NSAIDs) such as aspirin, ibuprofen, and flurbiprofen have long been considered as a treatment for alleviating the symptoms of DOMS. Theoretically, NSAIDs have a strong case for helping to combat the inflammation and swelling which occurs with exercise induced muscle damage. A parallel review of NSAID's basically concludes that they are simply not warranted This review also reported th at the use of such drugs may hinder the healing process and affect long-term muscle adaptation, so important to athletes in their development. Furthermore, unwanted physiological side effects may also occur including gastrointestinal and renal complication s (12).

The athlete and the strength and conditioning coach should be aware of the potential implications of exercise-induced muscle damage on sport performance and the time course for recovery between training sessions. Periodization plans must account for the days following eccentrically biased training, which results in mechanical muscle damage. Prevention has been identified as the most appropriate approach to overtraining, thus emphasizing the role of thoughtful planning of training and recovery is critical (1). "Of particular concern is the approach to optimizing recovery following muscle damaging exercise, allowing an immediate return to training and further competition, as is commonly associated with intermittent, high-intensity activities (1)."

The main conclusion is that adapting the body more effectively to eccentric stresses can reduce the impact of DOMS. In addition to warming up, Szymanski (13) introduces the repeated-bout effect as a meaningful means of reducing DOMS. It has been reported that repeated bouts of lower intensity eccentric exercise performed 1-6 weeks before the initial higher intensity eccentric bouts have been shown to consistently reduce DOMS and exercise induced muscle damage. Thus, a gradual introduction of eccentric exer cise, over a period of weeks, is encouraged. Szymanski states that the repeated bout effect is proposed to allow for a faster recovery of strength and range of motion in effected muscles, providing for increased resistance to damage after the first bout. It is also thought that muscle and connective tissue gradually adapt to increasing intensities of eccentric exercise, minimizing incidence and severity of DOMS.

Further examinations (12) expand on this and enforce the need to allow one to two days of reduced intensity training following activities likely to invoke DOMS. In other words better and more appropriate and specific training including resistance loading and progressive time-based training more in keeping with the capability of the body to adapt to t he overload applied and to allow adequate recovery rather than continue to produce the DOMS effect in training or competition. Finally, in this review series another set of authors (6) looked at the effect of chronic muscle damage from repeated exercise bo uts and the effect this has on the ability of the body to continuously remodel skeletal muscle. Ultimate limitations do exist and there appears to be a point at which the capacity for repair and adaptation is exhausted.

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