The Role of Warming-Up and Stretching to Prevent Injuries: With a Focus on Muscle Strains

One of the most common injuries to the body is a muscle strain. This type of injury has an increased incidence in high speed sports that involve quick acceleration and decelerations. A recent study reports that muscle strains are 10-40% of all injuries occurred in sports like soccer, Australian football and American football11. An additional study shows that stretch-induced injuries account for close to 30% of the injuries seen in a typical sports medicine clinic12. Findings show that muscles that cross multiple joints are more susceptible to a strain injury. Strain injuries do not result solely from the muscle contraction; they are the result of excessive stretching, or stretching while the muscle is activated. Once the muscle has torn, it is weaker and at an increased risk for re-injury10,17.

Recent data has emerged that looks at the effect of warm-ups, temperature, stretching and eccentric loading on the mechanical properties of muscle and their abilities to decrease the risk for injury14,17,18. With the high reoccurrence rate of muscle strains, it is imperative to decrease the initial incidences of this type of injury. The following paper will aim to look at the physiological effects of warming up and stretching the tissues and what the current evidence shows about various ways to reduce the risk a muscle strains.

There are three types of muscles: cardiac, smooth and skeletal. The muscle strains that are referred to in this paper are strains of the skeletal muscles. Skeletal muscles have a contractile portion that is composed of striated muscle and a non-contractile portion that is composed of collagen bundles. These muscles are attached directly or indirectly through tendons and aponeuroses to bones, ligaments or fascia. When a muscle contracts, the fibers shorten to 70% of their resting length1. There are three ways that a muscle can contract. These three ways are reflexive contraction, tonic contraction and phasic contraction. Muscle strains occur with phasic contractions. These contractions consist of isometric contractions, where the muscle length stays the same and isotonic contractions, where the muscle length changes and movement is produced1. Concentric and eccentric contractions are two types of isotonic contractions. Concentric contractions cause shortening of the muscle to produce movement, whereas eccentric contractions lengthen the muscle in order to produce movement1,18.

The muscle-tendon junction is the interface between the end of the skeletal muscles and the end of the connective tissue of the tendons13. A large amount of membrane folding at the junction creates increased contact area and increases the strength of the interface13. Muscle strain injuries are a disruption of this muscle-tendon unit. It is generally accepted that muscle strains occur when the muscle is stretched passively or activated during a stretch. Once a muscle strain occurs, it disrupts the vascular and connective tissues in the area and causes muscle fiber damage10. These injuries often occur with eccentric contractions because the muscle forces are generally higher when the muscle is contracting and lengthening. Strain injuries that result from passive and active stretching most frequently occur at the distal muscle-tendon junction12. Close proximity to the muscle-tendon junction has the highest incidence of injuries, specifically at the muscle-tendon junction of the biceps femoris in the case of hamstring strains10,13.

The connective tissue framework of the muscle is the primary source of the muscle’s resistance to passive elongation. This connective tissue framework includes the endomysium, the perimysium and the epimysium. When the muscle is stretched, the stretch force is transmitted to the muscle fibers via the endomysium and the perimysium. Passive stretching creates a rapid increase in the tension of the connective tissue. This causes the cross-bridges of the filaments to slide apart and creates lengthening of the sarcomeres, which is also referred to as “sarcomere give”². After the stretch force is removed, the sarcomeres return to their original resting length. In order to achieve more permanent length increases, the stretch force on the muscle needs to be maintained for an extended period of time².

Connective tissue deformation requires breaking of the collagen bonds and realignment of the fibers in order to create permanent elongation and increased flexibility in the area². Microfailure is a way to create this permanent lengthening of the tissues. This can be completed through the ideas of creep, stress-relaxation and cyclic loading. The mechanical behavior of non-contractile tissue is determined by the proportion of collagen and elastin fibers present. Collagen fibers absorb the majority of the tensile stresses. They elongate quickly and under light loads. Collagen fibers are five times as strong as elastin fibers, but only elongate 10% of their length, whereas elastin fibers can elongate up to 150% without permanent deformation2,13.

Creep occurs when a low-magnitude load is applied for an extended period of time13. This results in a gradual rearrangement of collagen fibers and redistribution of water within the surrounding tissues. Complete recovery of creep can occur, but it occurs at a much slower rate than the recovery that occurs from a single strain to the area². Stress-relaxation occurs when the length of the tissue is kept constant and the force required to maintain the length decreases over time13. This theory also relates to the viscoelastic qualities of the connective tissues². Cyclic loading can be used by applying repetitive sub-maximal loads successively. This repetitive loading can increase the heat production in the area and create a failure beyond the original yield point². One study found that the tension in the muscle decreased by nearly 17% after completing ten cycles of stretching the muscle 10% past its resting length. The majority of the reduction in tension occurred after the first four cycles12. This repetitive stretching reduces the overall load on the muscle-tendon unit².

Flexibility is an intrinsic property of the body that has been shown to increase with several types of stretching: passive, isometric, static and ballistic. It is what determines the range of motion that is achievable at each joint without causing an injury like a muscle strain². Numerous studies have shown that stretching programs can increase a person’s flexibility; however, the link between increased flexibility and decreased risk of injury is still being debated. The literature review completed by Thacker et al. found 27 studies whose results supported the use of stretching to increase a person’s flexibility at the knee, hip, trunk, shoulder and ankle joints17. When creating a stretching program, it is important to think about the type, intensity, duration and frequency of the stretches.

The intensity of the stretch depends on the level of the load that is applied to the muscle. Several research studies show that a low load producing a low intensity stretch is ideal for elongation. This low-intensity stretch is more comfortable for the patient, which results in a decrease in muscle guarding during the stretching maneuver. Low-intensity stretches have also been shown to elongate connective tissues with less soft tissue damage than high-intensity stretches, which is ideal for injured, recovering or older tissues².

The duration of the stretch refers to how long the patient holds the stretch during a single cycle. If a stretch is held for a shorter duration, then more repetitions are needed3,4,6. Several studies provided conflicting evidence regarding the ideal duration. One study by Cipriani et al. found that two repetitions of 30-second hamstring stretches were just as effective as six repetitions of 10-second stretches for increasing flexibility5. Roberts et al. compared the effects of differing durations of stretches. One group held the stretch for 5-seconds, nine nine times; the other group held the stretch for 15-seconds, three times. After five weeks, they found significant improvements in the range of motion of both stretching groups as compared to the control group that did not stretch7. These studies show that the total duration of stretch is more important than the duration of the individual repetitions5,7. Additional evidence proves that there is no further benefit to holding the stretch cycle longer than 60 seconds in any population4,17. The stretches completed in these studies were static stretches4,5,7. Static stretching involves elongating the soft tissues past the point of resistance and holding it there in the lengthened position for a period of time. It has been found that static stretching is a safer than ballistic stretching; due to the fact that the tension created in the muscle during static stretching is about half the tension created during ballistic stretching².

Ballistic stretching involves a rapid and forceful intermittent stretch. This stretch is high-speed and high-intensity. It is often achieved from bouncing movements that use the momentum of the body part to move it through the desired range of motion. Ballistic stretching has been shown to increase range of motion and flexibility, but also create an increased amount of trauma to the area, which results in an increased amount of muscle soreness17. Therefore, ballistic stretching can be used in young, healthy populations; however, it should not be used for the elderly since their tissues are already weakened and easily injured. Ballistic stretches also should not be used for individuals returning from an injury, since their muscles are in a compromised state. Patients who have been injured but wish to return to dynamic sports or activities can use a Progressive Velocity Flexibility Program. This consists of beginning with static stretching and slow, short end-range stretching; then transitioning to slow-full range stretching, fast-short end stretching and finishing with fast- full range stretching. This program allows for a safe transition from static stretching into ballistic stretching, which is required to regain their dynamic flexibility².

An additional component of a stretching program is the frequency of the stretch. This refers to the number of stretches completed each day, or each week. Currently there is no evidence based research that looks at the frequency of a stretching program. Generally it is recommended that stretching 2-5 sessions a week, while allowing the muscles time to heal between sessions, is ideal. There is a fine balance between the collagen breakdown and repair required to see an increase in tissue lengthening and causing injury to the tissue. Goniometry measures can be used to establish if flexibility gains are being made, or to determine if negative results are occurring. If a person is not gaining range of motion, low levels of inflammation could be forming in the muscles from repetitive stress, which could create hypertrophic scarring in the area².

Gains in flexibility are transient. One study by Willy et al. found that increases in muscle range of motion and flexibility only last four weeks after ending a stretching program9. An additional study found that applying a cold compress to the tissues after they have been stretched, minimizes the post-stretch muscle soreness that formed as a result of microtrauma associated with stretching. Positioning the muscle in a lengthened position while being cooled has been shown to have an increase in the range of motion that is maintained from the stretching8. Thacker et al. found that the duration of increased flexibility after completing a stretching program lasted between 6-90 minutes; however, completing a stretching program for an extended period of time showed an increased flexibility for several weeks17.

In many instances, stretching is found in conjunction with a pre-competition/activity warm-up. Warming the tissues before stretching has been documented in numerous studies to increase the extensibility of the contractile and non-contractile tissues. The warmed muscle is able to stretch further before failure and produce an increased amount of muscle force. This also increases the strength of the muscle-tendon junction 12. The term “warm-up” is defined as a preparatory period of exercise to enhance the performance of the athlete in the subsequent competition or training exercises14. The purpose of low-intensity active exercises is to increase circulation and core body temperature2. It also increases the speed of nerve impulses, decreases the muscle viscosity and decreases the activation energy for cellular reactions. These processes prepare the body for the subsequent vigorous exercise17. In addition, it is a way to warm-up the large muscle groups prior to stretching. Several studies have shown that completing a warm-up or using a thermal agent, without stretching, has no effect on improving the flexibility of the muscles. Using a warm-up, followed by a stretching program, has shown significant improvements in the subject’s range of motion². One limitation is that frequently athletes prepare for competition by completing a warm-up and stretching program; therefore, it is difficult to assess the independent effects of preventing injury from these two pre-exercise components17.

Fradkin et al. completed a systematic review that looked at randomized control trials researching the effects of warming-up and stretching for reducing sports injuries. All of the articles included at least one of these three features of a warm-up. These components included: a period of aerobic exercise to increase the core body temperature, a period of sport-specific stretching and a period of exercise that incorporated movements similar to the ones being used in the following sport’s activity. None of these articles investigated the cumulative role of these three components; therefore, this is an area that needs further research. One common conclusion from all of the articles is that merely stretching does not prevent injuries14.

Within the systematic review, only five articles met the inclusion criteria. Of these five, three of them found that completing a warm-up prior to intense physical activity, significantly reduced the risk of injury14. One specific article used a period of warm-up during halftime of American football games. This period of warm-up significantly reduced the number of strains and sprains that were experienced in the 3rd quarter, compared to the control group that did not complete the warm-up. Their warm-up included 30 seconds of light running followed by 30 seconds of moderate running, 30 seconds of jumping jacks, 15 seconds of trunk twists, and then 25 seconds of hamstring, groin and quadriceps stretches15. An additional study looked at a population of handball players and found that the players in a control group were 5.9 times more likely to sustain an injury that the players in the intervention group, who completed a warm-up before competition and training. This study used a much longer warm-up period. It included 10-15 minutes of an aerobic activity with an ankle disk followed by two functional activities for each of the major muscle groups16.

Interestingly, in the two articles from the review that did not support the use of a warm-up to decrease injuries, their warm-ups relied heavily on the stretching component. One article only used 20 second stretches as a warm-up, whereas the other article showed a very poor compliance rate with the warm-up activities prior to beginning the intense activity14. It was established earlier that the duration of the stretch should ideally be 30 or 60 seconds to achieve optimal results4,5,6. Other studies concluded that using stretching as the sole component of the warm-up is not sufficient to decrease the risk and incidence of injuries. Therefore, it is clear that a low compliance rate with the given warm-up, and a warm-up that focused strictly on stretching do not provide significant evidence to refute the claim of using warm-ups to decrease sport-related injuries14.

Looking specifically at muscle strain injuries, the evidence regarding warm-up and stretching is conflicting. Some authors found decreases in muscle strains after completing these pre-exercise components; however, numerous other authors did not. Since it is unethical to create muscle strain injuries in humans, Garrett et al. used rabbit models to examine the viscoelastic properties of muscles. The researchers first determined the overall force to failure of the rabbit’s hindlimb muscle. Then, ten cycles of stretching to 50% of the failure force were applied to the muscle. This resulted in an increase of muscle stretch at failure; therefore, reducing the incidence of muscle strain injuries by completing cycles of cyclic stretching12.

It is critical to identify an athlete’s risk factors for muscle strain injuries. These risk factors include: decreased flexibility, decreased muscle endurance, decreased strength, increased age and previous history of muscle strains to the area. Pre-season training provides a period of time where the athlete can focus on these risk factors11. Extensive evidence has been provided above that looks at increasing the flexibility of an athlete. It has been found that one of the underlying mechanisms for hamstring strains is the rapid changes from eccentric to concentric muscle contractions. Researchers have suggested that since hamstring strains commonly occur during the eccentric phase of the muscle contraction, prevention strategies should include overloading the muscle with eccentric specific exercises10. The results from one study show that using repeated bouts of eccentric muscle loading can cause a shift in the length-tension curve, which results in a peak tension that is created at an overall longer muscle length and can reduce the potential for a stretch-injury to the area18. This is illustrated by the diagram in Appendix A, Figure 118.

Hibbert et al. completed a systematic review that looks at the role of eccentric strength training for preventing specifically hamstring muscle strain injuries. Three studies used a “hamstring lowers” protocol where the participants had their legs secured and they lowered their body eccentrically to the table. A picture of this is found in Appendix A, Figure 218. Results from these studies showed that the incidence of hamstring strains was 65% lower for the “hamstring lowers” group versus the control group; however, the severity and re-injury rates were not significantly different between the groups10. An additional study found a significantly lower incidence of hamstring strains in the “hamstring lowers” group than from a conventional strengthening program. One thing to note is that none of these studies looked solely at the effect of eccentric hamstring strength training. All of them used combined stretching and general strengthening protocols; therefore, further research is recommended that isolates the effect of the “hamstring lowers” protocol and its consequences on hamstring strains10,18.

When someone is trying to decrease the incidence of sports-related injuries, it is critical to look at the risk factors11. In order to decrease these risk factors, the focus should be on a proper warm-up and stretching program prior to vigorous activity, combined with an eccentric-focused strengthening protocol. Creating an appropriate warm-up for an athlete should have a balance between the intensity and duration of the pre-exercise period. It is vital to complete a warm-up that is long and intense enough to increase the body temperature of the athlete, but without over fatiguing them, since that could impact their overall performance14. Stretches should be held for 30-60 seconds, with the type of stretch depending on the activity of the athlete4,5,7,17. Lastly, eccentric strengthening can be added to the strengthening program to decrease the hamstring muscle’s vulnerability to the lengthening contractions10,18. Completing these things can reduce the athlete’s overall risk for sustaining a muscle strain or other sports-related injuries.

Appendix A

Figure 1- Optimum angle for torque generation shifted in the direction of longer muscle length18



Figure 2-“Hamstring Lowers” protocol18



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