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Cold therapy of sporting injury in upper thigh region a comprehensive study on the time required to achieve optimal cooling and the effects of swelling

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Abstract
One of the most common injuries amongst athletes is soft tissue injury due to impact, and the traditional treatment for this is cold therapy using an ice pack. While this treatment is effective, inexpensive, and easily accessible, there is very little quantitative data available on the actual effects of ice on the muscle. The most common advice found in medical textbooks and literature is a 20 minute on, 20 minute off icing cycle. In this study we model the temperature distribution in the upper leg region after one and a half cycles of ice therapy. Our ax symmetric model consists of three layers: skin, fat, and muscle, and we include an initial swelling of the muscle layer that decreases as a function of the muscle temperature. After an initial 20 minutes of cooling, the desired temperature change of 10°C penetrated to only 4 mm into the muscle layer, but after a 60 minute cycle, the desired cooling increased to 1 cm. Our sensitivity analysis revealed that slight changes in properties such as density, specific heat and conductivity did not alter the results significantly. Also, using a fixed muscle thickness independent of temperature yielded a lower temperature drop in the muscle layer. It was concluded that ice therapy, though slow, is effective in cooling some of the muscle to the desired temperature, and its main advantages stem from its inexpensiveness and ease of application. One of the most common injuries amongst athletes is soft tissue injury due to impact.

Keywords: common injuries, muscle, tissue injury

Introduction
One of the most common injuries amongst athletes is soft tissue injury due to impact, and the traditional treatment for this is cold therapy using an ice pack. While this treatment is effective, inexpensive, and easily accessible, there is very little quantitative data available on the actual effects of ice on the muscle. The most common advice found in medical textbooks and literature is a 20 minute on, 20 minute off icing cycle. In this study we model the temperature distribution in the upper leg region after one and a half cycles of ice therapy. Our ax symmetric model consists of three layers: skin, fat, and muscle, and we include an initial swelling of the muscle layer that decreases as a function of the muscle temperature. After an initial 20 minutes of cooling, the desired temperature change of 10°C penetrated to only 4 mm into the muscle layer, but after a 60 minute cycle, the desired cooling increased to 1 cm. Our sensitivity analysis revealed that slight changes in properties such as density, specific heat and conductivity did not alter the results significantly. Also, using a fixed muscle thickness independent of temperature yielded a lower temperature drop in the muscle layer. It was concluded that ice therapy, though slow, is effective in cooling some of the muscle to the desired temperature, and its main advantages stem from its inexpensiveness and ease of application. One of the most common injuries amongst athletes is soft tissue injury due to impact. Typically, as a result of impact, cells in the underlying muscle tissue rupture, causing a bruise, while the cells of the skin and fat layers remain undamaged. For treatment of these common soft tissue injuries, cold therapy has been used for thousands of years, and while any physician today will agree that it is effective, there is very little data and even fewer studies on the actual effects of putting ice on an injured site.

Because of this, recommendations for the duration of application vary from physician to physician and even in medical textbooks. In this project, we hope to examine the effect of applying ice on soft tissue injury in the leg by modeling this process in COMSOL. To create a realistic model, we will consider factors such as metabolic heat generation and swelling due to impact.

Problems Encountered

The modeling of constriction of muscle upon ice cooling required implementation of a moving boundary and mesh. Unfortunately, we could not successfully incorporate the thermal constriction into FIDAP, because FIDAP cannot model an elastic solid, though this problem could have been addressed by defining the muscle layer as fluid with very high viscosity. However, we chose not to pursue that option and decided to model using another finite element software package, COMSOL Metaphysics. With the more user-friendly interface and capability to model a moving mesh, we could come up with a reliable solution for simulating the cooling of injured muscle.

Defining the mathematics of thermal constriction was another challenge. The literature on this subject is rather limited; sports medicine journals were our primary sources in our literature search. However, studies in the field were generally heuristic, lacking mathematical explanations on the process. While there were some studies on effect of temperature change on vascular dilation in muscle which were more mathematically oriented, the relationship between a single blood vessel and a whole muscle was not discussed.

Design Recommendations

Our model found that after 60 minutes of a "20 minute on, 20 minute off" cycle, the desired temperature drop of 10°C was achieved 1 cm deep into the muscle layer. While this method does achieve the desired cooling, there is still room for improvement. We therefore recommend looking into other forms of cooling or different timing cycles. For example, using cold running water over the leg may provide a quicker cooling of the deep muscle tissues than using an ice pack. Similarly if the ice is applied for longer it may be possible to cool deeper into the muscle. However, the therapy as presented in this report is a convenient and cheap method of cooling some of the muscle.

Exercises to treat a pulled groin

In most cases, this type of injury will heal on its own, but after a few days of rest when the pain has started to subside, you can help move the process along by performing stretching and strengthening exercises.

Stretching Exercises

Start with gentle static stretches and move on to dynamic stretches when you can do the static stretches without pain. For each static stretch, hold the position for 30 seconds and repeat it several times a day.

- **Seated short groin stretch:** - While seated on the floor, bend the knees and bring the soles of the feet together in front of you. With a straight back, use your elbows to gently push your knees toward the floor until you feel a light stretch in the inner thigh and hold the position.
- **Seated long groin stretch:** - From a seated position, extend both legs out to the sides of your body to create a V shape. With a straight back, gently walk your hands forward as you bring your torso toward the floor and hold the position. Repeat this process while facing each leg.
- **Hip flexors stretch:** - Start in a forward lunge position and lower the back knee to the floor. Keeping your shoulders above your hips, gently lean forward to stretch the muscles in the front of the hip and hold the position. Repeat on the opposite side.
- **Swinging leg stretch:** - Balancing on one leg, swing the opposite leg forward and back without forcing it to go too high. The motion should feel relaxed and not strain the muscles in the hip and groin. Swing each leg for 10 repetitions.

Strengthening Exercises

When you are ready to start stretching exercises, you can also complement them with movements that will strengthen the muscles in the groin area. Again, start with static exercises and then move on to dynamic ones.

- **Bent-knee adductor exercise:**- Lie down with your knees bent and feet flat on the floor. Use a small medicine ball placed between the knees to create resistance and squeeze for five-second intervals. Repeat 10 times and increase the duration and number of repetitions as strength improves.
- **Straight-leg adductor exercise:**- Remain in a reclined position and extend the legs flat on the floor. Place the medicine ball between the ankles and repeat the squeezing exercises outlined above.
- **Hip adduction against gravity** - Lie on your side on the floor with the top leg raised and the ankle resting on the seat of a chair, with the bottom leg under the chair. Slowly lift the bottom leg to touch the bottom of the chair seat, pause briefly, then lower the leg back to the floor. Perform the exercise 10 times on each leg and repeat three times a day.
- **Hip adduction with resistance bands:**- As groin strength improves, you can add more resistance to hip adduction exercises with bands. Secure one end of a resistance band around your ankle, and the other end around an object that will not move. Standing on the opposite leg, position yourself so that the resistance of the band will increase as you gently swing your leg toward the centerline of your body without bending the knee. Do 10 repetitions on each side and increase the number as strength improves.

Additional Pulled Groin Treatment Ideas

Like most other types of soft tissue injuries, a pulled groin will benefit from RICE treatment:

- Rest
- Ice
- Compression
- Elevation

You can administer this treatment with traditional ice packs and compression bandages, or increase the effectiveness of therapeutic cold and compression with a cold therapy system.

If the pain is so severe that cold therapy cannot sufficiently dull it, your doctor might recommend temporarily taking an over-the-counter pain medication to help reduce pain and swelling.

For more information about pulled groin treatment and prevention, download the Guide to Accelerating Hip and Groin Recovery. This free resource provides methods for pain relief and activities you can do to shorten your recovery time.

Conclusion

Injuries to the quadriceps muscle group occur frequently in sports and athletic activities. Muscle strains and contusions constitute the majority of these injuries. The clinical presentation and assessment of quadriceps strains and contusions are reviewed along with discussion of appropriate imaging used in diagnosis. Treatment protocols for acute injuries are reviewed including rehabilitation techniques frequently utilized during recovery. Special consideration is given to discussing the criteria for return to sports for athletes after injury. Myositis ossificans is a potentially disabling complication from quadriceps contusions and risk factors, prevention, and treatment are reviewed.

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