# THE ACUTE EFFECTS OF ACTIVE WARM-UP AND PASSIVE WARM-UP ON PASSIVE TENSION

by

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ABSTRACT

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The purpose of this study was to investigate the effects of active warm-up (stationary cycling) and passive warm-up (heat pack) on the mechanical properties of the hamstring musculature in vivo. Passive tension measurements were recorded during the passive knee extensions of ten men before and after an active warm-up, passive warm-up, and control treatments. The results of the present investigation revealed no effect of active warm-up or passive warm-up on the passive tension variables of energy absorbed, energy returned, peak torque, average stiffness, or peak stiffness of the hamstring musculature. These findings suggest that the mechanical properties of the

connective tissue were unaltered by the warm-up techniques utilized in this study. Although these results do not support the use of active or passive warm-up to facilitate increased muscle tendon unit compliance to stretching activity, we do not recommend discontinuation of these practices before athletic competition, exercise, physical recreational activity, or stretching exercise.

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# CHAPTER 1

## INTRODUCTION

Warm-up and stretching have been reported to improve athletic performance and prevent injury by increasing muscle flexibility (32, 33). There is widespread use of warm-up and stretching in the fields of athletic training, physical therapy, strength and conditioning, and coaching despite limited knowledge of the true physiological effects of warm-up and stretching. Active warm-up includes stationary cycling, jogging, and calisthenics. Passive warm-up includes heat packs, hot whirlpool, ultrasound, and pulsed shortwave diathermy. Previous research suggests that warm-up and stretching improves joint range of motion or flexibility (14, 39) and researchers attribute these gains to changes in the mechanical properties of the muscle (36). Athletes often perform warm-up activities to increase muscle temperature, facilitate stretching exercises, and improve flexibility. Theoretically, a more flexible muscle-tendon unit should be more compliant to external loads, less stiff, and less likely to be injured (24). However, there is little evidence defining the mechanisms responsible for the observed increases in range of motion or flexibility obtained by warm-up and stretching. The observed increases in joint range of motion or flexibility may be due to an increased stretch tolerance (25), an inhibition of reflex activity (12), or a change in the mechanical properties of the muscle-tendon unit (36).

The mechanical properties of the muscle-tendon unit have viscoelastic characteristics that are temperature dependent (10). Many researchers have demonstrated that the muscle-tendon unit is more extensible when temperature is increased (18, 27, 29, 34). One of the theories for the increased extensibility is that increases in muscle temperature should lower tissue viscosity, resulting in improvements in the muscle-tendon unit's extensibility or compliance to stretch. Both passive and active warm-ups are commonly performed to increase muscle temperature in order to enhance stretching exercises through the subsequent reduction in viscosity and muscle-tendon unit stiffness.

Because tissue temperature seems to be an important mediating factor, we explored the literature investigating the effect of increased temperature on muscle-tendon unit stiffness. The methods of raising tissue temperature include both active and passive warm-ups. In vivo research has reported intramuscular temperatures of 38°C and 39.2°C (13, 23, 30) during active warm-ups, including treadmill running and isolated muscle contractions, and temperatures of 35°C to 37°C during passive heat pack warm-ups (7, 21). But most of the research (18, 27, 29, 34) on tissue temperature and compliance to stretch has been performed in vitro or with animal models. To date, only Magnusson et al. (23) has compared the in vivo effect of warm-up on the muscle-tendon unit stiffness. Although the in vitro and animal studies contribute to our knowledge of muscle-tendon unit behavior there are limitations to their clinical meaningfulness. One limitation is that the passive tissue temperatures used may be higher then the actual tissue temperatures obtained with typical active or passive warm-

ups. Therefore, the purpose of this study was to investigate the effects of active warm-up (stationary cycling) and passive warm-up (heat pack) on the mechanical properties of the hamstring musculature in vivo. We predict that active warm-up (stationary cycling) will be a more effective method to reduce passive tension and prepare the muscle for stretching and activity then passive warm-up (heat packs) because intramuscular temperature should be greater after the active warm-up.

## 1.1 Hypothesis

We predicted that active warm-up would invoke the following changes in the muscle-tendon unit properties: decreased stiffness, decreased energy returned, and a decrease in energy absorbed due to a decrease in viscosity.

## 1.2 Definitions

Muscle flexibility - the ability of a muscle to lengthen, allowing one joint (or more then one joint in a series) to move through a range of motion.

Elasticity - the property of a tissue to return to its original shape after a force is removed.

Viscous - properties are characterized as temperature and time-dependent where the rate of deformation is directly proportional to the applied forces.

Viscosity - the property of materials to resist loads that produce shear and flow.

Viscoelastic – tissue that displays both viscous and elastic properties.

Hysteresis - a phenomenon associated with energy loss by viscoelastic materials subjected to loading and unloading.

Viscoelastic stress relaxation - the decline in tension during a prolonged stretch

Passive stretching - the elongation of connective tissue using either a partner or machine, with no muscle contribution from the subject.

Passive tension - the resistance of the muscle tendon unit to a passive stretch. Peak passive tension - the maximum amount of tension measured during a stretch.

Stiffness - the change in torque (N•m) divided by the change in angle (radians) and is expressed as the slope of the torque-angle curve.

Energy absorbed - the area (J) under the torque-angle curve.

Active warm-up - increasing overall body temperature through active movements of major muscle groups.

Passive warm-up - raising muscle temperature or core temperature by some external means.

## 1.3 Delimitations

The delimitations to this study are:

1) Subjects included males between 19 and 35 years of age.
2) Subjects were healthy as assessed by Pre-exercise Testing Health Status Questionnaire
3) Subjects were physically active, recreationally trained (1-5 hrs a week of regimented exercise)

4) Subjects possessed hamstring skinfold thickness less then 30 mm.

5) Subjects s possessed supine 90/90 knee extension less then 90 degrees.

## 1.4 Assumptions

The assumptions to this study are:

1) Subjects will complete the health history questionnaire honestly.
2) Passive tension measurement is a direct reflection of the mechanical properties of connective tissue.
3) The active warm-up protocol will be sufficient to raise intramuscular temperature.

## 1.5 Limitations

The limitations to this study are:

1) Intramuscular temperature will not be measured.
2) Females will be excluded.
3) Only the acute effects of active and passive warm-ups will be investigated.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Stretching

The goal of stretching is to improve joint range of motion and increase muscle flexibility. Stretching is defined as the process of elongation (1). Muscle flexibility has been defined as "the ability of a muscle to lengthen, allowing one joint (or more then one joint in a series) to move through a range of motion" (41). The goal of the present study is to investigate the effects of active and passive warm-up on the mechanical properties of the muscle-tendon unit during a single passive stretching session. Passive stretching is the elongation of connective tissue using either a partner or machine, with no muscle contribution from the subject (1).

### *2.1.1 Mechanical Properties of the Muscle-Tendon unit*

Biological tissue has the ability to react to a load in a variety of ways depending on the mode, amount, and speed of the forces applied to the tissue. Connective tissue is viscoelastic and displays both elastic and viscous properties. Elasticity refers to the property of a tissue to return to its original shape after a force is removed (1). Viscosity is the property of materials to resist loads that produce shear and flow (1). Viscous properties are characterized as temperature and time-dependent where the rate of deformation is directly proportional to the applied forces (36). Connective tissue is considered viscoelastic because tension decreases with time (viscous) while maintaining

tension (elastic) until failure (36). Hysteresis is a phenomenon associated with energy loss by viscoelastic materials subjected to loading and unloading (1). A viscoelastic material that undergoes hysteresis displays a stress-strain curve that has unequivocal ascending (loading) and descending (unloading) curves, but returns to the same starting point, representing energy loss. Viscoelastic stress relaxation is the decline in tension during a prolonged stretch (26). McHugh et al. (26) observed visoelastic stress relaxation in the human hamstring musculature during 45 s static stretches.

*2.1.2 Stretching Measurement*

Many previous researchers have observed an increase in acute joint range of motion as a result of stretching (8, 39). This increase in joint range of motion is commonly believed to be the result of increased extensibility of connective tissue. However, joint range of motion may not be an accurate method to assess acute changes in muscule-tendon unit extensibility, because observed acute increases in joint range of motion may be due to an increased stretch tolerance (25), an inhibition of reflex activity (12), or a change in the mechanical properties of muscle (36). Many researchers (3, 4, 14, 35, 39) have measured joint range of motion in their flexibility studies despite the possibility of the measurement not representing changes in the mechanical properties of the muscle tendon unit.

A method to measure the mechanical properties of the muscle-tendon unit in vivo has been developed by Magnusson and colleagues (24). The method allows for simultaneous sampling of the angle and velocity of a stretch, and resistance to stretch while recording the electromyographic (EMG) activity of the muscle. The variables of

passive torque, peak passive tension, stiffness, and energy absorbed are measured during the stretch. Passive torque, which represents the passive tension of the muscle tendon unit, is extracted during the measure. Passive tension is the resistance of the muscle tendon unit to a passive stretch. Peak passive torque refers to the maximum amount of tension measured during a stretch. Recording the torque-angle curve during repeated stretches at the same angle and speed allows for stiffness and energy absorbed to be calculated. Stiffness is defined as the change in torque (N•m) divided by the change in angle (radians) and is expressed as the slope of the torque-angle curve. Energy absorbed is the area (joules) under the torque-angle curve. The EMG signal enables the researcher to monitor the muscle contractile response to the stretching load.

*2.1.3 Effects of Stretch on Tendon*

Kubo and colleagues (15-17) have investigated the effects of stretching on tendons. They observed an 8% decrease in stiffness and a 29% decrease in hysteresis after 5 min of continuous static stretching (16) and decreases of 9% and 34% respectively after 10 minutes of stretching (17), indicating an increase in the length of tendon structures. The results of these studies lead the authors to believe that the increases in flexibility created by stretch training are not related to tendon structure elasticity, but are the result of decreased hysteresis and changes in tendon viscosity (15-17).

*2.1.4 Effects of Stretch on Muscle*

Ledderman (19) suggested that during passive stretching most of the elongation would take place in the muscle belly rather than its tendon. During a stretch the

individual length of the actin and myosin filaments remain the same; however, their alignment and attachment to connective tissue changes. The filaments slide past each other allowing the muscle to lengthen. Resting or passive tension is attributed to the parallel elastic component of the muscle and provides resistance to stretching (1). At a given point during a stretch the resting tension increases steeply to resist the stretch, creating elastic stiffness. Titin, a strong connective tissue found in the muscle fiber, produces this elastic stiffness. The series elastic component of muscle also contributes to passive tension. When a muscle is stretched, actin and myosin separate allowing the actin filaments to pull on the Z-line. As a result, a thickening occurs within the Z-line, which produces elasticity of the muscle fiber (1).

*2.1.5 Effect of Stretch on Muscle-Tendon Unit*

The effect of stretching on the muscle tendon unit has been investigated in animal and human models. Taylor et al. (36) stretched rabbit muscle tendon units 10 times to 10% beyond resting length and observed a 16.6% decrease in peak tension between the 1st stretch and the 10th stretch. When the rabbit tendons were held at a substantial stretch for 10, 30-second repetitions the muscle tendon unit lengthened 3.46% ± 1.08%, showing a change in the viscoelastic properties (36). Many studies have shown a decrease in passive torque resulting from stretching in vivo (2, 8, 15-17, 24). Passive torque has been shown to decrease by approximately 30% with repeated static stretching of up to 45 seconds in duration (24). Fowles et al. (8) observed a 27% decrease in muscle stiffness with prolonged stretching. Magnusson et al. (25) observed a decline in energy from 14.2 ± 2.7 J (stretch 1) to 9.1 ± 1.5 J (stretch 2) after 5, 90-

second static stretches of the hamstring musculature. Viscoelastic stress relaxation has also been reported within the hamstring musculature by a 11.35 ± 1.76 N reduction in force during 45 second static stretching (26).

The speed of stretch has also been shown to influence the muscle-tendon units resistance to stretch. Taylor et al. (36) studied innervated and denervated rabbit tibialis anterior and extensor digitorum longus muscle-tendon units response to stretch at speeds of 0.01, 0.1, 1, and 10 cm/s. Both muscle-tendon unit types exhibited increased peak tensile forces and greater absorbed energy when stretched at faster rates with intact nerves (36). Therefore, the behavior of the muscle-tendon unit in response to stretch can be explained by both neural and viscoelastic properties (36).

## 2.2 Effect of Temperature Increase on the Muscle-tendon Unit

Temperature has a significant influence on the mechanical behavior of tissue and muscle unit under tensile loading (1). Many researchers (18, 27, 29, 34) have observed increases in the extensibility of muscle-tendon units when heated in vitro. Noonan et al. (27) heated rabbit anterior tibialis muscle from 25°C to 40°C and observed a decrease in muscle stiffness. Laban (18) observed an approximate 25% increase in the elastic response of canine tendons when the temperature was raised from 37°C to 42.5°C. Safran et al. (29) showed that a 1°C increase in intramuscular temperature, elicited from electrically stimulated isometric muscle contractions, in rabbit muscle-tendon units required greater force and length of stretch to tear. Strickler et al. (34) observed that tibialis anterior and extensor digitorum longus rabbit muscle

tendon-units passively warmed from 35°C to 39°C in baths were 2.8% and 2.0% more extensible then cold muscles and as a result less susceptible to strain injury. Connective tissue extensibility is inversely related to the tensile strength of connective tissue. Therefore, the tensile strength seems to decrease with increasing temperature (18, 27, 29, 34).

Magnusson and colleagues (23) investigated the influence of increased intramuscular temperature on passive energy absorbtion in vivo. The subjects' resistance to stretch and intramuscular temperature were measured before and after 10 min of treadmill running at 70% of $VO_{2max}$. Resistance to stretch was measured during a 90 second static stretch and intramuscular temperature was measured at a depth of approximately 15 mm into the biceps femoris muscle. Despite an increase of 3°C in intramuscular temperature, the passive energy absorption of the hamstring muscle-tendon unit was not significantly affected. This suggests that intramuscular temperature increases of 3°C do not affect the viscoelastic properties of the muscle-tendon unit (23). These findings demonstrate that a typical active warm-up may not produce changes in connective tissue properties, unlike previous studies (18, 27, 29, 34) that used temperatures above those achieved by active warm-up.

## 2.3 Active Warm-up

Active or general warm-up increases overall body temperature through active movements of major muscle groups (33). A common mode of active warm-up is stationary cycling (5). Active warm-ups are performed to elevate body temperature,

and gain the effects of increased tissue compliance facilitated by increased temperature. However, few studies exist examining the intramuscular temperatures achieved during activity. Kenny et al. recorded maximum vastus medialis intramuscular temperatures of approximately 100°F at 10, 25, and 40 mm during 15 minutes of continuous bilateral concentric knee extensions (13). After 10 min and 30 min of treadmill running at 70% of $VO_{2max}$, Magnusson et al. (23) recorded peak temperatures of 38ºC and 38.8ºC at a depth of 15 mm into the biceps femoris muscle. Saltin and Hermansen (30) observed mean intramuscular temperatures of 39.2ºC after 2 hrs of stationary cycling. These studies investigating intramuscular temperature during activity reported temperatures in the low end range of the temperatures previously demonstrated to elicit the changes in connective tissue(18, 27, 29, 34). Therefore, generalization of in vitro studies (18, 27, 29, 34) to the capabilities of active warm-up may be incorrect. Only Magnusson et al. (23) used activity that could be considered a typical active warm-up and they found no changes in connective tissue resulting from a 3°C intramuscular temperature increase.

*2.3.1 Effects of Active Warm-up on Range of Motion*

Research investigating the effect of active warm-up, independent of stretching, on flexibility has produced conflicting results. Wiktorsson-Moller et al. (38) showed an increase in ankle dorsiflexion after 15 minutes of stationary cycling but no change in hip abduction, hip extension, hip flexion or knee flexion. Others have reported that warm up alone does not increase muscle length (6). Many researchers have observed greater increases in range of motion when stretching following a warm-up was performed vs. stretching alone (14, 39). Willford et al. (39) showed a greater increase

in ankle, hamstring, and shoulder flexibility after 5 minutes of light jogging and stretching when compared to stretching only. These conflicting results may provide little insight into the effect of warm-up on tissue extensibility because joint range of motion may not be a true representation of changes in the mechanical properties of the muscle tendon unit (22). Joint range of motion can be limited by other intrinsic factors like the joint capsule, skin, adipose tissue, and bony structures (1)

## 2.4 Passive Warm-up

Passive warm up involves raising muscle temperature or core temperature by some external means (5). A common method of passive warm up in the athletic training and physical therapy settings is the application of hydrocollator heat packs. Heat packs are stored in a hydrocollator tank filled with 71.1°C to 79.4°C water (20). Heat packs are covered in seven layers of terry cloth and placed on the area desired. Heat is then transferred to the skin and underlying tissue through conduction. The effect of increased temperature on connective tissue has been previously discussed in this review. Despite the widespread use of heating packs in athletic training and physical therapy, few studies exist investigating their effect on intramuscular temperature. Lehmann et al. (21) observed no temperature change 3.9 cm below the skin surface during 30 minute application of hydrocollator heat packs and less than 1°C increase at 3.0 cm depth. During a 30 min hot pack application to the human thigh, Erdman and Stoner (7) recorded only a 0.4ºC intramuscular temperature increase above resting (~37ºC). These findings suggest that temperature increases from hot pack

application are too insignificant to elicit temperature dependent changes in the hamstring muscle-tendon unit.

*2.4.1 Effects of Passive Warm-up on Range of Motion*

Funk et al. (9) compared the effects of 20 min hot pack application vs. 3, 30 s static stretches on the hamstring flexibility of 30 collegiate football players. They (9) recorded hamstring range of motion before and after either hot pack application or static stretching and observed greater mean range of motion after the hot pack treatment. Knight et al. (14) investigated the effect of 15 min hot pack application paired with static stretching on plantar flexor extensibility over four weeks and noted increases in range of motion. These findings suggest that hot pack application may be a beneficial modality when increased range of motion is desired. However, the observed increases in range of motion may not be attributed to temperature induced changes in connective tissue properties due to the small intramuscular temperature increase recorded during hot pack treatment (9, 14).

# CHAPTER 3

# METHODS

## 3.1 Design

Our study used a crossover 3 x 2 (treatment x time) repeated measures design to compare the acute effects of active warm-up and passive warm-up on hamstring muscle passive tension. Treatment had three levels: active warm-up, passive warm-up and control and time had two levels: pre-treatment and post-treatment. The independent variables were treatment mode and time. Dependent variables were the average stiffness (N•m/rad), peak stiffness (N•m/rad), peak torque (N•m), energy absorbed (J), and energy returned (J).

All subjects completed all treatments with a minimum of 48 hours between testing sessions. Treatment order was counterbalanced. Measurements were recorded pre-treatment and post-treatment. Each subject attended a familiarization trial (prior to the experiment) to orient them to the passive tension measurement of the Biodex System 3 dynamometer. Electromyography (EMG) measurements were taken to insure that the subject remained relaxed during testing.

## 3.2 Subjects

Subjects included 10 healthy male volunteers between the ages of 19 and 35 years. Subjects read, signed, and dated the informed consent document before being allowed to participate in the study. Subjects completed a health history questionnaire to

determine eligibility for the study. Subjects were excluded from the study if a health risk was detected due to cardiopulmonary, metabolic, or coronary heart disease. A history of injury to the low back or right lower leg also warranted exclusion from the study. Subjects were also excluded from the study for having a posterior thigh skinfold thickness ≥ 30 mm, or supine 90/90-knee extension equal to 180º.

### 3.3 Instrumentation

A Biodex System 3 Dynamometer (Biodex Medical Systems, Shirley, NY) was used to record passive tension. A Biopac MP100 (Biopac Systems Inc., Goleta, CA) was used to measure the EMG signals from the biceps femoris muscle. The data from the Biopac was imported into a desktop computer (Dell Computer Corporation) for analysis. Moist Heat Packs (Thermal-Pack, Whitehall Manufacturing, Inc., City of Industry, CA) were used as the passive warm-up treatment and stored in a Hydrocollator tank (Chattanooga Corporation, Chattanooga, TN) heated to 76.6°C. A Monark 818 stationary cycle (Vansbro, Sweden) was used for the active warm-up treatment.

### 3.4 Passive Tension Measurements

Passive tension was quantified by measurement of average stiffness, peak stiffness, peak torque, energy absorbed, and energy returned using an isokinetic dynamometer (Biodex System 3). Stiffness is defined as the change in torque (N•m) divided by the change in angle (radians) and is expressed as the slope of the torque-angle curve (22). Average stiffness is defined as the slope of the torque-angle curve during the last 0.1745 radians (10°) of passive knee extension. Peak stiffness is defined as the highest stiffness value recorded during the last 0.1745 radians (10°) of passive

knee extension. Passive torque (N•m) is considered as the resistance to stretch produced by the hamstring musculature during testing. Peak torque is the maximum amount of resistance produced by the hamstring musculature during passive knee extension. Energy absorbed was calculated using two methods. The first method determined the area under the load phase of the torque-angle curve to be energy absorbed. The second method considered energy absorbed to be the area between the load and unload phases of the torque-angle curve. Energy returned is the energy under the unload portion of the force-angle graph for a stretched muscle-tendon unit.

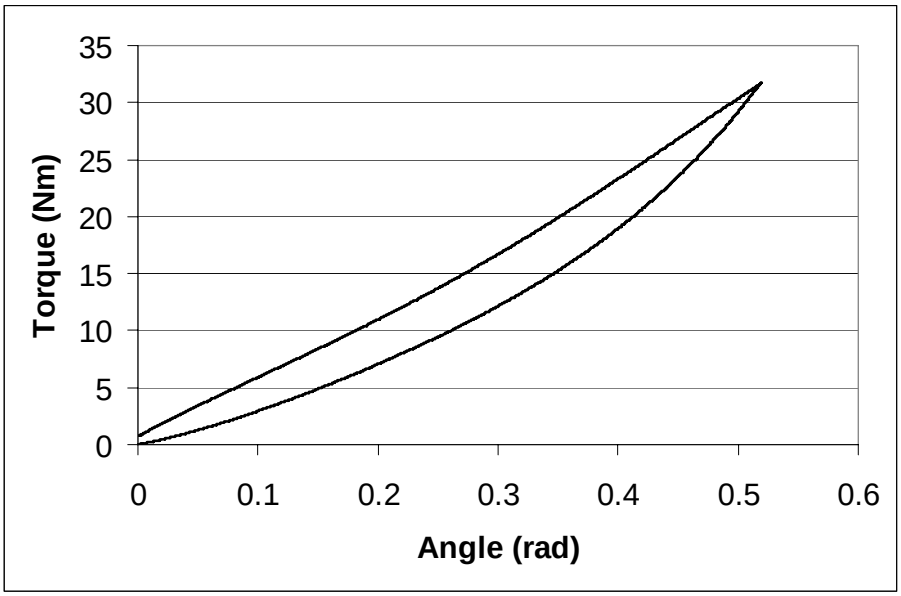


Figure 3.1 Torque angle curve.

## 3.5 EMG Measurement

A 5 x 5 cm area half the distance between the ischial tuberosity and popliteal crease in the center of the biceps femoris muscle belly was shaved, lightly rubbed with emery paper, and cleaned with an alcohol prep pad. A bipolar surface EMG electrode (Noraxon product #272) arrangement was placed on the shaved area over the biceps

femoris muscle belly in the direction of the muscle fiber. The Noraxon electrodes have a 2 cm inter-electrode distance and a circular recording area with a diameter of 1 cm. EMG and Biodex position, velocity and torque signals were sampled using a Biopac 16 bit analog to digital card at 100 Hz. The Biopac EMG amplifier has a common mode rejection ratio CMRR of 100 dB, a bandwidth of 10-1000 Hz and a noise level of 0.2 μV.

### 3.6 Familiarization Trail

Subjects reported to the Neuromuscular Lab (Room 150) located in the Department of Kinesiology Exercise Science Research Laboratories, read and signed an informed consent, and completed a health history questionnaire. Three skinfold measurements were taken over the hamstring muscles half the distance between the ischial tuberosity and popliteal crease. The average of these three measurements determined the skin and subcutaneous fat thickness. If the average was ≥ 30 mm the subject was excluded from the study. The subject's hip range of motion was also measured. The subjects laid supine on a treatment table with their left leg fully extended, and their right hip and knee passively flexed to 90º. A standard goniometer was used to measure knee extension. The fulcrum of the goniometer was centered over the lateral femoral epicondyle, the stationary arm aligned over the midline of the femur in line with the greater trochanter, and the movement arm aligned with the midline of the tibia and the lateral malleolus. The subject's knee was passively extended until the subject reported feeling a strong stretching sensation, and the angle achieved was recorded. If the angle recorded equaled 180º the subject was excluded from the study.

Subjects were then seated with their right hip flexed at 55-60º and secured to the Biodex chair with restraining straps over the torso, hips, and legs. The input axis of the dynamometer was aligned with the axis of the knee and their ankle secured to the dynamometer arm. The dynamometer arm was then positioned parallel to the floor and with this position considered anatomical zero. With the dynamometer arm set at anatomical zero, the limb weight was recorded. The subject's knee was then extended until they reported a strong stretching sensation and the position of the dynamometer arm was set as the maximum for knee extension. The dynamometer arm was then lowered 30º from the maximum position to complete the passive tension measurement range. A torque reading was recorded from a 5 s contraction performed by the subject. The Biodex then passively extended and flexed the knee, through the 30º range of motion, for 60 s at a speed of 0.087 rad/s (5°/s) recording passive tension. The range of motion setting on the Biodex remained the same between pre and post passive tension measurements. When the subjects were returned to the Biodex for post-testing, their hip angle was re-measured and the knee joint realigned with the axis of the dynamometer to ensure that the subjects were in the same position as they were during pre-testing.

## 3.7 Procedures

Subjects reported to the Neuromuscular Lab (Room 150) located in the Department of Kinesiology Exercise Science Research Laboratories. A bipolar surface electrode arrangement was placed on the subject's right biceps femoris to measure EMG. Prior to receiving treatment (active warm-up, passive warm-up, control), passive

tension was measured using a Biodex System 3 dynamometer. The subjects then performed one of the three treatment protocols (active warm-up, passive warm-up, control) followed by passive tension measurement. During each of their three testing sessions the subjects performed a different treatment protocol. The order of treatment was counter balanced.

During the active warm-up protocol a Polar heart rate monitor was strapped around the subjects torso to record heart rate. The subject laid supine for five minutes allowing for resting heart rate to be obtained. The active warm-up treatment consisted of stationary cycling on a Monark bike. The subject biked at a self-selected speed and workload for four minutes or until 60% of heart rate reserve (HRR) was achieved. If the subject had not reached their target heart rate after four minutes of cycling, 2 lbs of resistance was added to the stationary bike every two minutes until the target heart rate was reached. When the subject achieved their target heart rate, they continued to bike for an additional 3 minutes maintaining 60% of HRR. The difference between maximum heart rate and resting heart rate is known as HRR. The %HRR is calculated using the following equation: Target Heart Rate = (HRRfraction)(HRmax – HRrest) + HRrest. The HRRfraction was selected as 60% to ensure that the subject was working at intensity capable of maintaining or improving cardiorespiratory fitness with regular exercise (37).

The passive warm-up treatment required the subject to lay prone for 15 minutes with a moist heat pack (Thermal-Pack, Whitehall Manufacturing, Inc., City of Industry, CA) applied to their hamstring. Moist heat packs were stored in a Hydrocollator tank

(Chattanooga Corporation, Chattanooga, TN) heated to 76.6ºC. The moist heat pack was then wrapped in 7 layers of terry cloth to prevent burning the subject. If the subject experienced discomfort due to the heat additional toweling was added. Once a moist heat pack was used it was not returned to the hydrocollator tank until a minimum of 6 hours before the next moist heat pack treatment, ensuring that the water in the tank and remaining heat pack temperatures remained consistent.

The control group was required to lay prone for 15 minutes, receiving no treatment before post-measurements were taken.

Immediately following treatment, the subject returned to the Biodex for post-treatment passive tension measurement. Our pilot study revealed that the average time to return the subject to the Biodex to be less than two minutes. The post-treatment protocol for passive tension measurement was identical to the pre-treatment protocol for measuring passive tension. When all post-treatment measurements were obtained the subject was removed from the Biodex and the testing session complete.

### 3.8 Data Collection and Analysis

Biceps femoris EMG, dynamometer position, velocity and torque were measured for 60 s at a sampling rate of 100 Hz using a Biopac 16 bit analog to digital card. The EMG signals were used to verify that the subject remained relaxed during passive knee extension on the Biodex. The Biodex torque was gravity corrected.

The 60 s testing period allowed four cycles of passive knee extension to be completed, which produced four torque-angle curves. The torque-angle curves were fitted with fourth order polynomials to compute muscle stiffness. All variables were

calculated using the final torque-angle curve recorded by the Biodex during pre-testing and post-testing.

### 3.9 Statistical Analysis

A 3 x 2 repeated measures ANOVA (NCSS, Salt Lake City, UT) was used to compare the effects of treatment (active warm-up, passive warm-up, control) and time (pre-treatment, post-treatment) on the acute effects of active and passive warm-up on hamstring muscle passive tension. Treatment and time were both within-subjects factors. Treatment had three levels: active warm-up, passive warm-up and control and time had two levels: pre-treatment and post-treatment. The independent variables were treatment mode and time. Dependent variables were average stiffness, peak stiffness, peak torque, energy absorbed and energy returned. Alpha was set at 0.05 for all comparisons.

# CHAPTER 4

# RESULTS

## 4.1 Results

Mean and SD for energy absorbed are present in Table 1 by test (pre, post) and treatment groups (active, passive, control). There were no significant differences between test [Test $F(1,18) = .04$, $p = .84$, power = .05], treatment groups [$F(2,18) = .12$, $p = .89$, power = .07] or test by treatment groups [$F(2,18) = 2.23$, $p = .14$, power = .39].

| Table 1 | | |
|---|---|---|
| Energy Absorbed (J) Mean and SD | | |
| Group | Pre | Post |
| Active | 1.91 ± 0.25 | 1.71 ± 0.31 |
| Passive | 1.76 ± 0.33 | 1.92 ± 0.40 |
| Control | 1.81 ± 0.28 | 1.80 ± 0.29 |

Mean and SD for energy returned are present in Table 2 by test (pre, post) and treatment groups (active, passive, control). There were no significant differences between test [Test $F(1,18) = .22$, $p = .65$, power = .07], treatment groups [$F(2,18) = .04$, $p = .96$, power = .06] or test by treatment groups [$F(2,18) = .34$, $p = .72$, power = .10].

| Table 2 | | |
|---|---|---|
| Energy Returned (J) Mean and SD | | |
| Group | Pre | Post |
| Active | 3.59 ± 1.91 | 3.83 ± 1.50 |
| Passive | 3.42 ± 1.77 | 3.68 ± 2.19 |
| Control | 3.77 ± 2.08 | 3.68 ± 2.38 |

Mean and SD for peak torque are present in Table 3 by test (pre, post) and treatment groups (active, passive, control). There were no significant differences between test [Test $F(1,18) = .03$, $p = .87$, power = .05], treatment groups [$F(2,18) = .06$, $p = .94$, power = .06] or test by treatment groups [$F(2,18) = .99$, $p = .39$, power = .20].

| Table 3 | | |
|---|---|---|
| Peak Torque (N•m) Mean and SD | | |
| Group | Pre | Post |
| Active | 32.01 ± 5.35 | 32.48 ± 5.09 |
| Passive | 31.08 ± 4.37 | 32.33 ± 6.75 |
| Control | 32.81 ± 6.23 | 31.59 ± 6.74 |

Mean and SD for average stiffness are present in Table 4 by test (pre, post) and treatment groups (active, passive, control). There were no significant differences between test [Test $F(1,18) = .57$, $p = .47$, power = .10], treatment groups [$F(2,18) = .03$, $p = .97$, power = .05] or test by treatment groups [$F(2,18) = 2.11$, $p = .15$, power = .38].

| Table 4 | | |
|---|---|---|
| Average Stiffness (N•m/rad) Mean and SD | | |
| Group | Pre | Post |
| Active | 91.21 ± 12.53 | 94.15 ± 12.69 |
| Passive | 91.76 ± 14.78 | 91.89 ± 17.96 |
| Control | 95.32 ± 18.13 | 88.32 ± 20.14 |

Mean and SD for peak stiffness are present in Table 5 by test (pre, post) and treatment groups (active, passive, control). There were no significant differences

between test [Test F(1,18) = .30, p = .60, power = .08], treatment groups [F(2,18) = .76, p = .48, power = .16] or test by treatment groups [F(2,18) = 2.0, p = .16, power = .36].

| Table 5 | | |
|---|---|---|
| Peak Stiffness (N•m/rad) Mean and SD | | |
| Group | Pre | Post |
| Active | 102.58 ± 17.19 | 109.72 ± 17.28 |
| Passive | 105.01 ± 20.94 | 101.03 ± 18.14 |
| Control | 104.89 ± 21.57 | 95.22 ± 17.74 |

Mean and SD for energy absorbed under the load curve are present in Table 6 by test (pre, post) and treatment groups (active, passive, control). There were no significant differences between test [Test F(1,18) = .14, p = .72, power = .06], treatment groups [F(2,18) = .02, p = .98, power = .05] or test by treatment groups [F(2,18) = .40, p = .67, power = .11].

| Table 6 | | |
|---|---|---|
| Energy Absorbed (J) under the load curve Mean and SD | | |
| Group | Pre | Post |
| Active | 5.49 ± 1.83 | 5.54 ± 1.75 |
| Passive | 5.18 ± 1.73 | 5.60 ± 2.41 |
| Control | 5.56 ± 2.15 | 5.48 ± 2.43 |

# CHAPTER 5

# DISSCUSSION

## 5.1 Discussion

Our study was designed to investigate the effects of active warm-up (stationary cycling) and passive warm-up (heat pack) on the mechanical properties of connective tissue in vivo. Increasing intramuscular temperature via passive heat or exercise should lower the viscosity of the muscle-tendon unit. We predicted that if the warm-up techniques had been successful then the following changes in muscle-tendon unit properties would have been observed: decreased stiffness, decreased energy returned, and a decrease in energy absorbed due to a decrease in viscosity. However, the results of the present investigation revealed no effect of active warm-up or passive warm-up on energy absorbed, energy returned, peak torque, average stiffness, or peak stiffness between pre-treatment and post-treatment. Therefore, we agree with previous research by Magnusson et al. (23) which also demonstrated that the mechanical properties of the connective tissue are unaltered by active warm-up techniques without stretching.

Magnusson et al. (23) researched the effect of 10 minutes of treadmill warm-up (with and without repeated 90 second static stretches) on the passive tension of the hamstring musculature. The warm-up only group was pre-tested, ran at 70% of their $VO_{2max}$ for 10 min, and then was post tested using one dynamic knee extension followed by a 90 s static stretch. The warm-up and stretch group was post tested after

three dynamic knee extensions each followed by a 90 s static stretch. Magnusson et al. (23) calculated energy absorption as the area under the load phase of the torque-angle curve. They (23) determined that 10-minutes of treadmill warm-up alone resulted in no significant difference between pre energy absorption (14.3 ± 2.3 J) and post energy absorption (14.5 ± 3.5 J). Using an active warm-up (approximately 8.13 ± 1.23 min of stationary cycling), we also determined there was no significant difference between pre energy absorption (5.49 ± 1.83 J) and post energy absorption (5.54 ± 1.75 J). Our analysis of the current results also did not reveal a change in energy absorption when calculated using the area between the load and unload phases of the torque-angle curve. However, Magnusson et al. (23) did report a significant difference between pre energy absorption (14.5 ± 1.7 J) and post energy absorption (13.5 ± 1.9 J) and a 29% stress relaxation when warm-up was followed by three dynamic and static stretches. They (23) concluded that the differences noted in passive energy absorption were due to the repeated passive stretching and not related to the increase in intramuscular temperature caused by warm-up. We believe our results showing no difference between stiffness and energy absorbed, with either active warm-up or passive warm-up, agree with Magnusson et al. (23) results which indicate you need to stretch a muscle to see a decrease in stiffness and energy absorption.

We were surprised that our control group showed some changes in average and peak stiffness. It appears that doing four stretches (60 s) over a 30 range of motion at 5º/s, decreases stiffness after 15 minutes of laying prone. The control was affected by the passive motion protocol, because average stiffness and peak stiffness decreased 7

N•m/rad and 9.67 N•m/rad, respectively. However, our findings support Magnusson's previous research outcomes suggesting that warm-up without stretch has no measurable effect on passive energy absorption of the hamstring muscle-tendon unit (23).

The influence of temperature increase, due to active and passive warm-up, on passive tension in vivo has not been extensively researched. However, the impact of temperature on the mechanical properties of the muscle-tendon unit has been the focus of many in vitro studies. Laban (18) observed an approximate 25% increase in the elastic response of canine tendons when the temperature was raised from 37°C to 42.5°C. Noonan et al. (27) reported rabbit tendons are less stiff at 40°C then at 25°C tendons. Strickler et al. (34) observed that tibialis anterior and extensor digitorum longus rabbit muscle tendon-units passively warmed from 35°C to 39°C in baths were 2.8% and 2.0% more extensible then cold muscles and therefore less susceptible to strain injury. However, these studies utilized temperatures above the normal physiological range achieved in common warm-ups or exercise. Resting intramuscular temperatures of the human thigh have been reported between 34°C and 36°C (7, 13, 21). Safran (29) raised the temperature 1°C in rabbit muscle-tendon units, using electrically stimulated isometric muscle contractions, and observed a greater force and length to tear. Magnusson et al. (23) demonstrated the mean maximum hamstring intramuscular temperature achieved after 10 min and 30 min of treadmill running at 70% $VO_{2max}$ is 38°C and 38.8°C respectively. During 15 min of continuous bilateral concentric knee extensions, Kenny et al. (13) recorded mean peak intramuscular temperature of 38.23°C. Saltin and Hermansen (30) observed mean intramuscular

temperature of 39.20° C after 2 hrs of stationary cycling. Kenny et al. (13) and Saltin et al. (30) recorded intramuscular temperatures in vivo close to the lower end range of temperature (39 C°) required to elicit tissue mechanical property change. Kenny et al. (13) and Saltin et al. (30) implemented exercise protocols that exceed the normal amount of work performed during a warm-up and Saltin et al. (30) did not report the depth at which intramuscular temperature was measured. Lehmann et al. (21) reported less than a 1°C temperature increase 3.0 cm below the skin and no temperature change 3.9 cm below the skin during 30 min hot pack application to the human thigh. Only the rabbit muscle-tendon unit study conducted in vitro by Safran et al. (29) showed increased compliance to stretch with a 1°C temperature increase, which is achievable under normal warm-up conditions.

Professionals in the field of athletic training believe that warm-up and stretching play vital roles in injury prevention (33). Adequate joint range of motion is considered to be an important component of injury prevention. Individuals who have poor flexibility or joint range of motion are commonly believed to be at a higher risk for muscloskeletal injury (33) because the muscle-tendon unit is stiffer and less compliant (22). Witvrouw et al. (40) suggested that stretching before explosive activity, which requires a more compliant muscle-tendon unit, would be beneficial in injury prevention. Stretching exercises improve joint range of motion and flexibility (3, 4, 8, 35, 39). Individuals who have poor flexibility are at risk of exceeding the extensibility limits of the musculoskeletal unit increasing their likelihood of injury (33). Warm-up is also considered advantageous in injury prevention because of increases in connective tissue

temperature and the subsequent increases in connective tissue extensibility (18, 28) and joint range of motion (31). Increased range of motion after active warm-up (11, 37) or passive warm-up (9, 37) has been linked to changes in the mechanical properties of connective tissue created by increased temperature. However, these conclusions were drawn using range of motion measurements, which do not adequately assess the mechanical properties of tissue behavior.

To increase tissue temperature we employed stationary cycling and hot pack application as active and passive warm-up conditions, respectively. We chose stationary cycling and 15-minute hot pack application because they are common methods of warm-up utilized in athletic training, physical therapy, and strength and conditioning settings. We believed that stationary cycling warm-up performed at 60% HRR for 3 min would elevate intramuscular temperature because of muscular work. Previous researchers (23) have noted a 3°C increase in biceps femoris temperature after 10 min of running at 70% $VO_{2max}$. The passive warm-up protocol was designed in accordance with Lehman et al. (21) in which intramuscular tissue temperatures were elevated approximately 1°C due to treatment. However, we did not measure tissue temperature during the current study. Therefore, we are unable to directly compare our study to those that measured intramuscular temperature.

There are a few limitations to this study including method of data collection, subject conditioning, sample size, and temperature increase. The present study was conducted under the assumption that connective tissue temperature would increase as a result of the implemented warm-up conditions. This assumption is based on previous

research (13, 21, 23, 30) that demonstrates temperature increases due to active and passive warm-ups. Our sample size (n=10) may not have been sufficient for any differences in variables to reach statistical significance. We also assumed that the subjects who participated in the study were conditioned well enough to perform the stationary cycling protocol without inducing muscular damage. Another limitation of the study was the researcher's ability to identically reproduce the subjects' position during passive tension measurement during all testing trials. Equipment settings and hip angles were recorded in an attempt to limit the amount of variation between trials. However, any difference in subject position would impact the measured variables. The influence of temperature on the mechanical properties of connective tissue may be greater when the speed of stretch is increased due to the role of viscosity in muscle-tendon unit extensibility. Future studies investigating passive tension in vivo should evaluate the influence of tissue temperature and the speed of stretch on viscosity and muscle-tendon unit extensibility.

## 5.2 Conclusions

The results of the present investigation revealed no effect of active warm-up or passive warm-up on the energy absorbed, energy returned, peak torque, average stiffness, or peak stiffness of the hamstring musculature. These findings suggest that the mechanical properties of the connective tissue were unaltered by the warm-up techniques utilized in this study. Although these results do not support the use of active or passive warm-up to facilitate increased muscle tendon unit compliance to stretching

activity, we do not recommend discontinuation of these practices before athletic competition, exercise, physical recreational activity, or stretching exercise.

# APPENDIX A

# INFORMED CONSENT

THE UNIVERSITY OF TEXAS AT ARLINGTON

PRINCIPAL INVESTIGATOR: _Troyce Solley_____

TITLE OF PROJECT: __The acute effects of active warm-up and passive warm-up on passive tension.

IRB Approved Protocol 06.159s

This Informed Consent will explain about being a research subject in an experiment. It is important that you read this material carefully and then decide if you wish to be a volunteer.

PURPOSE:

The purpose of the study is to investigate the effects of active warm-up (stationary bike) and passive warm-up (heat pack) on the passive tension (stiffness) of your hamstring muscle. Both methods of warm-up are commonly used in the athletic population as a means to increase muscle flexibility and decrease the occurrence of injury. Information obtained from this study will be used to determine proper methods of warm-up when increased tissue flexibility is desired. During this study your muscle flexibility will be measured using the Biodex.

The specific purposes of this research study are as follows:

1. How does an active warm-up affect the passive tension of the hamstrings musculature?
2. How does a passive warm-up affect the passive tension of the hamstrings musculature?
3. Which method of warm-up, active or passive, is more effective in reducing hamstring muscle passive tension?

DURATION

In this study you will be scheduled for four testing sessions lasting approximately 60 minutes. During each testing session skinfold thickness, hamstring range of motion, pre-treatment passive tension, treatment (either active warm-up, passive warm-up, or no warm-up), and post-treatment passive tension measurements will be performed. Subjects will report to the Department of Kinesiology Exercise Science Research Laboratory (Room 154) in the Activities Building at the University of Texas at Arlington. The total number of subjects participating is ten.

PROCEDURES

The procedures, which will involve you as a research subject, include:

1. You will report to the Neuromuscular Exercise Science Research Laboratory (Room 154) in the Activities Building and fill out a health history questionnaire. If you have any previous history of hamstring or low back injury you will be excluded from participation in the study. If you are selected for this study you will be scheduled for familiarization and testing sessions.

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2. During your initial familiarization session skinfold measurement of your hamstring will be taken to assess the adipose (fat) layer of your hamstring. Skinfold measurement is obtained using calipers that apply a mild pinch to the skin and tissue overlying the muscle. If your skinfold is greater then 30 mm you will be excluded from the study.
3. During your initial familiarization session knee range of motion will be taken to determine your hamstring flexibility. If you can fully extend your knee with your hip flexed to 90 degrees, you will be excluded from the study.
4. During your familiarization session you will be seated in the chair of the Biodex with your right leg elevated to allow access to your hamstring. The passive tension (stiffness) of your hamstring will be tested using the Biodex. Your leg will be slowly extended until you indicate the maximum tolerated position of extension. Then your leg will be lowered 30º and the Biodex will move your leg slowly through the 30º range for 60 seconds.
5. Upon arrival for each of your three testing sessions a small area on the hamstring musculature and the base of your neck will be shaved for EMG electrode placement. Two EMG electrodes will be applied to the skin over the hamstring and one EMG electrode will be applied to the base of your neck to record EMG data.
6. Then you will be seated in the Biodex and passive tension measured following the same protocol used during the familiarization session.
7. During each of the three sessions following your familiarization session you will receive one of the three treatments (active warm-up, passive warm-up, or control).
8. During the active warm-up you will perform approximately 10 minutes of stationary cycling. During the passive warm-up you will lay on your stomach will a moist heating pack place on your hamstring for 15 minutes. During the control treatment you will lay on your stomach for 15 minutes.
9. At the conclusion of treatment the Biodex will measure the passive tension (stiffness) of your hamstring.

POSSIBLE RISKS/DISCOMFORTS

The possible risks and/or discomforts of your involvement include:

1. Brief discomfort with skinfold measurement as the skin is being pinched for measurement.
2. Mild discomfort resulting from the shaved area underneath the electrodes.

Throughout the tests laboratory personnel trained in CPR and First Aid will monitor you. Emergency (911) will be called for any emergency situations.

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POSSIBLE BENEFITS

The possible benefits of your participation are:

1. Information gathered from this study will educate allied health professional with valuable information regarding the effectiveness of active and passive warm-ups on the elasticity of muscle tissue.
2. You will be provided with feedback regarding your hamstring flexibility and passive tension.

ALTERNATIVE PROCEDURES / TREATMENTS

There are no alternative procedures or courses of treatment. **However, you can elect not to participate in the study at any time with no negative consequences.**

CONFIDENTIALITY

Every attempt will be made to see that your study results are kept confidential. A copy of the records from this study will be stored in a locked file cabinet in the Neuromuscular Exercise Science Research Laboratory (Room 154) for at least three (3) years after the end of this research. The results of this study may be published and/or presented at meetings without naming you as a subject. Although your rights and privacy will be maintained, the Secretary of the Department of Health and Human Services, the UTA IRB, the FDA (if applicable), and personnel particular to this research (individual or department) have access to the study records. Your (e.g., student, medical) records will be kept completely confidential according to current legal requirements. They will not be revealed unless required by law, or as noted above.

COMPENSATION FOR MEDICAL TREATMENT

The University of Texas at Arlington (UTA) will pay the cost of emergency first aid for any injury that occurs as a result of your participation in this study. UTA will not pay for any other medical treatment. Claims against UTA or any of its agents
or employees may be submitted according to the Texas Tort Claims Act (TTCA). These claims may be settled to the extent allowable by state law as provided under the TTCA, (Tex. Civ. Prac. & Rem. Code, secs. 101.001, et seq.). For more information about claims, you may contact the Chairman of the Institutional Review Board of UTA at 817/272-1235.

FINANCIAL COSTS

The possible financial costs to you as a participant in this research study are:
There should be no financial costs to you as a participant unless you incur medical treatment outside the UTA covered costs.

THE UNIVERSITY OF TEXAS AT ARLINGTON

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TITLE OF PROJECT: __The acute effects of active warm-up and passive warm-up on passive tension.

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CONTACT FOR QUESTIONS

If you have any questions, problems or research-related medical problems at any time, you may call Troyce Solley at 817-559-2941 (tjs4871@exchange.uta.edu), Dr. Cindy Trowbridge at 817-272-3134 (ctrowbridge@uta.edu), or Dr. Mark Ricard at 817-272-0764 (ricard@uta.edu).

You may call the Chairman of the Institutional Review Board at 817/272-1235 for any questions you may have about your rights as a research subject.

VOLUNTARY PARTICIPATION

Participation in this research experiment is voluntary. You may refuse to participate or quit at any time. If you quit or refuse to participate, the benefits (or treatment) to which you are otherwise entitled will not be affected. You may quit by calling Troyce Solley, whose phone number is 817-559-2941. You will be told immediately if any of the results of the study should reasonably be expected to make you change your mind about staying in the study.

By signing below, you confirm that you have read or had this document read to you. You will be given a signed copy of this informed consent document. You have been and will continue to be given the chance to ask questions and to discuss your participation with the investigator.

You freely and voluntarily choose to be in this research project.

PRINCIPAL INVESTIGATOR: _____
DATE

_____
SIGNATURE OF VOLUNTEER DATE

_____
SIGNATURE OF PATIENT/LEGAL GUARDIAN (if applicable) DATE

_____
SIGNATURE OF WITNESS (if applicable)

# APPENDIX B

# HEALTH STATUS QUESTIONAIRE

THE UNIVERSITY OF TEXAS AT ARLINGTON

DEPARTMENT OF KINESIOLOGY

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## PRE-EXERCISE TESTING HEALTH STATUS QUESTIONNAIRE

Name _____ Date_____

Home Address _____

Work Phone _____ Home Phone _____

Person to contact in case of emergency _____

Emergency Contact Phone _____ Birthday (mm/dd/yy)____/_____/_____

Gender _____ Age _____(yrs) Height _____(ft)_____(in) Weight_____(lbs)

**A. JOINT-MUSCLE STATUS** (✓Check areas where you have problems or meet criteria)

Do you currently have any problems with your:
( ) Knee
( ) Thigh
( ) Lower Leg
( ) Ankle

If any checked, please explain: _____
Do you have metal plates or screws in your:
( ) Knee
( ) Thigh
( ) Lower Leg
( ) Ankle

**B. HEALTH STATUS** (✓Check if you currently have any of the following conditions)

( ) High Blood Pressure
( ) Heart Disease or Dysfunction
( ) Peripheral Circulatory Disorder
( ) Allergic Reactions to Medication please describe_____
( ) Allergic Reactions to Any Other Substance
( ) Acute Infection
( ) Hypersensitivity to Needles
( ) Edema
( ) Others That You Feel We Should Know about_____
about_____

**C. CURRENT MEDICATION USAGE** (List the drug name and the condition being managed)

| MEDICATION | CONDITION |
|---|---|
| _____ | _____ |
| _____ | _____ |
| _____ | _____ |

THE UNIVERSITY OF TEXAS AT ARLINGT ON

***DECISION-MAKING CRITERIA***

DEPARTMENT OF KINESIOLOGY

IRB Approved Protocol 06.159s

## HEALTH STATUS QUESTIONNAIRE

Name _____ Date_____

Home Address _____

Work Phone _____ Home Phone _____

Person to contact in case of emergency _____

Emergency Contact Phone _____ Birthday (mm/dd/yy)____/_____/_____

Gender _____ Age _____(yrs) Height _____(ft)_____(in) Weight_____(lbs)

**A. JOINT-MUSCLE STATUS** (✓Check areas where you have problems or meet criteria)

Do you currently have any problems with your:
( ) Knee
( ) Thigh
( ) Lower Leg
( ) Ankle

If any checked, please explain: _____
_____

***DECISION-MAKING CRITERIA:***

1. If an individual checks ***one or more*** of the areas above this response by itself would preclude the subject from participation in this study.

Do you have metal plates or screws in your:
( ) Knee
( ) Thigh
( ) Lower Leg
( ) Ankle

If any checked, please explain: _____
_____

***DECISION-MAKING CRITERIA:***

1. If an individual checks ***one or more*** of the areas for metal implants, this response by itself would preclude the subject from participation in this study. No subjects will be included if they have metal implants.

**B. HEALTH STATUS** (✓Check if you currently have any of the following conditions)

( ) High Blood Pressure
( ) Heart Disease or Dysfunction
( ) Peripheral Circulatory Disorder
( ) Allergic Reactions to Medication
please describe_____
( ) Allergic Reactions to Any Other Substance
about_____
( ) Acute Infection
( ) Hypersensitivity to Needles
( ) Edema
( ) Others That You Feel We Should Know
about_____

***DECISION-MAKING CRITERIA:***

1. If an individual checks ***two or more*** of the Health Status Conditions above, this response by itself would preclude the subject from participation in this study.

2. If an individual checks ***one*** of the Health Status Conditions above and the potential subject feels comfortable participating in the experiment despite their problem denoted above, the subject can be included in this study.

3. If an individual checks ***other*** and the other description cannot be classified into one of the above categories, this response by itself would preclude the subject from participation in this study.

**C. CURRENT MEDICATION USAGE** (List the drug name and the condition being managed)

| MEDICATION | CONDITION |
|---|---|
| _____ | _____ |
| _____ | _____ |
| _____ | _____ |

***DECISION-MAKING CRITERIA:***

1. Taking certain medications ***does not*** preclude a subject from participating in this study.

2. However, if an individual indicates that he/she is currently taking medications that treat a condition that aligns with ***two or more*** of the conditions listed in sections A, B, C, and/or E, this response by itself would preclude the subject from participation in this study.

3. If no medications are listed, the subject can be included in this study.

REFERENCES


1. **Alter MJ.** *Science of Flexibility*. Champaign: Human Kinetics Inc., 2004.
2. **Avela J, Finni T, Liikavainio T, Niemela E, and Komi PV.** Neural and mechanical responses of the triceps surae muscle group after 1 h of repeated fast passive stretches. *J Appl Physiol* 96: 2325-2332, 2004.
3. **Bandy WD and Irion JM.** The effect of time on static stretch on the flexibility of the hamstring muscles. *Phys Ther* 74: 54-61, 1994.
4. **Bandy WD, Irion JM, and Briggler M.** The effect of time and frequency of static stretching on flexibility of the hamstring muscles. *Phys Ther* 77: 1090-1096, 1997.
5. **Bishop D.** Warm up I: potential mechanisms and the effects of passive warm up on exercise performance. *Sports Med* 33: 439-454, 2003.
6. **de Weijer VC, Gorniak GC, and Shamus E.** The effect of static stretch and warm-up exercise on hamstring length over the course of 24 hours. *J Orthop Sports Phys Ther* 33: 727-733, 2003.
7. **Erdman WJ, 2nd and Stoner EK.** Comparative heating effects of moistaire and hydrocollator hot packs. *Arch Phys Med Rehabil* 37: 71-74, 1956.
8. **Fowles JR, Sale DG, and MacDougall JD.** Reduced strength after passive stretch of the human plantarflexors. *J Appl Physiol* 89: 1179-1188, 2000.

9. **Funk D, Swank AM, Adams KJ, and Treolo D.** Efficacy of moist heat pack application over static stretching on hamstring flexibility. *J Strength Cond Res* 15: 123-126, 2001.

10. **Garrett WE, Safran MR, Seaber AV, Glisson RR, and Ribbeck BM.** Biomechanical comparision of stimulated and nonstimulated skeletal muscle pulled to failure. *Am J Sports Med* 15: 448-454, 1987.

11. **Hubley CL, Kozey JW, and Stanish WD.** The effects of static stretching exercises and stationary cycling on range of motion at the hip joint. *J Orthop Sports Phys Ther* 6: 104-108, 1984.

12. **Hutton RS.** Neuromuscular basis of stretching exercises. In: *Strength and Power in Sport*, edited by Komi PV. London: Blackwell Scientific Publications, 1992, p. 29-38.

13. **Kenny GP, Reardon FD, Zaleski W, Reardon ML, Haman F, and Ducharme MB.** Muscle temperature transients before, during, and after exercise measured using an intramuscular multisensor probe. *J Appl Physiol* 94: 2350-2357, 2003.

14. **Knight CA, Rutledge CR, Cox ME, Acosta M, and Hall SJ.** Effect of superficial heat, deep heat, and active exercise warm-up on the extensibility of the plantar flexors. *Phys Ther* 81: 1206-1214, 2001.

15. **Kubo K, Kanehisa H, and Fukunaga T.** Effects of resistance and stretching training programmes on the viscoelastic properties of human tendon structures in vivo. *J Physiol* 538: 219-226., 2002.

16. **Kubo K, Kanehisa H, and Fukunaga T.** Effects of transient muscle contractions and stretching on the tendon structures in vivo. *Acta Physiol Scand* 175: 157-164, 2002.

17. **Kubo K, Kanehisa H, Kawakami Y, and Fukunaga T.** Influence of static stretching on viscoelastic properties of human tendon structures in vivo. *J Appl Physiol* 90: 520-527., 2001.

18. **Laban MM.** Collagen tissue: implications of its response to stress in vitro. *Arch Phys Med Rehabil* 43: 461-466, 1962.

19. **Ledderman E.** *Fundamentals of Manual Therapy: Physiology, Neurology and Psychology*. New York: Churchill Livingstone, 1997.

20. **Lehman JF and De Lateur BJ.** *Therapeutic Heat and Cold*. Baltimore: Williams & Wilkins, 1990.

21. **Lehmann JF, Silverman DR, Baum BA, Kirk NL, and Johnston VC.** Temperature distributions in the human thigh, produced by infrared, hot pack and microwave applications. *Arch Phys Med Rehabil* 47: 291-299, 1966.

22. **Magnusson SP.** Passive properties of human skeletal muscle during stretch maneuvers. A review. *Scand J Med Sci Sports* 8: 65-77, 1998.

23. **Magnusson SP, Aagaard P, Larsson B, and Kjaer M.** Passive energy absorption by human muscle-tendon unit is unaffected by increase in intramuscular temperature. *J Appl Physiol* 88: 1215-1220, 2000.

24. **Magnusson SP, Simonsen EB, Aagaard P, Gleim GW, McHugh MP, and Kjaer M.** Viscoelastic response to repeated static stretching in the human hamstring muscle. *Scand J Med Sci Sports* 5: 342-347, 1995.

25. **Magnusson SP, Simonsen EB, Aagaard P, and Kjaer M.** Biomechanical responses to repeated stretches in human hamstring muscle in vivo. *Am J Sports Med* 24: 622-628., 1996.

26. **Mchugh MP, Magnusson SP, Gleim GW, and Nicholas JA.** Viscoelastic stress relaxation in human skeletal muscle. *Med Sci Sports Exerc* 24: 1375-1382, 1992.

27. **Noonan TJ, Best TM, Seaber AV, and Garrett WE, Jr.** Thermal effects on skeletal muscle tensile behavior. *Am J Sports Med* 21: 517-522, 1993.

28. **Rigby BJ.** The Effect of Mechanical Extension Upon the Thermal Stability of Collagen. *Biochim Biophys Acta* 79: 634-636, 1964.

29. **Safran MR, Garrett WE, Seaber AV, Glisson RR, and Ribbeck BM.** The role of warmup in muscular injury prevention. *Am J Sports Med* 16: 123-129, 1988.

30. **Saltin B and Hermansen L.** Esophageal, rectal, and muscle temperature during exercise. *J Appl Physiol* 21: 1757-1762, 1966.

31. **Sapega AA, Quedenfeld TC, Moyer RA, and Butler RA.** Biophysical factors in range-of-motion exercise. *Phys Sportsmed* 9: 57-64, 1981.

32. **Shellock FG.** Physiological, psychological, and injury prevention aspects of warm-up. *NSCA Journal* 8: 24-27, 1986.

33. **Shellock FG and Prentice WE.** Warming-up and stretching for improved physical performance and prevention of sports-related injuries. *Sports Med* 2: 267-278., 1985.

34. **Strickler T, Malone T, and Garrett WE.** The effects of passive warming on muscle injury. *Am J Sports Med* 18: 141-145, 1990.

35. **Sullivan MK, Dejulia JJ, and Worrell TW.** Effect of pelvic position and stretching method on hamstring muscle flexibility. *Med Sci Sports Exerc* 24: 1383-1389, 1992.

36. **Taylor DC, Dalton JD, Jr., Seaber AV, and Garrett WE, Jr.** Viscoelastic properties of muscle-tendon units. The biomechanical effects of stretching. *Am J Sports Med* 18: 300-309, 1990.

37. **Wenos DL and Konin JG.** Controlled warm-up intensity enhances hip range of motion. *J Strength Cond Res* 18: 529-533, 2004.

38. **Wiktorsson-Moller M, Oberg B, Ekstrand J, and Gillquist J.** Effects of warming up, massage, and stretching on range of motion and muscle strength in the lower extremity. *Am J Sports Med* 11: 249-252, 1983.

39. **Williford HN, East JB, Smith FH, and Burry LA.** Evaluation of warm-up for improvement in flexility. *Am J Sports Med* 14: 316-319, 1986.

40. **Witvrouw E, Mahieu N, Danneels L, and McNair P.** Stretching and injury prevention: an obscure relationship. *Sports Med* 34: 443-449, 2004.

41. **Zachezewski JE.** Improving flexibility. In: *Physical Therapy*, edited by Scully RM and Barnes MR. Philadelphia: JB Lippincott Co, 1989, p. 698-699.

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