# THE ACUTE EFFECTS OF MASSAGE ON MUSCLE TONE AND PERCEIVED RECOVERY

Piia Haakana

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Department of Biology of Physical Activity
University of Jyväskylä
Supervisor Taija Juutinen

# ABSTRACT

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The physiological effects of massage have been controversial in previous studies. There is one previous study on effects of massage on muscle tone but there were no effects during one month intervention. The purpose of this study was to determine the correlations between subcutaneous tissue and rectus femoris muscle thickness and muscle tone. The differences on muscle tone between groups that received massage immediately or one day after the resistance training were examined. The effects of massage on perceived recovery were monitored immediately and day after massage.

Ten subjects completed the study, five in each group. The thickness of subcutaneous and muscle tissue, and pennation angle was measured from rectus femoris muscle prior to the training session. Both groups had the same pre measurements and training session, with three sets at 70% of 1 RM squat until exhaustion on a Smith machine. Muscle tone was measured before and after the training and massage sessions, and a day after massage. Subjects filled in questionnaires of their state of perceived recovery each time the muscle tone was measured after the training. Massage was applied for group 1 immediately after the training and for group 2 one day after the training. Massage, 10 minutes per leg, was performed with effleurage and petrissage techniques by the same therapist for each subject.

A significant decrease in muscle tone was found in group 1 immediately after training. Following massage the tone increased. There was no effect of training or massage on group 2. This might be due lack of subjects and the control group, insufficient training session, incapability of subjects to totally relax during the muscle tone measurement or other factors such as elevated muscle tone due to activities prior to the measurements.

Keywords: massage, effleurage, petrissage, muscle tone and perceived recovery.

# CONTENTS

# INTRODUCTION

Even though massage has been used since ancient history, there is only little scientific evidence of its physiological and psychological effects. Regardless of this fact massage is widely used as a therapy method for athletes. (Hemmings et al. 2000, Jönhagen et al. 2004.) Massage is also believed to affect muscle tone and cause relaxation (Goats 1994).

A bachelor's thesis published from Jyväskylä polytechnic school researched the effects of massage on muscle tone. Subject received eight 30 minutes massages during one month. Applied massage techniques were effleurage, frictions, shakings and tapotements. There was no significant difference between group that received massage and the control group. Measurements were however not applied immediately after massage, and the massage therapist was not the same for all subjects in each massage sessions. (Myllyntaus & Rutanen 2006.)

In this present study subjects will receive massage immediately or one day after the training session and measurements will be done immediately after massage. The aim of this study is to find out the acute effects of massage on muscle tone after resistant exercise when massage is applied immediately or one day after the exercise session and whether the perceived recovery increases after massage.

# 1. NERVOUS SYSTEM AND MOTOR UNIT

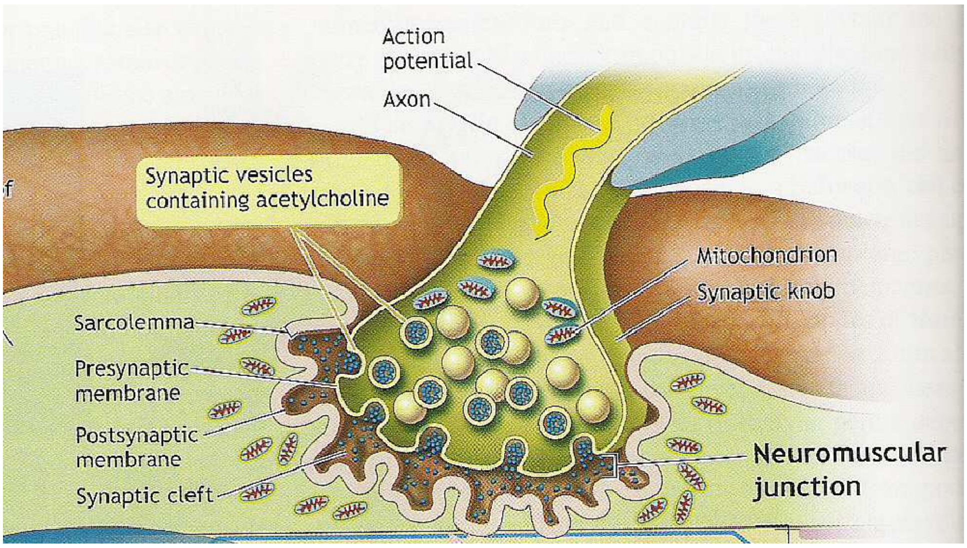
Nervous system receives, processes and stores information from receptors of sense organs and thus controls growth and functions of organs in human body. Nervous system affects organs quick and accurately via hormones, transmitters or trophic agents. Nervous system also produces some hormones that deliver information via blood from one part of the body to another. (Nienstedt, Hänninen & Arstila 1999, 517.)

The nervous system is divided into central nervous system and peripheral nervous system according to its structure, and according to its function to somatic and autonomic nervous system. The brain and spinal cord form the central nervous system. (Moore & Dalley 1999, 38.)

## 1.1 Peripheral nervous system

Peripheral nervous system connects the central nervous system with the peripheral structure and conducts the impulses between central and peripheral parts. Peripheral nervous system consists of nerve cell bodies and nerve fibers. Nerve fibers consist of an axon, a neurolemmal sheath and an endoneurial connective tissue sheath. Peripheral nervous system forms 11 pairs of cranial nerves and 31 pairs of spinal nerves, so that cranial nerves originates from the brain and spinal nerves from spinal cord so that each pair of spinal nerves exit from intervertebral foramina between two vertebrae. (Moore & Dalley 1999, 41-45.)

Neuromuscular junction (picture 1) is the junction between a nerve ending and a muscle fiber. Nerve ending branches and forms nerve terminals called end plates. The end plates lie outside the muscle fiber plasma membrane. The space between the end plate and fiber membrane is called synaptic cleft, whereas the folds in muscle membrane are called subneural clefts. There are about 300 vesicles in a nerve end plate that releases acetylcholine when a nerve impulse reaches the neuromuscular junction. The release and removal of acetylcholine happens fast, in about 1 ms. As asetylcholine is released into the synaptic clefts, it results movement of calsium ions from the extracellural fluid to the membranes when action potential causes a depolarization on membranes. (Guyton 1986 136-137.) Every nerve impulse that reaches the neuromuscular junction causes an impulse in muscle fibers. One nerve fiber may innervate several muscle fibers and thus one nerve impulse can cause contraction in all of these muscle fibers at the same time. (Nienstedt et al. 1999, 78-79.)




PICTURE 1. Neuromuscular junction (adapted from McArdle, Katch & Katch. 2001, 373).

## 1.2 Somatic and autonomic nervous systems

The somatic nervous system consists of somatic parts of central nervous system and peripheral nervous system. Somatic nervous system transports messages of touch, pain, temperature and position from different sensors all over the body. Both voluntary and reflexive movements are permitted by somatic nervous system. (Moore & Dalley 1999, 45.)

The autonomic nervous system consists of nerve fibers that innervate involuntary muscles, cardiac muscle and glands. This nervous system is divided into sympathetic and parasympathetic divisions. Even though functions of sympathetic and parasympathetic nervous systems are quite the opposite, they also need to cooperate in some functions. (Moore & Dalley 1999, 45, Nienstedt et al. 1999, 538-540.)

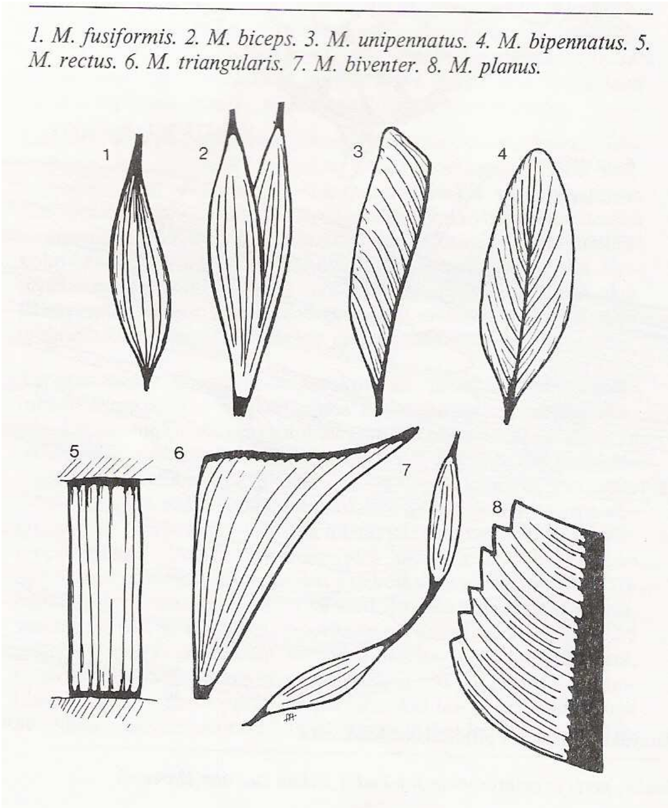
### 1.3 Motor unit

A motor unit consists of α (alpha)-motor neuron and all the muscle fibers it innervates. One motor neuron may innervate several muscle fibers as the axon branches out in several branches at its distal end. Motor neuron pool consists of all α-motor neurons that innervate the same muscle. When a motor unit is activated an impulse travels down the axon to all of the fibers in the motor unit. Some motor units include only few (about 41 000) fibers that they innervate such as the small muscles (m. interrosseus dorsalis) that move fingers in comparison to the calf muscle (m. gastrocnemius) that includes more than a million fibers. Movements are dependent on motor unit activation, as muscle is able to develop more force when more of its motor units are activated. (Moore & Dalley 1999, 30-31, Nienstedt et al. 1999, 79, McArdle et al. 2001 394-395, Billeter & Hoppeler 2003, 55.) Small muscles that need rapid, exact movement or control have only few muscle fibers in each motor unit and thus have plenty of nerve fibers going to muscle. In contrast, large muscle that move slowly or do not need precision in movement may have more muscle fibers in one motor unit. (Guyton 1986, 131.)

## 2. MUSCLE

### 2.1 Anatomy of muscle

There are three types of muscles, skeletal muscle, cardiac muscle and smooth muscle. In this study the focus is only on skeletal muscle. Skeletal muscle is attached to bones, cartilages, ligaments, tendons, fascia or combination of these structures either directly or indirectly. Muscles are classified by its shape to a flat muscle, pennate muscle, fusiform muscle, quadrate muscle and circular muscle (picture 2).




PICTURE 2. Different muscle types (Hervonen 1998).

1. fusiform muscle
2. biceps muscle
3. unipennate muscle
4. bipennate muscle
5. quadrate muscle
6. triangular muscle
7. biventer muscle
8. plane muscle.

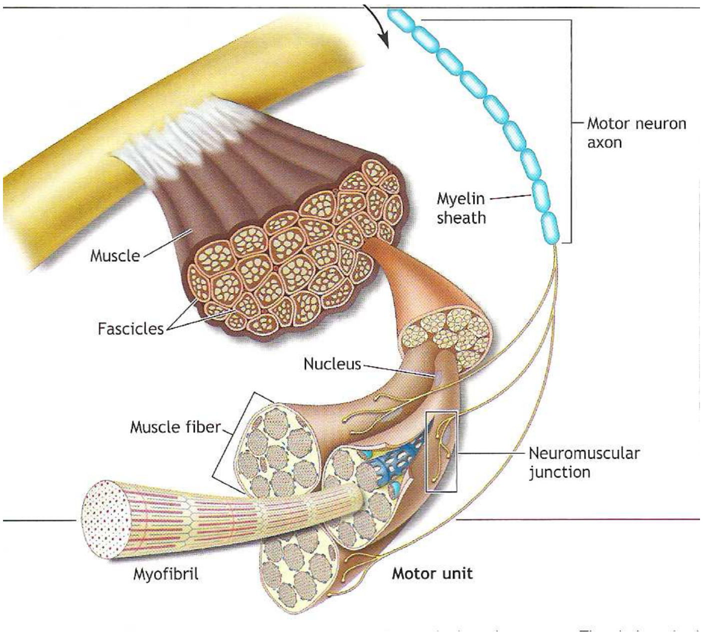
A flat muscle consists of parallel muscle fibers and they often are attached to an aponeurosis. The pennate muscles have arranged their fascicles like feathers and it can be either uni-, bi-, or multipennate muscle. A fusiform muscle is formed in a spindle shaped and it has a thick belly and it is tapering towards its ends. A quadrate muscle has received its name according to its four equal sides. A circular muscle surrounds a body opening, for example an eye. (Moore & Dalley 1999, 26-31.)

A whole muscle is surrounded by connective tissue in all layers of its structure and a muscle is also connected to tendons at its both ends via this connective tissue. This formation enables muscles and connective tissues operate together. (Enoka 2002, 225-227, McArdle et al. 2001, 359.)

Muscle fascicles consist of several, up to 150 muscle fibers and one fascicle is surrounded by fascia called perimysium. (McArdle et al 2001, 359.) A single muscle consists of muscle fascicle bundles surrounded by a connective tissue fascia, called epimysium (Enoka 2002, 219).

Muscle fibers are about 1 to 400 mm long and 10 to 60 µm in diameter. Muscle fiber consists of myofibrils and each fiber is separated from other myofibrils with endomysium fascia. Under the endomysium surrounding a muscle fiber there is a sarcolemma membrane. Sarcolemma is a plasma membrane that uses active and passive ways of transportation through itself. (Enoka 2002, 219-220.)

The part of a muscle fiber that is located between two Z-bands is called a sarcomere. Sarcomere is the basic contractile unit of a muscle and it is composed of myofilaments. (Enoka 2002, 220-221, Guyton 1986, 122.) A myofibril consists of a set of myofilaments (Enoka 2002, 220-221). There are two types of myofilaments, a myosin filament (thick filament, diameter 12 nm) is made of about 200 individual myosin molecules, as actin filament (thin filament, diameter 7 nm) is composed from three different components: actin, troponin and tropomyosin (Guyton 1986, 123-124). Each myofibrils (picture 3) has about 1500 myosin filaments and 3000 actin filaments. Filaments are lying between each other so that actin filaments are attached to Z-bands and myosin filaments are located between two Z-bands (picture 4). (Guyton 1986, 120-122.)




PICTURE 3. Structure of a muscle and neuromuscular junction (McArdle et al. 2001, 393).

## 2.2 Muscle fiber pennation angle

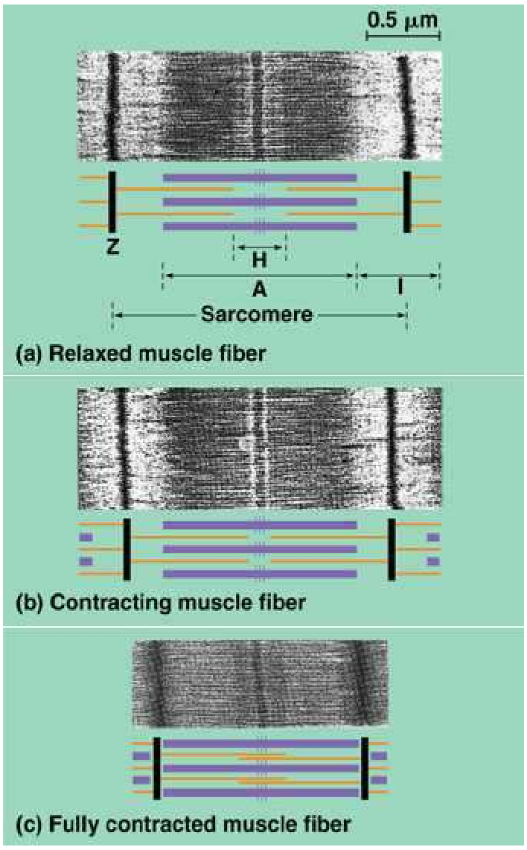
Pennate muscle has arranged its fibers in an angle that varies from muscle to muscle up to 30º angle. Named by its structure there are uni-, bi- and multipennate muscles. Muscle cross sectional area is greater in pennate muscles because more sarcomeres fit in smaller cross sectional area than in a flat muscle. (McArdle et al. 2001, 364-365.)

A muscle that has its fibers arranged pennated can produce greater force than a muscle that has fibers arranged in 0º angle, where the net force of the fibers act in the direction of whole muscle force. In pennate muscle the net force of a single fiber is the cosine of the angle of pennation. (Enoka 2002, 261.) These muscle fibre characteristics can be observed with ultrasound imagining or magnetic resonance imagining (Fukunaga et al. 1997).

## 2.3 Physiology of muscle

A skeletal muscle produces movement in skeleton by shortening, while remaining its other head fixed, and moving the other end. A muscle can be attached to a bone over one or two joints. (Moore & Dalley 1999, 26, Nienstedt et al. 1999, 78-80.) Muscle fibers are divided into two types, fast-twitch fibers (type 2) that have capability for rapid powerful actions, and slow-twitch fibers (type 1) that are more fatigue resistant and according to its name also slower to contract. Fast-twitch fibers are divided into two subclasses type 2a and 2b according to their energy transfer. Type 2a has both aerobic and anaerobic capacity and type 2b is more anaerobic and uses glycolytic energy system. (McArdle et al. 2001, 374-377.)

Muscle contraction is caused by an electrical activation that is followed by release of $Ca^{2+}$ from lateral sacks of tubule system and transported via transversal tubule into the muscle. $Ca^{2+}$ binds to troponin part of an actin filament and allows actin and myosin filaments to combine to each other through a cross bridge by removing the troponin-tropomyosin inhibition. Cross bridges pull filaments which slide past each other so that two Z bands will get closer to each other and thus sarcomer length decreases (picture 4). Adenosine triphosphate (ATP) coupling and uncoupling plays a role in building crossbridges when $Ca^{2+}$ concentration is high enough. When ATP molecule binds into myosin, the cross bridge detaches and without ATP binding the cross bridge remains attached. After detaching the cross bridge, the myosin filament head recombines with new spot of actin filament and thus moves Z bands closer. (McArdle et al. 2001, 369-374.)




PICTURE 4. Muscle contraction (Chen 2007). Seen in the picture myosin filaments are darker and thicker as actine filaments are lighter and thinner.

a) Relaxed muscle, filaments lay between each other

b) Contracting muscle fiber as filaments are sliding between each other

c) Fully contracted muscle where filaments have slide between each other so that sarcomere ends are as close to each other as possible.

Decrease in the electrical excitation causes active $Ca^{2+}$ ions trasportation back to the lateral sacks of the t-tubulus system and sarcoplastic reticulum. Because of termination of $Ca^{2+}$ ions release, troponin inhibits the interaction between actin and myosin filaments. Muscle is relaxed when crossbridges are detached and thus actin and myosin filaments are returned to their own place. (McArdle et al. 2001, 374.)

## 2.4 Effects of training on muscle

Rarely only one muscle is activated alone and a single muscle can participate in different activities. A muscle that produces a movement by its contraction is called agonist, as a muscle that shortens the opposite direction as wanted movement is called antagonist. The muscles that are cooperating with the agonist are called synergists. Muscles that fixate the limb during the contraction are called fixators. (Nienstedt et al. 1999, 146, Moore & Dalley 1999, 26-31.)

There are several types of muscle contraction. Isokinetic contraction causes dynamic, either concentric or eccentric contraction and change in a muscle length. In concentric contraction the work is done against external load, but the muscle is stronger than the load allowing the muscle to shorten. In eccentric contraction the muscle resists the external load and it is forced to stretch, as load is greater than the produced muscle force. Isometric muscle work means (lat. iso = constant, metric = length) that the whole muscle length remains constant during the contraction. (Nienstedt et al. 1999, 146-147.)

Exercise training causes a mechanical stress to different muscle system components and thus will stimulate a protein synthesis that will increase muscle size (McArdle et al. 2001, 532). Muscle cross-sectional area has a relationship with the force, so that 1 $cm^2$ muscle cross-sectional area can produce 16-30 Newton force. Enlarging a muscle fibre is an adaptation to increase the power output. (McArdle et al. 2001 505, Goldspink & Harridge 2003, 236.) Tesch, Colliander and Kaiser found that intense heavy resistance training causes reduction in adenosine triphosphate (ATP) and creatine phosphate (CP) concentrations. Also glycogen concentration decreased after training. Blood lactate increased after training and stayed elevated 40 minutes after training. (Tesch et al. 1986.)

Resistance training, especially eccentric exercise causes delayed onset muscle soreness (DOMS) that occurs after exercise and may last 3-4 days. Cause of DOMS is unknown. (McArdle et al. 2001, 540.) Weber, Servedio and Woodall researched effects of DOMS with maximal eccentric exercise in arm-curl machine. In a research they discovered that maximal eccentric exercise was a proper way to increase DOMS sensation, however researches did not succeed to reduce DOMS with massage, microcurrent electrical stimulation or upper body ergometry. (Weber et al. 1994.)

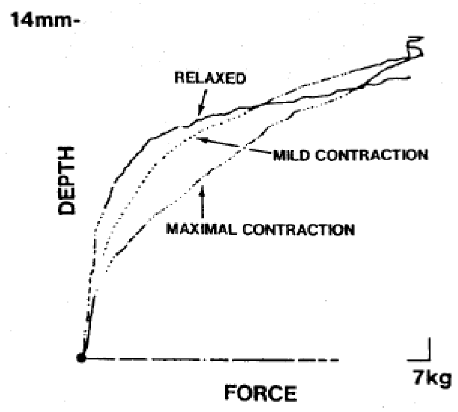
Hypertrofic training increases muscle mass more than specific neural resistance training. In hypertrofic training loads are submaximal, 60-80% of 1 RM (repetition maximum). Training is performed with 6-12 repetitions in each set with overload principle. Where the sets are performed with maximum repetition principle so that each set contains as many repetitions as athlete can accomplish or that last one or two repetitions are assisted (forced repetitions). In neural resistance training repetitions are performed close to maximum, 90-100% of 1 RM with only 1-3 repetitions in each set. (Häkkinen 1990, 69-72.)

## 2.5 Muscle tone

Muscle tone has several definitions in the literature. Muscle tone is the passive resistance that resists changes in muscle length (Enoka 2002, 367-368). Fisher defines muscle tone as “an expression of viscoelastic properties of muscle which is clinically evaluated by palpation of the consistency (firmness) of the tissue” (Fisher 1987b). Muscle tone is also defined as a weak constant contraction in muscle that is maintained by couple of motor units when muscle is relaxed (Nienstedt et al. 1999, 147). Guyton defines muscle tone as a residual contraction, tautness, in skeletal muscle that remains in rest (Guyton 1986, 132).

There are several factors that affect muscle tone. According to Fisher muscle tone is affected by temperature so that it increases in cold settings, e.g. muscle is cooled down with ice and decreases in warm settings (Fisher 1987b).

The thickness of underlying tissue affects the muscle tone. The thickness of the tissue affects the first and the last parts of the curve (picture 5) (Fisher 1987a). There was also a clear correlation between muscle tone and muscle thickness in a research of repeatability of a computerized muscle tonometer, and it should be considered according to the authors when measuring muscle tone in different muscles or different parts of the same muscle (Ylinen et al. 2006).




PICTURE 5. Depth -force curve of tissue compliance measured by a tissue compliance meter (Fisher 1987a).

Several conditions such as diseases affect muscle tone. Adults with cerebral palsy (CP) have increased muscle tone (Maruishi et al. 2001). Muscle tone decreases during sleep but vanishes only during rapid eye movement sleep (Nienstedt et al. 1999 147-148). Injury in a monosynaptic reflex arc causes reduction in muscle tone (Fisher 1987a).

Hypotonus is a reduced level of muscle tone, it appears among patients with lesions in the cerebral hemispheres or patients with experience on spinal transections. Hypertonus is defined as increase in muscle tone, caused by low motor neuron activity despite an attempt to relax. There are two types of hypertonus; spasticity and rigidity. In spasticity, which can be caused by several motor disorders, excitability of stretch reflex is increased. Rigidity is associated with Parkinson’s disease patients. (Enoka 2002, 367.)

Muscle tone is measured as compliance of the tissue. Muscle compliance is defined by Fischer as “quality of a material which allows yielding to deforming force” (Fischer 1987a). Tissue compliance measurements are reflections to both basic viscoelastic properties of the tissue and activation of muscle fibers (Fisher 1987b). Compliance is expressed as the amount of change in length per force used to stretch (mm/N) (Enoka 2002, 464). Viscoelasticity means that tissue looses energy as heat and returns slower to its original shape after strain caused by external load (hysteresis) (Whiting & Zernicke 1998, 76-78). Viscoelastic tissue such as tendon is also dependent on the rate of strain e.g. slow stretch will produce different respond than fast stretch (Zernicke & Whiting 2000, 511).

Horikawa measured the muscle hardness on trapezius muscle with an apparatus developed to measure the pressure and displacement of a transducer. Muscle hardness was measured by applying pressure to the muscle with a terminal plate which area was 1 $cm^2$. The terminal plate measured the amount of pressure applied. The displacement, which the transducer moved towards to the body, was measured. The subjects (n=9, age 21-22 years) worked with desktop PC and notebook PC for 15 to 30 minutes with different neck angles. The hardness increased when subjects were working with a desktop PC looking up for 15 minutes (elevation angle 15-20 degrees) or when they were looking down for 30 minutes (declination angle 15-20 degrees). Hardness also increased after 15 minutes of work with a notebook PC. (Horikawa 2001).

# 3. MASSAGE

Massage is defined by Caffarelli and Flint as “mechanical manipulation of body tissues with rhythmical pressure and stroking for the purpose of promoting health and well-being” (Caffarelli & Flint 1992).

The earliest notes about massage are in books of Kong Fu from 2700 BC. Massage has also been used in agent Greece and its mythology. During medieval time massage was connected to magical power and witchery and thus it was prohibited. During 1500 and 1600 -centuries medical researches worked to get massage approved as a physical treatment. Per Henrik Ling created medical gymnastic movements in Stockholm and massage became first accepted subject in Stockholms Kungliga Gymnastika Institut. (Arponen & Airaksinen 2001, 16-24, Ylinen, Cash & Hämäläinen. 1995, 7-9, Goats 1994.) Massage and manipulation has also been developed in the United States since late 19th century (Ylinen et al. 1995, 8).

There is only little evidence in literature that massage has positive effects on recovery or performance and researchers have found only little or no evidence on physiological effects of massage (Caffarelli & Flint 1992, Weerapong, Hume & Kolt 2005). Despite this lack of scientific evidence many coaches, athletes and sports medicine personnel believe, based on their experiences and observations, that massage has beneficial effects on human body (Weerapong et al. 2005). Researching massage has been shown to be problematic regarding the standardization of previous exercise, length and type of massage intervention and experimental control (Robertson, Watt & Gallaway 2004).

## 3.1 Massage techniques

There are several types of massage techniques based on five classic techniques, that are tapotement, petrissage, effluerage, frictions, and vibrations. These techniques have been the same over the years, developed according as humans increased knowledge about anatomy and physiology. Variety of these techniques brings a challenge for the scientific research, as they are not comparable in different countries. (Arponen & Airaksinen 2001, 95.)

### 3.1.1 Tapotement

Tapotement is a technique that consists of vigorous percussive treatment. There are several techniques, but most commonly and easiest to use is “clapping” with cups that therapist forms from his or her concave palmar surface. Other techniques are “hacking” with the ulnar axis of the hand or “beating” with loosely flexed fingers. (Goats 1994.)

Purpose of tapotement is to vibrate tissues, trigger cutaneous reflexes and cause vasodilation. Also sensitivity of muscle contractions might increase. Tapotement massage is supposed to reduce swelling and thus accelerate healing. Tapotements can also stimulate muscle contractility and thus can be used preparing for performance. (Goats 1994, Arponen & Airaksinen 2001, 102-103, Ylinen et al. 1995.)

### 3.1.2 Petrissage

Petrissage is a forceful technique that can only be applied to parts of the body (e.g. legs and arms) that does not consist of flat muscle (e.g. back). Skin, subcutaneous tissue and muscle are squeezed, lifted and rolled against the underlying tissue by making a circular motion. Therapist needs to adjust movement to the tissue so that patient does not have unpleasant feeling in his or her skin. Petrissage can be performed as “wringing” when superficial tissues are grasped with both hands and twisted in opposite directions or “picking up” when lifting soft tissues away from underlying tissue. (Goats 1994, Arponen & Airaksinen 2001, 101-102.)

Petrissage is believed to relieve a muscle spasm when used as stretch for contracted muscle tissue or adherent fibrous tissue. Other benefits of petrissage are resolving long-standing swelling by promoting the flow of body fluids, decreasing swelling, increasing elasticity of muscles and prevention of fiber adhesions. (Goats 1994, Arponen & Airaksinen 2001, 102, Ylinen et al. 1995, 63.)

### 3.1.3 Effleurage

Effleurage technique consists of rhythmic stroking following the shape of the muscle and skin. This technique is commonly used at the beginning and at the end of the massage session. Strokes are directed from distal to proximal end of the muscle of limb and parallel to the axis of the tissue. (Goats 1994.)

Strokes are divided in fast, slow, deep, superficial, long and short strokes. Therapist holds his or her hand on the skin of the patient and adjusts to the shape of the tissue during the stroke. Also when returning hand to the beginning therapist has to have a contact with the patient. When aiming to effect on lymph flow strokes are applied from distal part to proximal part, and when aiming to loose adhesions in the muscle strokes are applied transversely to muscle fibers. To decrease friction lotion or oil is used on patients skin. Normally effleurage is applied with large area of palm or a forearm, but when aiming to specific effects on a small area also thumb can be used. (Arponen & Airaksinen 2001, 96-98.)

Gradual compression is believed to reduce muscle tone and increase a state of relaxation. It also helps to relieve muscle spasm and prepares patient to more vigorous treatment. When using firm pressure blood flow accelerates and thus tissue drainage decreases in recent swelling. When applying rapid strokes the effect is opposite, as muscle tone will increase and this leads using rapid strokes for preparation for competition. (Goats 1994.)

### 3.1.4 Frictions

Frictions are usually applied through fingertips producing penetrating pressure in circular movements, within the stretch of the skin and other soft tissues. When using friction technique, the therapist needs less oil or lotion than in effleurage. Tendons and ligaments are treated in a slightly tensed position as muscles are treated in a relaxed position, therapist's hand directed diagonal to the muscle and subcutaneal tissues. Friction massage lasts about five to fifteen minutes and begins with gentle transverse movements and gradually increases the pressure so that effects will get deeper in to the tissue. A muscle needs to be warmed up with smoother techniques before applying frictions. Tendons, especially the line between muscle and tendon, are also good to handle with frictions. Friction causes mild inflammatory reaction and mild tissue destruction. Tensed muscles can be relaxed after receiving friction massage. It is important to apply strokes longitudinal to the muscle body so that muscle fibers can stretch instead of packing together when applying frictions transversally. (Goats 1994, Ylinen et al. 1995, 56-62, Arponen & Airaksinen 2001, 98-100.)

### 3.1.5 Vibrations

Vibrations are applied by trembling both hands holding them in contact with the skin all the time. Vibration technique requires training and skills from the therapist. The effects are based on mechanical irritation that is applied in deep subcutaneal tissues. Vibrations produce relaxation and decrease in pain through mechanical irritation. (Goats 1994, Arponen & Airaksinen 2001, 104.)

Vibrations can reduce edema by compressing swollen tissue and thus having less risk of spreading infection (Goats 1994). Caffarelli, Flint and Leibesman researched effects of vibratory massage after isometric contraction in quadriceps muscle that was applied in a dynamometer, both ankle and knee angles fixed to 90º. Percussive vibratory massage by a commercial device (Wellness innovations) was applied to the quadriceps muscle when the subject could no longer hold 70% of his maximal voluntary contraction (MVC), duration of a massage was four minutes. Control group received no massage, but five minutes rest. Exercise set was repeated three times followed by the massage. The next day dynamic exercise was performed by cycling at a workload that required 75% $VO_{2max}$ and followed by vibratory massage. This protocol was repeated three times. Massage had no effects on recovery or the capacity to perform repeated submaximal static contractions. (Caffarelli et al. 1990.)

### 3.1.6 Other techniques

Shaking is commonly used among athletes. Shaking technique consists of fast, rhythmic movements that are applied transversally to a relaxed muscle. The effects of shaking are relaxation and increase in tissue fluid flow. (Arponen & Airaksinen 2001, 104-105.) As shaking leaves a feeling of relaxation it is used at the end of the massage session or between some harder techniques (Ylinen et al. 1995, 69).

Kneading consists of circular compression of soft tissue against underlying bone. The therapist holds the contact to the patient’s skin continuously but the greatest pressure is applied as hands move proximally, when treating small areas only fingertips are used to give pressure. This technique promotes tissue fluid flow and causes reflex vasodilation (Goats 1994).

Rolling is based on rolling the skin between thumbs and other fingers. This technique is best used in back and can be applied longitudinally or transversally. Rolling increases elasticity of superficial tissues and improves capillary blood flow. Rolling does not affect muscle tissue, but it may have reflector effects via cutaneal tissue, comparable to connective tissue massage (Arponen & Airaksinen 2001, 105.)

Squeezing is applied when lifting and squeezing the muscle up from underlying bone and turning it totally aside. This will provide stretching also to deep structures. Squeezing can also be applied when lifting muscle up with both hands and moving them opposite directions. (Ylinen et al. 1995, 63-64.)

Muscle sculpting is applied when pressing a muscle with thenar, ulnar side of forearm or a thumb and stretching the muscle by moving limb with another (Ylinen et al. 1995, 70).

## 3.2 Effects of massage

There are several studies about effects of massage. Studies are done from several aspects, such as physiological (e.g. blood flow), neurological (e.g. H-reflex) and psychological. However there is a lack of studies on the mechanical effects of massage such as passive stiffness of muscles. (Weerapong et al. 2005.) In studies done on effects of massage there are several variables that should be considered and customized, such as technique applied, the length of the massage, timing of massage, control groups and testing procedures (Moraska 2005). Previous researches about the effects of massage are listed in table 1. Researches are divided on physiological, neurological and effects on delayed onset muscle soreness (DOMS).

TABLE 1. Previous researches on effects of massage.

| Name | Massage applied | Training | Foundings |
|---|---|---|---|
| Physiological | | | |
| Robertson et al. 2004. N= 9 male | 10 min different techniques | 6*30 cyckling (Wingate) | No effect on power output, blood lactate or heart rate. Fatiguing index decrease after massage. |
| Hemmings et al. 2000. N= 8 male | 8 min leg muscles, 2 min back, 10 min sholders and arms. Effleurage and petrissage. | 2* boxing performance, 5*2min | No effects on heart rate, blood lactate or blood glucose. Significant difference in perceived recovery. |
| Caffarelli et al.1990. N= 12 male | percussive vibratory massage on commercial device | 3*4*70% MVC isometric knee extension | No effect on heart rate or rate of fatigue. |
| Tiidus & Shoemaker 1995. N= 4 male, 5 female | 10 min effleurage | 180º-90º 7*20, 90% of MVC eccentric knee flexion | 48hours postexercise DOMS sensation lower in massage leg. No difference in femoral arterial blood flow. |
| Shoemaker et al. 1997. N= 7 male, 3 female | 5 min effleurage, petrissage, tapotement. | mild voluntary contraction, lifting and lowering leg on supine position. | No effects on blood flow. |
| Durst et al. 2003. N= 7 male | 5, 10 and 15 min deep effleurage, week appart from other session. | | Duration of massage had no effect. Temperature rised 0,5º-3º measured from 1,5 and 2,5cm deep in vastus lateralis muscle. |
| Hinds et al. 2004. N= 13 male | 2*6min deep effleurage and petrissage | 3*2min concentric knee extension | No effect on femoral artery blood flow, muscle temperature and blood lactate. |
| Aourell et al. 2005. N= 14 male | 30 min effleurage, shaking, petrissage and wringing on back, neck and chest or leg, arm and face. Twice a week for 4 weeks. | | Immediate decrease in systolic blood pressure, decrease in diastolic blood pressure after 6 weeks of massage treatment. |
| Neurological | | | |
| Jönhagen et al. 2004. N= 9 male, 8 female | 10 min postexercise. 12 min effleurage and petrissage. Other leg control. | 300* eccentric knee extension 10º-90º at 180º/s | No effect on maximal force, one leg jump. No difference between groups in feelings of pain and discomfort. |
| Morelli et al. 1990. N= 2 male, 7 female | 3 min one handed petrissage. | | H-reflex amplitude recuded during massage. No change in M-wave. |
| Hunter et al. 2006. N= 10 male | 30 min stroking, effleurage, petrissage, wringing and rolling on hamstring muscles. | Knee extension MVC + 3*60, 120, 180, 240º/s | Decline in isokinetic mean force on speed 60º/s only. |
| DOMS | | | |
| Lightfoot et al. 1997. N= 12 male, 19 female | 10 min petrissage on calf muscles immedialtely after exercise and 24hours post exercise. | 4*15 eccentric ankle dorsiflexion | No effects on DOMS or creatine kinase level 24hours postexercise, but both rised significantly 48hours postexercise. |
| Smidth et al. 1994. N= 14 male | 30 min effleurage, shaking, petrissage and wringing on arm and sholder muscles. | 4-5*35 eccentric arm extension contractions on a dynamometer. | Higher DOMS sensation in control group 48hours postexercise. |

# 4. PERCEIVED RECOVERY

Hemmings and his colleagues have researched subjectively perceived recovery after repeated boxing exercise and massage in amateur boxers. Exercise consisted of two sessions of five times two minutes using a boxing ergometer. Massage was applied to intervention group in between the exercise sessions. Duration of the massage was 20 minutes and techniques applied were effleurage and petrissage. The same qualified therapist performed all massage sessions that consisted eight minutes for legs, two minutes for back and ten minutes for shoulder and arms. Perceived recovery was measured with a questionnaire, where subjects answered their subjective feelings on scale 1-7 on four items that were: refreshed, recharged, rested and recovered. The research showed a significant difference on perceived recovery between experimental group that received massage and control group. Researchers made a conclusion that massage has psychological effects on recovery. (Hemmings et al. 2000.)

# 5. PURPOSE AND HYPHOTHESES

Purpose of this study was to define whether effleurage and petrissage massage have positive acute effects on reduction of muscle tone after resistant exercise. This study also searches whether there is a difference between the groups that receive massage immediately or one day after the training session. Psychological aspect of the study was to determine how possible reduction of muscle tone correlates with subjective perceived recovery.

Hypotheses are:

1. Muscle tone will decrease after massage more in intervention group 1 (20 minutes massage) than in control group 2 (20 minutes rest).
2. Perceived recovery will increase after massage in group 1 more than in group 2 after first intervention, massage versus rest.

3. Thickness of subcutaneous tissue will correlate with muscle tone so that thicker tissue will affect more on changes in muscle tone.

# 6. METHODS

Subjects, n= 10 (5 male, 5 female) physically active, university students, were randomly assigned to two experimental groups, five in each group (anthropometric characteristics are shown in table 2). Inclusion criteria were previous experience on strength training and massage therapy. Before any tests (figure 1) the subjects were given and asked to sign an informed consent (appendix 1). Experimental group 1 received massage for 20 minutes immediately after exercise, whereas group 2 received massage one day after exercise. Muscle tone was measured before and after the training session as well as the massage session and one day after the massage session. To determine subjective effects of massage, both groups filled in the questionnaire (appendix 2) each time the muscle tone was measured after exercise.

TABLE 2. Anthropometric characteristics of the subjects.

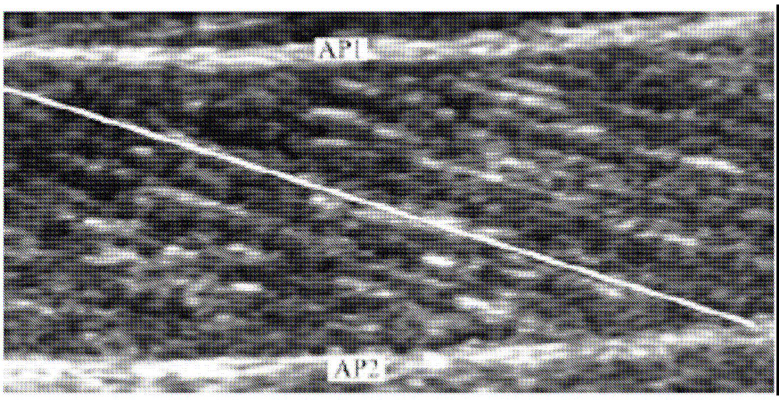
| | N | Age | Weight | Height | 1 RM |
|---|---|---|---|---|---|
| Group 1 | 5 | 23±1 years | 69±10 kg | 170±6 cm | 103±33 kg |
| Group 2 | 5 | 23±1 years | 74±11 kg | 174±12 cm | 116±39 kg |

| | Group 1 | Group 2 |
|---|---|---|
| Day 1 | Pre measurement<br>Training<br>Post training measurement<br>Massage 10+10 min<br>Post massage measurement | Pre measurement<br>Training<br>Post training measurement<br>Rest for 20 min<br>Post rest measurement |
| Day 2 | Day after massage measurement | Pre massage measurement<br>Massage 10+10 min<br>Post massage measurement |
| Day 3 | | Day after massage measurement |

FIGURE 1. Experimental design.

## 6.1 Muscle and subcutaneus tissue thickness

Thickness of muscle and subcutaneus tissue was measured by B-mode ultrasonography (Aloka SSD-2000) with a 7.5 MHz linear probe, from the middle point of rectus femoris muscle between trochanter major and lateral epicondylus on the right leg. Pennation angle was also measured by ultrasound imaging from the same point. The point was marked with a marker pen to the skin to ensure that all measurements were taken from the same point. Probe was set perpendicular to the tissue and gel was used between the probe and skin to improve visibility. Pennation angle was determined from the middle point of the image on the screen from one clearly visible muscle fiber between the muscle fascias, named as AP 1 and AP 2 in picture 6. The thickness of subcutaneous tissue was measured as the white layer between skin and superficial muscle fascia. Rectus femoris muscle thickness was measured from the same muscle fascia (AP 1) to deeper muscle fascia, similar to AP 2 in picture 6.



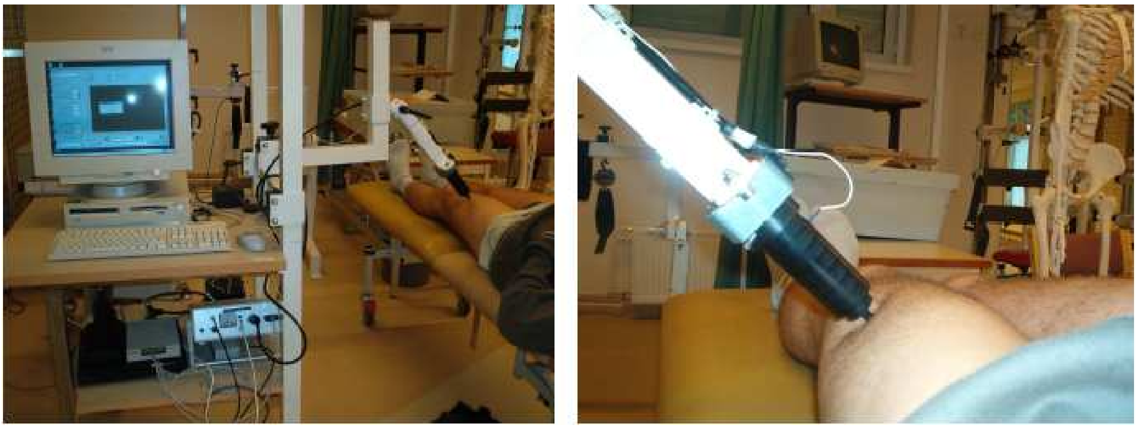

PICTURE 6. Pennation angle of medial gastrocnemius muscle (Martin et al. 2001).

## 6.2 Muscle tone

Ylinen and collegues have researched the repeatability of a computerized muscle tonometer (CMT) (picture 7) and found out that CMT (Medirehabook Ltd, Muurame, Finland) showed good repeatability and sensitivity in assessing muscle tone. CMT presses a shaft with a constant speed to the tissue and calculates the displacement per unit force when pressing the shaft to the tissue. (Ylinen et al. 2006.)

In this study, muscle tone was measured from middle point of rectus femoris muscle on right leg before and after exercise, as well as before and after massage session or rest and day after massage. The measurements were performed with computerized muscle tonometer (CMT) and results were analyzed with muscle tone software. During the measurements legs were stabilized with a strap around the ankles to hold legs still in order to avoid artifacts caused by any movement.

A motorized inner cylinder of the shaft is pushed to the tissue from the CMT with constant speed set to 5 mm $s^{-1}$. The inner cylinder has surface area of 1 $cm^2$, and was located in this study to the middle point of rectus femoris muscle measured from trochanter major and lateral epicondylus. CMT started to measure overall work when force level reached 0,03 N. (Ylinen et al. 2006.) Measurement was proceeded until the force level reached 30N or the displacement reached 5 cm. Data was collected to a computer and immediately drawn into x-y-coordination (picture 8) where muscle tone can be seen as a logarithmic curve, and tension or movements of a muscle as aberration in the curve. The beginning of the force-distance curve expresses the compliance of the superficial tissue (Fisher 1987b). Muscle tone results are expressed as displacement (mm) per force (N) performed or overall work (J). Overall work is calculated as the area under the curve and it correlates inversely with tissue stiffness. When the probe is compressed smaller distance to the tissue, work will also be smaller at constant force and hence tonus will be higher. (Ylinen et al. 2006.) Changes in muscle tone were measured before and after exercise and massage or rest periods as well as one day after the massage, the mean of three repeated measurements was used in analyses.



PICTURE 7. Computerized myotonometer (Haverinen 2005).

## 6.3 Exercise

A 10 -minute warm up period (cycling and squatting with light load) preceded the squat exercise. During the exercise session 1 repetition maximum (RM) squat was determined with a Smith machine for each subject. Fatiguing exercise was performed with submaximal load, 70% of 1 RM. Subjects were asked to perform three sets untill exhaustion. Subjects were verbally encouraged during the training session. Rest between sets was set to one minute. The subjects were asked to perform the squat with 90º knee angle which was visually controlled by the examiner.

## 6.4 Massage

Massage therapist palpated the subject’s thighs prior to the massage session, results were used to estimate the intensity of massage that was used for each subject. The massage table was set on a force platform and thus the force level used for massage was shown on an oscilloscope. Oscilloscope was used as guidance for the massage therapist to help keeping the strokes as smooth as possible, yet the force was smaller at the beginning and at the end of the strokes. Subjects were asked their subjective feelings during the massage using modified Borg scale 6-20, rate of perceived exertion (RPE) (appendix 3). Massage was not meant to cause any pain. Results of force and subjective feelings were not analyzed, only used to control the massage. Muscle tone and ultrasound was measured from right leg. Left leg received massage first. Force level was set to match subjective feeling on Borg's RPE scale 10-14, the same force level was applied to right leg.

Massage was applied with effleurage and petrissage techniques. Duration of massage was set to 10 minutes per leg and only quadriceps muscles were massaged. Same therapist performed the treatments to all of the subjects. Length of a stroke was controlled to begin at the level of knee joint and last until the level of trochanter major. Strokes were applied from distal end of the muscle to the proximal end. To reduce effects of friction therapist used massage lotion (Schupp GmbH & Co, Freudenstadt Germany).

## 6.5 Perceived recovery

Subjects were asked to fill in the perceived recovery questionnaire each time when muscle tone was measured after exercise, in order to find out the correlation between muscle tone and perceived recovery.

For perceived recovery a new questionnaire was developed to determine how subject describes his or her feelings in scale 0 - 4 in each of the nine questions: "relaxation of a muscle", "relaxation of whole body", "warmth in a muscle", "heaviness of legs" "refreshed muscle", "refreshed body", "pain in the muscle during massage session", "perceived recovery in the muscle" and "perceived recovery in the whole body" (appendix 2).

From perceived recovery (questionnaire) comparison between groups 1 and 2 was analyzed as well as comparison between answers before and after massage. The sum of all nine questions was used in analyses.

## 6.6 Statistical analyses

Statistical package for social sciences (SPSS) program was used for statistical analyses. First Shapiro-Wilk test was applied to determine the normality of the data. Mann Whitney-U test was used to find out the differences between groups and Friedman's Anova to find out the differences between measurements in one group. When significant difference was found, results were further analyzed with Wilcoxon test.

Correlation between rectus femoris muscle thickness as well as subcutaneous tissue thickness or perceived recovery and muscle tone was determined by Pearson's correlation coefficient. Significant difference was set $p<0.05$.

# 7. RESULTS

All ten subjects completed all measurements. Women had thicker subcutaneous tissue (0.85±0.5 mm) than men (0.46±0.3 mm), this difference was however non significant. There was no significant difference between the two groups in muscle tone variables or rectus femoris muscle or subcutaneous tissue thickness at pre measurements, after exercise, after massage or day after massage. There was no significant difference between measurement sessions in group 2. However in group 1 there was a significant difference between pre exercise and post exercise ($p = 0.043$) as well as pre massage and post massage ($p = 0.043$) measurements on work performed by the myotonometer. Other variables (force and displacement) did not differ significantly. Muscle tone is calculated form the work and displacement performed with a constant force by the myotonometer. The muscle tone increases when work and displacement values decrease, as the probe is pushed shorter distance to a tense muscle and thus less work is performed. (Ylinen et al. 2006.)

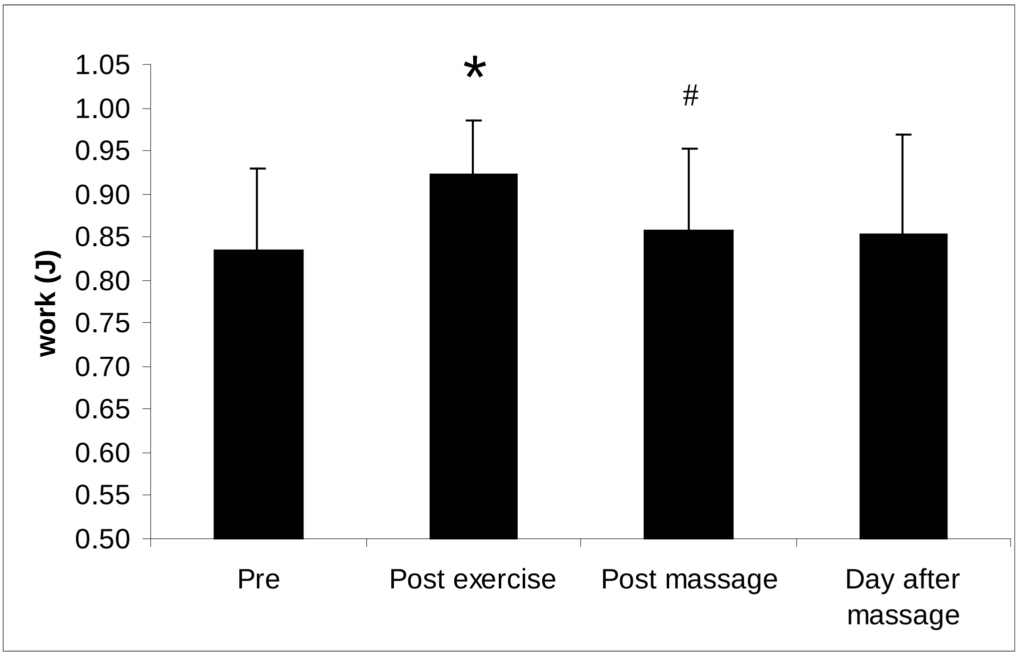



FIGURE 2. Work performed by myotonometer in group 1. * Significant difference between pre measurements and post exercise (p = 0.043), # significant difference between post exercise and post massage measurements (p = 0.043).

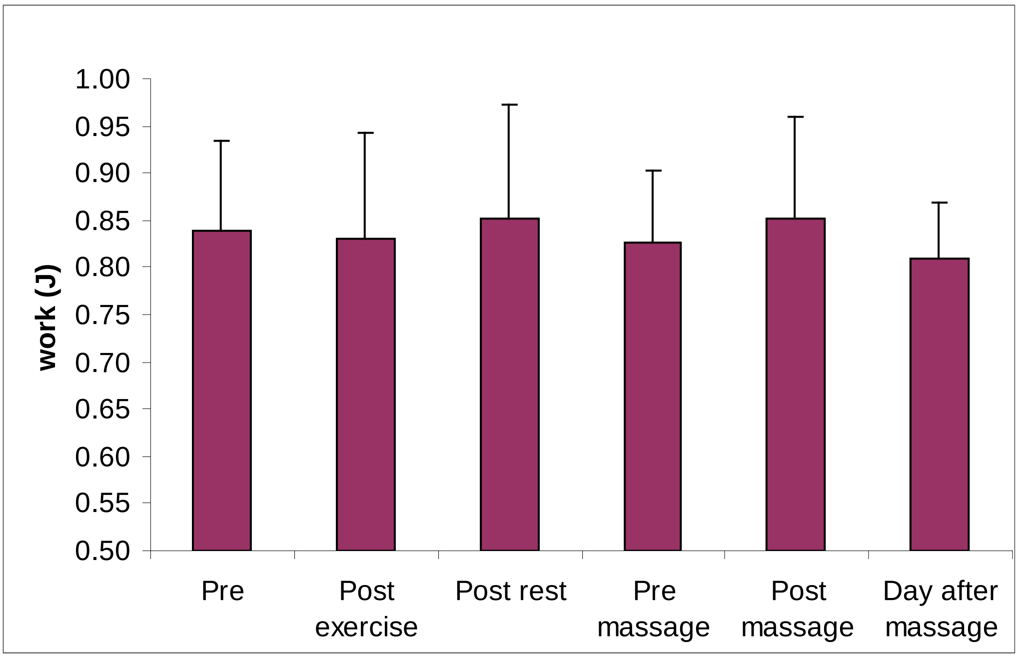



FIGURE 3. Work performed by the myotonometer in group 2. There was no significant difference between measurements.

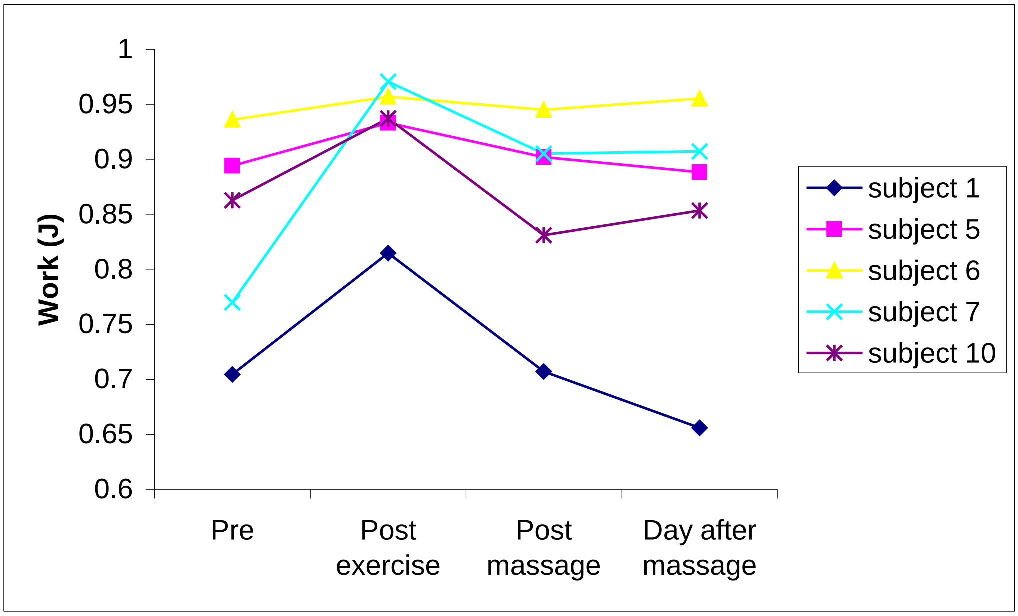



FIGURE 4. Individual differences on work performed by the myotonometer in group 1.

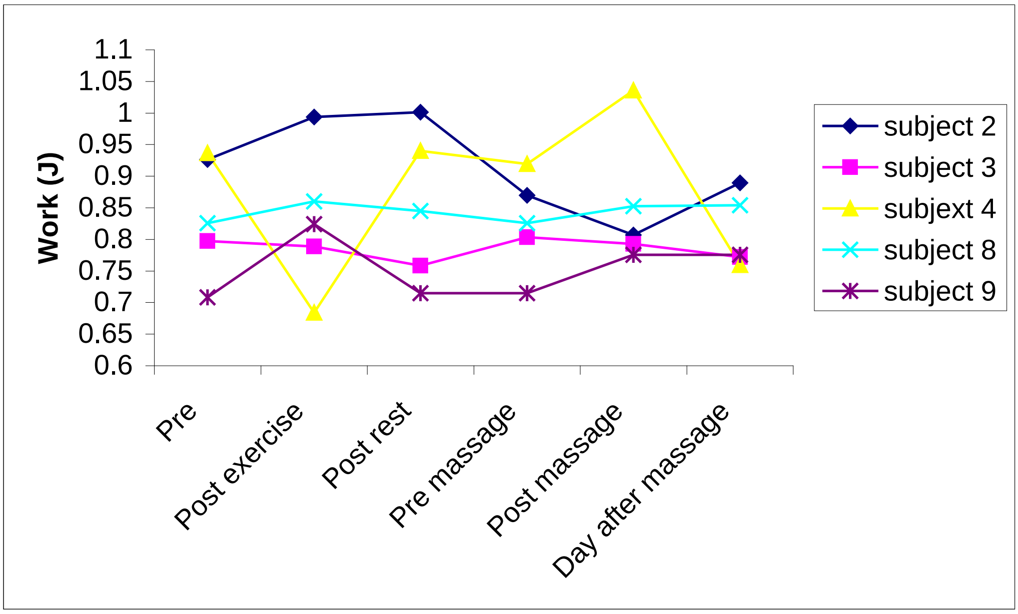



FIGURE 5. Individual differences on work performed by the myotonometer in group 2.

There were no significant correlation between rectus femoris muscle thickness or subcutaneous tissue thickness and muscle tone measured by work, force or distance.

There were no significant changes on perceived recovery between measurements. The sum of all nine questions was used in analyses. Perceived recovery did not show any correlations with muscle tone. Individual differences are shown in figure 6 (group 1) and figure 7 (group 2).

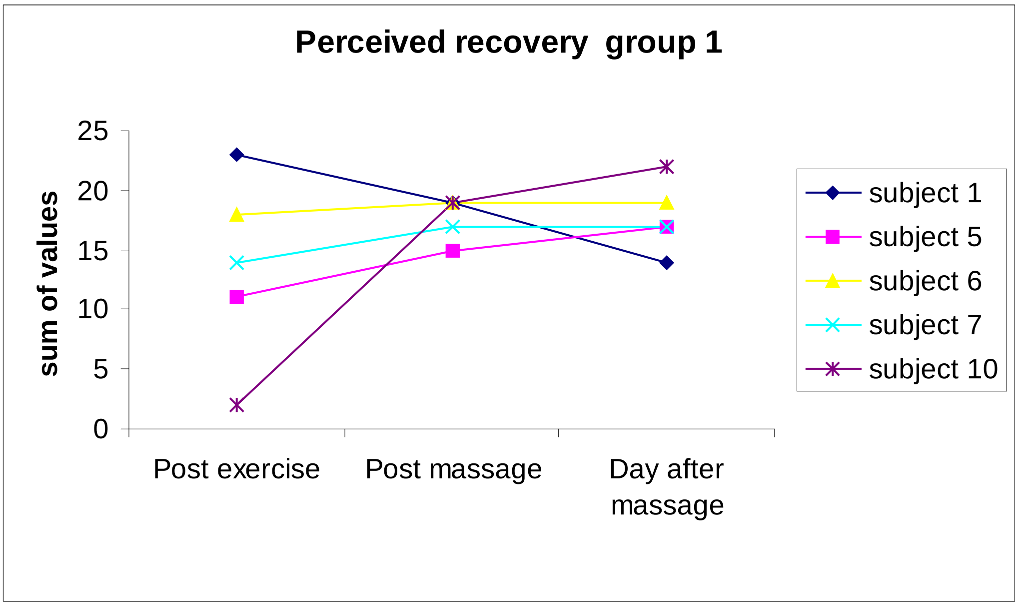



FIGURE 6. Perceived recovery in group 1.

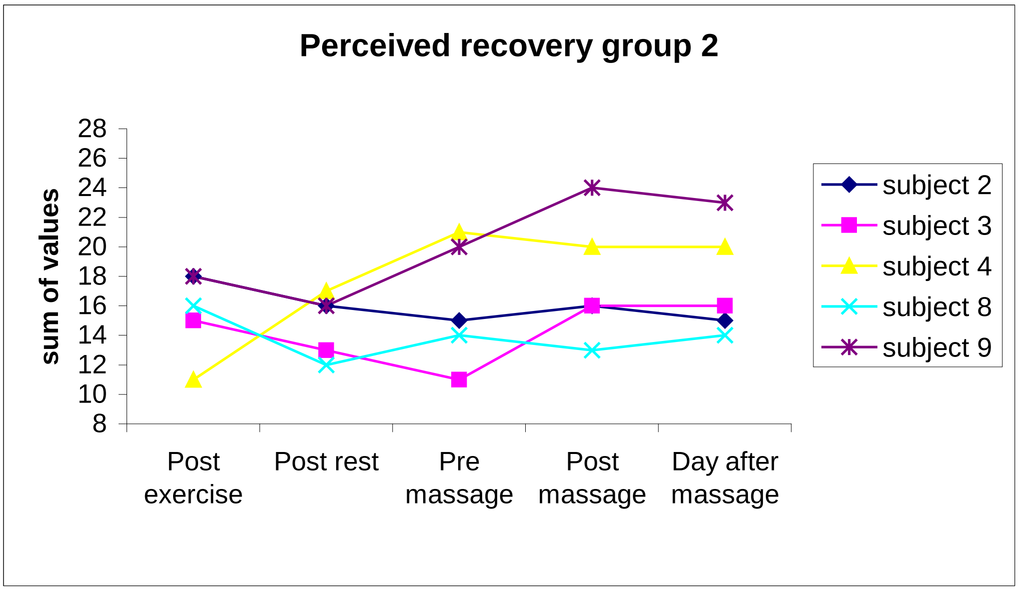
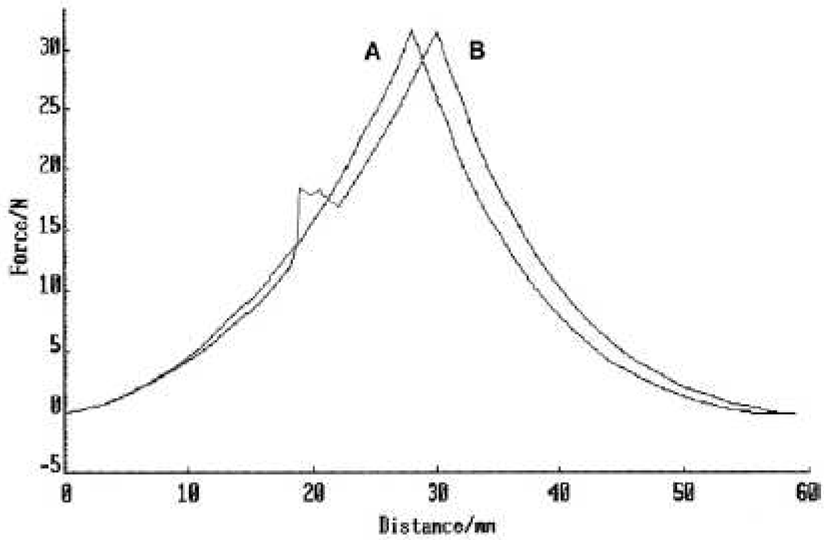



FIGURE 7. Perceived recovery in group 2.

# 8. DISCUSSION

In this study muscle tone was measured as displacement, force and overall work performed by the myotonometer. There was no significant difference on muscle tone between the two groups. There was also no effect of training or massage on muscle tone in Group 2. In group 1 there was a significant decrease ($p = 0.043$) in muscle tone (increase in work) after exercise and a significant increase ($p = 0.043$) in muscle tone (decrease in work) after massage. According to hypothesis 1 the muscle tone was expected to decrease more in group 1 after the 20 minutes massage session than in group 2, that rested for 20 minutes. The contrary result on muscle tone might be due the lack of subjects, individual differences, failed training session, artifacts during measurements e.g. muscle contraction or effects of other factors such as training on previous day. Also, contrary to hypothesis 3 there was no correlation between subcutaneous tissue thickness, rectus femoris muscle thickness or perceived recovery and muscle tone.

The work performed by the myotonometer is determined as an area under the force-distance curve, as the shaft is pushed into the tissue with a constant force, the muscle tone is higher when work and displacement values are less (Ylinen et al. 2006). The maximal force performed by the probe of the myotonometer was set to 30 N and displacement of the probe to 5 cm and when either one was reached the probe started to move away from the muscle. All of the subjects reached the 30 N level before 5 cm displacement. According to Fisher the thickness of the tissue affects the beginning and the end as well as the shape of the force-distance curve (picture 8) (Fisher 1987a). Effects of tissue will be shown in the curve, e.g. how steep the curve increases and decreases as for a tense muscle the probe requires more force to move the same distance than for a less tense muscle. The differences in the curves A and B in picture 7 are most likely caused by changes in tissue properties and resistance. The deviation in curve B during increase is due tension, muscle contraction or other artifact such as movement of the muscle in regard to the shaft and it will affect the calculated overall work. Movements were controlled in this study by attaching ankles together with a strap and subjects were asked to lay relaxed.




PICTURE 8. Force - distance curve from muscle tone measures (Ylinen et al. 2006).

In this study thickness of subcutaneous tissue or rectus femoris muscle did not correlate with the muscle tone. This might be due to small number of subjects and thus weak statistical significance. There were also men and women as subjects in both groups, which differ on body fat. Body fat was measured in this study by subcutaneous thickness and it did not differ significantly between men and women, individual variations was 0,2 – 1,6 mm. Massage therapist also noticed individual differences in muscle stiffness, when palpating the muscles by hands before the massage session, those differences were however not recorded. Individual differences in muscle tone are natural and that could be one reason to explain the variability in results. By including more subjects in the study the results would have been more reliable.

Individual differences in muscle tone and perceived recovery are shown in figures 4-7. The subjects in group 1 show more similar changes in muscle tone than subjects in group 2. In group 2 there are differences between individuals for muscle tone, subject 4 has the greatest difference in both muscle tone and perceived recovery compared to the rest of the group. This might explain why there was no significant difference in group 2, if the results for all individuals are not behaving the same way. In perceived recovery subjects 4 and 9 have the most individual differences compared to the rest of the group, both having the highest values on perceived recovery from pre massage to day after massage measurements except subject 4 has the lowest value at the after training measurement.

Even though the training session was supervised the subjects might not have reached their true 1 RM squat due to e.g. lack of motivation or poor technique, and thus they might have performed the training session on lower load than 70% of 1 RM. Training was performed with a Smith machine that might have affected the technique so that quadriceps muscles have performed less work than e.g. in leg extension machine due to activation of other muscles and the support from the Smith machine. Subject 4 had the highest 1 RM value, being also the only subject who shows increase in muscle tone after the training and decrease after the massage session (figure 5).

Squat training might cause DOMS sensation (McArdle et al. 2001, 540). To avoid this effect, all the recruited subjects were used to strength training. Subjects were asked to avoid heavy exercise during the measurements. As perceived recovery is a subjective feeling, there are several factors that might have affected the results. Such factors are e.g. subjects used bicycles to travel to the measurements, psychological stress or hard exercise periods prior to the study might affect the perceived recovery results. There were variations between subjects on perceived recovery, which might be one of the reasons why the groups did not have any significant difference. Subjects listed such factors that could have affected perceived recovery state as follow: “six hours from last meal”, “came here with bicycle”, training last night”, “rested well last days”, “performed strength training to upper body last night”, “I feel tired”, “eight hours working day” and “I did not sleep well last night”. All comments listed above might have had an effect on perceived recovery.

During massage sessions subjects were asked to answer their subjective feelings of the massage on modified Borg’s RPE scale (6-20) (appendix 3). Massage was not meant to reach higher value than 14. RPE is a subjective feeling and there might be individual differences on how subjects experienced the massage. The same therapist performed all massage sessions and had force level shown on oscilloscope to control the applied force and keep it the same during the session. Massage therapist also noticed differences between individuals and different parts of subject’s muscle on palpation of thigh muscles, which might also affect the subjective feeling of the force massaged.

There are only few previous research with focus on the timing of massage. One purpose of this study was to compare the timing of massage applied immediately versus one day after exercise and its effects on muscle tone and perceived recovery. Muscle tone increased significantly after massage session in group 1, that received massage immediately after exercise, whereas there was no changes in group 2. Group 2 also worked as a control to group 1, as the massage session was timed for group 2 at the same time when group 1 performed their last measurements day after massage. A control group with no massage intervention would have been better to compare the effects of massage with group 2 even at day after massage. Also including more control measurements and subjects in both groups would have made this study more statistically reliable.

Massage techniques applied were petrissage and effleurage. These are commonly used techniques (table 1). Duration of massage was set to ten minutes per leg. As there is a lack of reliable studies of massage, one purpose of this study was to determine the effects of ten minutes of effleurage and petrissage massage on both legs. Further studies are needed to determine whether ten minutes is optimal duration for massage for enhancing recovery after resistance training. Also more studies are needed involving different techniques, such as shaking and tapotemet that are often used to enhance recovery. One problem that makes it hard to compare massage researches is the unique massage technique each therapist has, that might have different effects on how subjects experience the massage session, as well as the personality of the massage therapist. Already the size of a hand makes a difference as small hand might feel harder than bigger hand for a subject and thus he or she might experience massage more heavy. Including more control measurements such as two hours post massage and four hours post massage could have been useful to give additional information about the recovery. Also other factors such as heart rate are easy to measure and it would give good additional information about the recovery.

# 9. CONCLUSIONS

This study showed a significant decrease in muscle tone immediately after squat training in one experimental group. The same group received massage for 20 minutes and after the massage there was a significant increase in muscle tone. The other group that received massage day after training showed no significant change in muscle tone or perceived recovery at any time of the measurements. Another major finding in this study is that muscle tone did not correlate with perceived recovery or subcutaneous tissue thickness.

In future studies more control measurements are needed. In this study only acute effects were measured, it would be useful to also combine measurements with long period training program.

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# 11. APPENDICES

## Appendix 1. Informed consent in Finnish

**Jyväskylän yliopisto**
**Liikuntabiologian laitos**
**Koehenkilötiedote ja suostumuslomake**

### Hieronnan vaikutus lihastonukseen ja koettuun palautumiseen

TIEDOTE TUTKITTAVILLE JA SUOSTUMUS TUTKIMUKSEEN OSALLISTUMISESTA

### Tutkijan yhteystiedot

Piia Haakana,
puhelin: 044-2699138
email: pikrhaak@jyu.fi
Osoite: Schaumanin puistotie 8A1, 40100 Jyväskylä

### Tutkimuksen taustatiedot

Tutkimus suoritetaan liikuntabiologian laitoksella kandidaatin tutkielmana. Mittaukset suoritetaan maalis- ja huhtikuun 2007 aikana.

### Tutkimusaineiston säilyttäminen

Tutkimuksen vastuullinen tutkija vastaa tutkimusaineiston säilyttämisestä, aineisto on vain tutkijan käytössä. Kun työ on hyväksytty ja valmis, poistetaan koehenkilöiden tiedot ja yhteys tuloksiin, jolloin vain data säilytetään eikä koehenkilöitä voi tunnistaa.

### Tutkimuksen tarkoitus, tavoite ja merkitys

Tutkimuksessa on tarkoitus selvittää miten hieronta vaikuttaa yksittäisestä maksimaalisesta voimaharjoittelun aiheuttamaan lihastonuksen muutokseen ja koettuun palautumiseen seuraavan 24 tunnin aikana. Tutkimuksella pyritään määrittämään auttaako hieronta kovasta voimaharjoittelusta palautumista ja kuinka paljon harjoittelun jälkeen hieronta tulisi suorittaa.

### Menettelyt, joiden kohteeksi tutkittavat joutuvat

Tutkittavilta mitataan lihastonus etureidestä, sekä ultraäänikuva 4 tai 6 kertaa riippuen ryhmästä ja tutkittavat täyttävät kyselylomakkeen ennen ja jälkeen hieronnan, sekä seuraavana päivänä. Tutkimuksessa mitataan lihastonusta, lihaksen paksuutta, ihonalaiskudoksen paksuutta sekä koetun palautumisen tilaa. Näytteistä analysoidaan lihaksen ja ihonalaiskudoksen paksuuden ja hieronnan vaikutusta lihastonukseen sekä koettuun palautumiseen.

### Tutkimuksen hyödyt ja haitat tutkittaville

Mitä tutkittavat hyötyvät osallistumisestaan tutkimukseen.
Tutkittava saa tietoa lihastensa kireydestä, hieronnan etureisille ja ohjausta

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APPENDIX 1. (continues)
voimaharjoitteluun. Tutkittava saa myös tietoa ja ohjeita lihashuoltoon.
Tutkimukseen liittyvät riskit ja mahdolliset haitat.
Tutkimuksessa käytettävät menetelmät ovat turvallisia sekä täysin vaarattomia ja kivuttomia koehenkilölle. Maksimaalinen harjoitus saattaa aiheuttaa lihaskipua mittauksen jälkeisinä päivinä. Hieronnassa käytettävä rasva saattaa harvoin aiheuttaa ilolle allergisen reaktion. Tutkija on perehtynyt laboratorion ensiaputarvikkeisiin sekä ensiavun antamiseen loukkaantumis- ja sairaskohtauksissa.

### Miten ja mihin tutkimustuloksia aiotaan käyttää

Tutkimustuloksia käytetään aineistona valmennus- ja testausopin kandidaatin tutkielmaan.

### Tutkittavien oikeudet

Osallistuminen tutkimukseen on täysin vapaaehtoista. Tutkittavilla on tutkimuksen aikana oikeus kieltäytyä mittauksista ja keskeyttää testit ilman, että siitä aiheutuu mitään seuraamuksia. Tutkimuksen järjestelyt ja tulosten raportointi ovat luottamuksellisia. Tutkimuksesta saatavat tiedot tulevat ainoastaan tutkittavan ja tutkijaryhmän käyttöön ja tulokset julkaistaan tutkimusraporteissa siten, ettei yksittäistä tutkittavaa voi tunnistaa. Tutkittavilla on oikeus saada lisätietoa tutkimuksesta tutkijaryhmän jäseniltä missä vaiheessa tahansa.

### Vakuutukset

Tapaturmien ja sairastapausten välittömään ensiapuun mittauksissa on varauduttu tutkimusyksikössä. Laboratoriossa on ensiapuvälineet ja varusteet, joiden käyttöön henkilökunta on perehtynyt. Tutkittavalla olisi hyvä olla oma henkilökohtainen tapaturma/sairaus- ja henkivakuutus, koska tutkimusprojekteja varten vakuutusyhtiöt eivät myönnä täysin kattavaa vakuutusturvaa esim. sairauskohtauksien varalta. Tähän tutkimukseen koehenkilöt eivät ole vakuutettuja tutkimusorganisaation puolesta.

### Tutkittavan suostumus

**Olen perehtynyt tämän tutkimuksen tarkoitukseen ja sisältöön, tutkittaville aiheutuviin mahdollisiin haittoihin sekä tutkittavien oikeuksiin ja vakuutusturvaan. Suostun osallistumaan mittauksiin ja toimenpiteisiin annettujen ohjeiden mukaisesti. En osallistu mittauksiin flunssaisena, kuumeisena, toipilaana tai muuten huonovointisena. Voin halutessani peruuttaa tai keskeyttää osallistumiseni tai kieltäytyä mittauksista missä vaiheessa tahansa. Tutkimustuloksiani saa käyttää tieteelliseen raportointiin (esim. julkaisuihin) sellaisessa muodossa, jossa yksittäistä tutkittavaa ei voi tunnistaa.**

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Päiväys Tutkittavan allekirjoitus

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Päiväys Tutkijan allekirjoitus

## Appendix 2. Questionnaire for perceived recovery

Questions 1-9. Answer with the most suitable number 0-4. With muscle we mean the muscle that has received massage therapy. Subject no_______ before/after

1. How relaxed you feel your body (0 = I do not feel relaxed, 4 = very relaxed)

0 1 2 3 4

2. How relaxed you feel your muscle (0 = I do not feel relaxed, 4 = very relaxed)

0 1 2 3 4

3. How much of warmth you feel in your muscle (0 = not at all, 4 = very much)

0 1 2 3 4

4. How heavy you feel your legs are (0 = not at all, 4 = very much)

0 1 2 3 4

5. How refreshed you feel in general (0 = not at all, 4 = very much)

0 1 2 3 4

6. How refreshed your muscle feels (0 = not at all, 4 = very much)

0 1 2 3 4

7. Feeling of pain in your muscle (0 = not at all, 4 = very much)

0 1 2 3 4

8. Perceived recovery state in whole body (0 = not at all, 4 = very much)

0 1 2 3 4

9. Perceived recovery state in your muscle (0 = not at all, 4 = very much)

0 1 2 3 4

List here if there are any reasons to affect your state of recovery in positive or negative way:

continues

APPENDIX 2. (continues)

Kyselylomake koetun palautumisen tilasta. Vastaa kysymyksiin 1-9, valitsemalla sopivin numero 0-4 (0 = ei lainkaan, 4 = todella paljon) Koehenkilö nro____ ennen/jälkeen

1. Kuinka rennoksi tunnet koko kehosi

0 1 2 3 4

2. Kuinka rennoksi tunnet etureiden lihakset

0 1 2 3 4

3. Kuinka paljon tunnet lämpöä etureiden lihaksessa

0 1 2 3 4

4. Kuinka painavilta alaraajasi tuntuvat

0 1 2 3 4

5. Kuinka virkeäksi tunnet koko kehosi

0 1 2 3 4

6. Kuinka virkeäksi tunnet etureiden lihaksesi

0 1 2 3 4

7. Kuinka paljon tunnet kipua etureiden lihaksessasi

0 1 2 3 4

8. Kuinka levänneeksi tai palautuneeksi tunnet koko kehosi

0 1 2 3 4

9. Kuinka levänneeksi tai palautuneeksi tunnet etureiden lihaksesi

0 1 2 3 4

Listaa tähän asioita jotka voivat vaikuttaa positiivisella tai negatiivisella tavalla palautumistilan tuntemuksiisi tänään:

# Appendix 3. Modified Borg scale for massage

6 Hieronta ei tunnu miltään / Massage does not feel at all

7

8 Hieronta tuntuu erittäin kevyeltä / Massage feels extremely light

9

10 Hieronta tuntuu hyvin kevyeltä / Massage feels very light

11

12 Hieronta tuntuu kevyeltä, ei aiheuta kipua / Massage feels light, does not cause pain

13 Hieronta tuntuu vähän kovalta / Massage feels bit hard

14

15 Hieronta tuntuu kovalta, hieman kivuliaalta / Massage feels hard, bit painful

16

17 Hieronta tuntuu erittäin kovalta, kivuliaalta / Massage feels extremely hard, painful

18

19 Hieronta aiheuttaa huomattavaa kipua / Massage causes remarkable pain

20 Hieronta aiheuttaa sietämätöntä kipua / Massage causes unbearable pain