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THE IMMEDIATE EFFECT OF TRIGENICS MYONEURAL MEDICINE MANIPULATION ON LOWER EXTREMITY MUSCLES TONE AND VISCOUS-ELASTIC PROPERTIES IN MALE BASKETBALL PLAYERS

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ABBREVATIONS

CNS	central nervous system
CAM	complementary and alternative medicine
CT	combined technique
EMG	electromyograph
EMS	elektromyostimulation
FAOS	foot and ankle outcome score
KC	kinetic chain
PDM	proproceptive distortional myoneuromanipulation
PNF	proprioceptive neuromuscular facilitaion
PR	positional release
RI	reciprocal inhibition
ROM	range of motion
SR	sports and recreation activity
TMM	Trigencs Myoneural Medicine
VC	voluntary contraction

INTRODUCTION

The musculoskeletal system is the means whereby we act out and express our human existence. The musculoskeletal system is also by far the greatest energy user in the body as well as being one of our primary sources of pain, discomfort and disability, whether localized or general, referred or reflex, acute or chronic (Chaitow, 2003). A systems level understanding of the human body is more complex than defining characteristics of isolated parts of a cell or the organism (Masi *et al*, 2008).

Muscle tone has received considerable neurophysiological attention over the years, but it has mainly been viewed as a manifestation of *stretch reflex* neuromotor control (Simons et al, 1998). Relatively little research has been done on *resting* muscle tone. In early work of Sir Charles Sherrington (1906), he suggested a role for skeletal muscle *reflex tonus* in maintaining postural attitude (Masi *et al*, 2008).

As a human begins on his or her production of movement, it depends on the structural integrity and alignment of kinetic chain (KC) (Clark, 2000). If one component in KC is out of alignment, it creates predictable patterns of tissue overload and dysfunction, leading to decreased neuromuscular control and initiating the cumulative injury cycle. When the cumulative injury cycle is initiated, it will cause musculoskeletal instability, a decrease in sport performance and eventually injury (Chaitow, 1991; Baldry, 1993).

Today the training load in basketball has sharply increased and this puts bigger demands on the neuromuscular system of athletes. Powerful trainings load the joints, muscles, ligaments, tendons, followed by the decreased elasticity and increased tension of the muscles which could lead the increase of injury accidents. A structured program of warm-up exercises can prevent knee and ankle injuries of young people practicing sports. Preventive training should therefore be introduced as an integral part of youth sports programs (Messina, 1999). If the muscles are shortened or lengthened beyond the optimum length, the amount of tension that the muscle is able to generate decreases (Knott, 1968).

In this study the immediate effect of interactive and integrated Trigenics Myoneural Medicine manipulation on muscle tone, elasticity and stiffness was examined in highly qualified basketball players using Myoton-3. As a result of this study we show beneficial application of injury prevention and rehabilitation field of activity for athletes and any other patient. At the same time cumulative effect of combining both western and eastern medicine is being demonstrated for clinicians and practitioners.

1. REVIEW OF LITERATURE

1.1. INJURY PREVENTION IN ATHLETES

1.1.1. Injury incidence in basketball

With more than a million high school athletes playing during the 2006-2007 academic year in the United States. The most frequent injury diagnoses were ligament sprains (44.0%), muscle/tendon strains (17.7%), contusions (8.6%), fractures (8.5%), and concussions (7.0%) (Borowski *et al*, 2008). Basketball is one of the most frequently mentioned sport and recreational activities (14.4%), accounting for about four injury episodes per 1000 persons in United States in 1997 - 1999. Males were most commonly injured while engaging in basketball, football, or pedal cycling activities, which accounted for 40.1% of all sport and recreational injury episodes. Among females, about 32% of all SR injury episodes occurred during exercising, gymnastics/cheerleading, or basketball (Conn *et al*, 2003).

Messina *et al* (1999), found a greater number of injuries during games than in practice in a prospective study of 1863 male and female high school basketball athletes. A reportable injury was one that resulted in any time loss from participation, an incident that necessitated a consultation with a doctor, or one that involved the head or face. The ankle and knee were the most commonly injured body parts in both boys and girls.

According to Pollard (2002), basketball has also one of the most commonly produce high ankle injury rates in its participation.

As physical activity continues to be promoted as part of a healthy lifestyle, SR injuries are becoming an important public health concern for both children and adults. Prevention efforts aimed at reducing SR injuries through targeting high risk activities, places of occurrence, activity, risk behaviors, and use of protective devices need to go beyond focusing on children and also consider physically (Conn et al, 2003). This area appears to be under-researched and there is a lack of evidence in Estonia about the current situation. Future investigations should be carried out to determine injury incidence in Estonia.

1.1.2. Injury risk factors

Numerous injuries occur each year caused by sport, resulting in decreased physical activity and work time lost in addition to substantial medical costs. Prevention and intervention have become focal points for researchers and clinicians. Before these types of studies can be used, the risk factors for injury must be clearly established. Many injury risk factors, both extrinsic (those outside of the body) and intrinsic (those from within the body), have been suggested (Williams, 1971). Extrinsic risk factors include level of competition, skill level, and shoe type, use of ankle tape or brace, and playing surface. Intrinsic risk factors include age, sex, previous injury and inadequate rehabilitation, aerobic fitness, body size, limb dominance, flexibility, limb girth, muscle strength, imbalance and reaction time, postural stability, anatomical alignment, and foot morphology (Taimela *et al*, 1990). According to the National Collegiate Athletic Association injury surveillance system for 2000–2001, the most common injury sites were the ankle, knee, and lower leg among collegiate soccer, field hockey, basketball, and lacrosse athletes (NCAA, 2002). The most common injury types were muscle strains, ligament sprains, and contusions.

There is general agreement among researchers that injury incidence is greater during competition than in training sessions (Murphy *et al*, 2003). There is strong evidence that previous injury, especially when followed by inadequate rehabilitation, places an athlete at increased risk of suffering an injury to the ankle (McKay *et al*, 2001) knee, and all injuries as a group (Chomiak *et al*, 2000). Several studies have shown a relation between muscle tightness and injury likewise muscle strength and imbalance, articular ROM, postural stability etc. (Murphy *et al*, 2003).

1.1.3. TMM in injury prevention

From TMM point of view, it is important for any athlete to possess structural efficiency. It is important for any athlete to possess structural efficiency. This efficiency is necessary for the alignment of the musculoskeletal system and a key component in manufacturing balance and allowing the athlete to maintain that balance over a constantly changing base of support during functional movements. Studies by Shambaugh *et al*. (1991), Power *et al* (1995), Watson (2001), and Cowan (1996) indicated that deficiencies in posture are important predictors of specific types of sport injury. Watson (2001) noted that posture evaluation must be quantitative, precise and carefully carried out if it is to be of value in the prediction of sport injury. Furthermore, the athlete must also possess functional efficiency, which permits the neuromuscular system to perform functional tasks with the least amount of energy and will create the least amount of stress on the kinetic chain. A structured programme of warm-up exercises can prevent knee and ankle injuries in young people practising sports. Preventive training should therefore be introduced as an integral part of youth sports programmes (Olsen *et al*, 2005). As a result, a warm-up and stretching protocol should be implemented prior to physical activity. The routine should allow the stretching protocol to occur within the 15 minutes immediately prior to the activity in order to receive the most benefit (Woods *et al*, 2007). Considering the issue of the current study it is manipulative therapies can be applied to prevent the extremity disorders delivered as multimodal therapy, blending exercise, soft tissue treatment, modalities, or multiple extremity joint and/or combined spinal and extremity joint manipulative therapy, and is usually condition and patient specific (Brantingham, 2009). Several authors have identified PNF techniques (used in TMM manipulation) as being superior to other stretching methods for improving flexibility (Sady *et al*, 1982). PNF is a normalized, facilitated training method for muscles that involves stretching, resisted movement, traction (separating the joint surface) and approximation (compressing the joint surface) to ameliorate muscle decline, disharmony, atrophy and joint movement (Myers *et al*, 2000)

1.2. SENSORIMOTOR INTEGRATION OF NEUROMUSCULAR SYSTEM

The musculoskeletal system is the means whereby we act out and express our human existence – “The primary machinery of life” is what one of osteopathy's greatest researchers, Irwin Korr (1970), called it. While, medically speaking, the musculoskeletal system may lack the glamour and fascination of vital organs and systems, the fact is that the cardiovascular and neuroendocrine and digestive (and other) systems and organs exist only to service this great biomechanical structure through which we live and function. It is by means of our musculoskeletal system (not our kidneys or livers) that we perform tasks, play games, make love, impart treatment, perform on musical instruments, paint and, in these and a multitude of other ways, interact with one another and the planet. The musculoskeletal system is also by far the greatest energy user in the body, as well as being one of our primary sources of pain, discomfort and disability, whether localized or general, referred or reflex, acute or chronic (Chaitow, 2003).

When the muscular system, articular system and neutral system are activated during functional movements, the cumulative information from all structures is sorted out by the CNS (sensorimotor integration) (Enoka, 1988).

The central nervous system (CNS) designed to optimize the selection of muscle synergies to produce movement (Messina, 1999). Muscles work as force couples to produce force, dynamically stabilize, and reduce force efficiently. The CNS recruits the appropriate muscles in a synergy during specific movement patterns (Ikai *et al*, 1996). Optimum posture enables the development of high levels of functional strength and neuromuscular efficiency. Functional strength permits the neuromuscular system to perform dynamic, eccentric, isometric and concentric actions in a multi-planer environment (Knott, 1968). Neuromuscular efficiency is the ability of the neuromuscular system to allow agonists, antagonists, synergists, neutralizers to work together to reduce force, stabilize and produce force efficiently in all three planes of movement (sagittal, frontal, transverse plane) (Knott, 1968).

The various neural reporting organs provide a constant information feedback to the CNS (central nervous system) and higher centers as to the current state of tone, tension, movement, etc. of the tissues housing them. Such sensory information can be modulated and modified both by the influence of the mind and by changes in blood chemistry, to which the sympathetic nervous system is sensitive (Jones, 1980; Stiles, 1984).

When the muscular system, articular system and neural system are activated during functional movements, the cumulative information from all structures is sorted out by the CNS (sensorimotor integration) (Enoka, 1988)

As a human begins on his or her production of movement, it depends on the structural integrity and alignment of Kinetic Chain (KC). This structural alignment is known as posture and the KC consists of the myofascial system, articular system and neural system (Clark, 2000). All information must go through the CNS by way of a process called *sensorimotor integration*. Once a person has neuromuscular control, optimum posture and alignment will provide optimum structural and functional efficiency to the KC (Chaitow, 1997; Lewit, 1985; Liebenson, 1996). If one component in KC is out of alignment, it creates predictable patterns of tissue overload and dysfunction, leading to decreased neuromuscular control and initiating the cumulative injury cycle. When the cumulative injury cycle is initiated, it will cause musculoskeletal instability, a decrease in sport performance and eventually injury (Chaitow, 1991).

Postural distortion patterns refer to the state in which the structural integrity of the KC is compromised because components of KC area out of alignment (Knott, 1968; Janda, 1988). This places abnormal distorting forces on the structures in the KC that are above or below the dysfunctional segment. For example, if one segment in the KC is out of alignment (lumbar spine in a lower crossed syndrome), other movement segments have to compensate in attempts to balance the weight distribution of the dysfunctional segment (Janda, 1988). Posture is the independent and interdependent alignment (static posture) and function (transitional and dynamic posture) of all components of the KC at any given moment and is under control of CNS. If an athlete is allowed to exercise without proper postural alignment, that athlete may develop muscle imbalances and joint dysfunctions that can lead to injury (Sharmann, 1992; Hammer, 1999). Optimum posture and alignment help prevent serial distortion patterns and provide optimal shock absorption, weight acceptance and transfer of force during functional movement (Liebenson, 1989). Studies by Shambaugh *et al*, 1991, Power *et al*, 1995, Watson *et al*, 2001, all indicate that deficiencies in posture are important predictors of certain type of sport injury. Furthermore, the athlete must also possess functional efficiency, which permits the neuromuscular system to perform functional tasks with at least amount of energy and will create the least amount of stress on the KC (Knott, 1968). This promotes optimum length-tension relationship, force-couple relationships and joint kinematics. There is an optimum length at which the muscle is capable of developing maximal tension (length-tension relationship) (Hammer, 1999).

Several studies have shown a relation between muscle tightness and injury. Krivickas and Feinberg (1996) introduced a new scale for assessing muscle tightness of hip flexors, hamstrings, quadriceps, and gastrocnemius and applied it in a prospective study of lower extremity injury among collegiate athletes. No relation between muscle tightness and injury was found for women; however, for men, there was a significant relation between increased muscle tightness and incidence of lower extremity injury in general and, more specifically, between increased iliopsoas tightness and overuse knee injury. Muscular injury is one of the major problems facing today's athletes, both recreational and professional. Injuries to skeletal muscle represent >30% of the injuries seen in sports medicine clinics. As a result, it is imperative to utilise the most effective means to aid in deterring these injuries. However, there are conflicting opinions regarding methods of reducing muscular injury through warm-up and stretching techniques (Woods *et al*, 2007).

1.2.1. Mechanisms that alter proprioceptors

- Ischaemic or inflammatory events at the receptor site may produce diminished proprioceptive sensitivity due to metabolic byproduct build-up stimulating groups III and IV, mainly pain afferents (this also occurs in muscle fatigue).
- Physical trauma can directly affect receptor axons (articular receptors, muscle spindles and their innervations).
- In direct trauma to muscle, spindle damage can lead to denervation and atrophy (e.g. following whiplash) (Hallgren *et al*, 1993).
- Structural changes in parent tissue leads to atrophy and loss of sensitivity in detecting movement, plus altered firing rate (e.g. during stretching).

- Loss of muscle force (and possibly wasting) may result when a reduced afferent pattern leads to central reflexogenic inhibition of motor neurons supplying affected muscle.

Psychomotor influences (e.g. feeling of insecurity) can alter patterns of muscle recruitment at the local level, and may result in disuse muscle weakness (Lederman, 1997).The main reporting stations:

Ruffini end-organs

These are found within the joint capsule, around the joint, so that each is responsible for describing what is happening over an angle of approximately 15°, with a degree of overlap between it and the adjacent end-organ. These organs are not easily fatigued, and are recruited progressively as the joint moves, so that movement is smooth and not jerky. The prime concern of Ruffini end-organs is to maintain a steady position. They are also, to some extent, concerned with reporting the direction of movement.

Golgi end-organs

These, too, adapt slowly, and continue to discharge over a lengthy period. They are found in the ligaments associated with the joint. Unlike the Ruffini end-organs, which respond to muscular contraction that alters tension in the joint capsule, Golgi end-organs are not thus affected, and can deliver information independently of the state of muscular contraction. This helps the body to know just where the joint is at any given moment, irrespective of muscular activity.

Pacinian corpuscle

This is found in periarticular connective tissue, and adapts rapidly. It triggers discharges, and then ceases reporting in a very short space of time. These messages occur successively, during motion, and the CNS can therefore be aware of the rate of acceleration of movement taking place in the area. It is sometimes called an acceleration receptor. There are other end-organs, but these three can be seen to provide information regarding the present position, direction and rate of movement of any joint.

Muscle spindles

This receptor is sensitive and complex. It detects, evaluates, reports and adjusts the length of the muscle in which it lies, setting its tone. Acting with the Golgi tendon organ, most of the information as to muscle tone and movement is reported. The spindles lie parallel to the muscle fibres, and are attached either to skeletal muscle or to the tendinous portion of the muscle. Inside the spindle are fibres that may be one of two types. One is described as a "nuclear bag" fibre, and the other as a chain fibre. In different muscles the ratios of these internal spindle fibres differ. In the centre of the spindle is a receptor called the annulospiral receptor (or primary ending), and on each side of this lies a "flower spray receptor" (secondary ending). The primary ending discharges rapidly and this occurs in response to even small changes in muscle length. The secondary ending compensates for this, because it fires messages only when larger changes in muscle length have occurred.

The spindle is a "length comparator", and may discharge for long periods at a time. Within the spindle there are fine, intrafusal fibres that alter the sensitivity of the spindle. These can be altered without any actual change taking place in the length of the muscle itself, via an independent g-efferent supply to the intrafusal fibres. This has implications in a variety of acute and chronic problems.

The proprioceptive role of muscles of the suboccipital region is directly related to the number of spindles per gram of muscle. There are an average of 36 spindles per gram in some of the suboccipital muscles, such as rectus capitis posterior minor, and 30.5 spindles per gram in rectus capitis posterior major, compared, for example, with 7.6 spindles per gram in splenius capitis and just 0.8 spindles per gram in gluteus maximus (Peck *et al*, 1984). McPartland and Brodeur (1999) suggest that "The high density of muscle spindles found in the RCPM muscles suggests a value ... [which] lies not in their motor function, but in their role as proprioceptive monitors" of the cervical spine and head.

Buzzell (1970) describes the neural connections with the CNS thus:

The central connections of the spindle receptors are important. The annulospiral fibre has the only known monosynaptic relationship in the body. As the fibre passes to the cord, and through the dorsal horn, it goes without synapse, directly to the anterior horn cells that serve the muscle fibres in the vicinity of the spindle. This is the basis of the so called "tendon reflex", which actually is not a tendon reflex, but simply a spindle response to a sudden elongation of the muscle.

In contrast, the secondary fibres have various synapses in their central connection which can be traced to higher cortical centres. Conscious activity may, therefore, provide a modifying influence, via these structures, on muscle tone. The activities of the spindle appear to provide information regarding length, velocity of contraction and changes in velocity. How long is the muscle? How quickly is it changing length? And what is happening to this rate of change of length? (Gray, 1977).

Golgi tendon receptors

These structures indicate how hard the muscles are working. They reflect the tension of the muscle, rather than its length, as does the spindle. If the tendon organ detects excessive overload it may cause cessation of function of the muscle, to prevent damage. This produces relaxation (Chaitow, 2003).

1.2.2. Muscle groups

Postural muscles (type I)

Muscles have a mixture of fibre types, although there is usually a predominance of one type or another. There are those that contract slowly ("slow twitch fibres" or "slow white fibres"), which are classified as type I. These have very low stores of energy-supplying glycogen but carry high concentrations of myoglobulin and mitochondria. These fibres fatigue slowly and are mainly involved in postural and stabilising tasks (Woo *et al*, 1987).

Phasic muscles (type II)

There are also several phasic/active type II fibre forms, notably: Type IIa fibres ("fast twitch" or "fast red" fibres), which contract more speedily than type I and are moderately resistant to fatigue, with relatively high concentrations of mitochondria and myoglobulin.

Type IIb fibres ("fast twitch/glycolytic fibres" or "fast white fibres"), which are less fatigue-resistant and depend more on glycolytic sources of energy, with low levels of mitochondria and myoglobulin.

Type IIm ("superfast" fibres), found mainly in the jaw muscles, which depend on a unique myosin structure which, along with a high glycogen content, differentiates this from the other type II fibres (Rowlerson, 1981).

The implications of the effects of prolonged stress on these different muscle types cannot be emphasised too strongly, because long-term stress involving type I muscles indicates that they will shorten, whereas type II fibres undergoing similar stress will weaken without shortening over their whole length (they may, however, develop shortened areas within the muscle). It is important to emphasise that shortness or tightness of a postural muscle does not imply strength. Such muscles may test as strong or weak. However, a weak phasic muscle will not shorten overall and will always test as weak (Janda, 1982).

Fibre type is not totally fixed, in that evidence exists as to the potential for adaptability of muscles, so that committed muscle fibres can be transformed from slow-twitch to fast-twitch and vice versa (Lin *et al*, 1994).

An example of this potential, which is of profound clinical significance, involves the scalene muscles, which Lewit (1999) confirms can be classified as either postural or phasic. If the largely phasic scalene muscles, which are dedicated to movement, have postural functions thrust upon them (as in an asthmatic condition in which they will attempt to maintain the upper ribs in elevation to enhance lung capacity) and if, owing to the laboured breathing of such an individual, they are thoroughly and regularly stressed, their fibre type will alter and they will shorten, becoming postural muscles (Lin *et al*, 1994).

Stabilisers and mobilisers.

Norris (1995, 1998) designates muscles according to their major functions, i.e. as "stabilisers" or "mobilisers". According to Norris, research has shown that muscles that are inhibited or weak may lengthen, adding to the instability of the region in which they operate. It is the "stabiliser" muscles that have this tendency: if they are inhibited because of deconditioning they become unable adequately to perform the role of stabilising joints in their "neutral posture".

"Stabiliser" muscles, which are more deeply situated, slow twitch, and have a tendency to weaken and lengthen if deconditioned, include: transverse abdominis, multifidus, internal obliques, medial fibres of external oblique, quadratus lumborum, deep neck flexors, serratus anterior, lower trapezius, gluteus maximus and medius. These muscles can be correlated to a large extent (apart from quadratus lumborum) with muscles designated by Lewit (1999) and Janda (1982, 1983) as "phasic".

The more superficial, fast-twitch muscles which have a tendency to shortening (i.e. "mobilisers" in Norris's terminology) include: suboccipital group, sternocleidomastoid, upper trapezius, levator scapulae, iliopsoas and hamstrings. These fall into the category of 'postural' muscles as described by Lewit (1992), Janda (1982) and Liebenson (1996).

Norris calls these "mobilisers" because they cross more than one joint. This redefining of "postural" as "mobiliser" appears to be confusing, and many prefer to refer to these muscles simply as "having a tendency to shortening" (Liebenson 1999).

1.2.3. Muscle tone

It is nearly impossible to overrate the importance of the functional state of the skeletal muscles as a component of the state of the organism as a whole. One of the significant criteria determining the functional state of the skeletal muscle is its tone (Vain, 1995). Human resting muscle (*myofascial*) tone (HRMT) is the passive tonus or tension of skeletal muscle that derives from its intrinsic (EMG-silent) molecular viscoelastic properties. Clinical experience indicates that persons with certain symptomatic musculoskeletal conditions may have increased resting muscle firmness or hardness (EMG-silent), such as that of the upper trapezius in tension-type headache, and the lumbodorsal extensors (*hartspann*) in degenerative lumbar disc disease and ankylosing spondylitis (Masi *et al*, 2008). Muscle tone has received considerable neurophysiological attention over the years, but it has mainly been viewed as a manifestation of *stretch reflex* neuromotor control (Simons *et al*, 1998).

On the elasticity of skeletal muscle depend the prevention of muscle traumas as well as the economy of energy consumption in the process of active movements and posture maintenance by the muscular tone (Vain, 1999). One of the possible ways of estimating the functional state of neuromuscular system is the use of the method of damped oscillations. This method requires the registration of the damped oscillation period T and the damped oscillation decrement of an impact on muscle's surface. These parameters form the basis for estimating the viscous-elastic properties of neuromuscular system (Ereline, 1987). To describe the viscous-elastic parameters of the skeletal muscles the frequency of damped mechanical oscillation of the muscle tissue, indicating the tension in the muscle, [Hz]), logarithmic decrement of the oscillations, indicating the elasticity of the muscle and stiffness ([N/m]) are measured (Vain, 1995).

Norris (2005) brings out the factors affecting flexibility, dividing them under internal and external factors. Internal factors include muscle tone and elasticity. Muscle tone is defined as a descriptive measure for the period of muscle recovery between training. Increased tone equals worsened condition for recovery (Vain, 1995). Muscle elasticity considers connective tissue framework of the muscles and provides passive resistance. The lower the decrement, the better is the elasticity and ability of contraction (Norris, 2005). Despite limited scientific knowledge, stretching of human skeletal muscle to improve flexibility is a widespread practice among athletes (Magnusson, 1998). Flexibility can be defined as "the range of motion available at a joint or group of joints" (Corbin *et al*, 1994). Three methods of stretching to develop flexibility have emerged: ballistic stretching, static stretching, and PNF. All three methods have been shown to increase ROM immediately after stretching (Sady *et al*, 1982). However, because of the rapid and forceful nature of ballistic stretching and the theoretical potential to exceed the extensibility limits of a muscle, this method of increasing ROM has not been widely supported in the literature. Research investigating the biophysical properties of connective tissue and neurophysical factors affecting ROM has also brought into question the ability of ballistic stretching to promote long term improvements in flexibility (Bandy *et al*, 1994).

1.3. MAIN PRINCIPLES OF TRIGENICS MYONEURAL MEDICINE

1.3.1. Trigenics Myoneural Medicine

Eastern medicine prospective. Complementary and alternative medicine (CAM) is described to use of alternative medicine as an adjunct to, and not primarily a replacement for, conventional medical care. There is an ongoing effort to integrate complementary and alternative medicine into conventional medical practice. Many of the CAM modalities, as defined today, have been used for thousands of years as the mainstay of the healing arts in various cultures and societies. Chinese medicine has used bioenergy ("qi" manipulation [Qi gong], insertion of needles [acupuncture], and ingestion [herbs and foods]) as part of a systematic approach to healthcare. Practitioners of Indian medicine (Ayurveda and Yoga) have used the combination of meditation and exercise as part of their healing approach. Native American medicine emphasizes "shamanism" and spiritualism. During the past 150 years, Western medicine has included the development of allopathic medicine along with the CAM fields of homeopathy, vitamin therapy, osteopathic manual manipulation, chelation therapy, and talk therapies (Frishman, 2009).

Depending upon the source, upper and lower extremity problems have been reported to account for up to 20% of all of chiropractic care, with lower extremity pain and injury specifically accounting for up to 10% of common chiropractic practice and with most practitioners using extremity manipulative therapy based upon location, methodology, training, and philosophy (Brantingham, 2009).

There are various ways of "manipulating" the neural reporting stations to produce physiological modifications in soft tissues – notably of Golgi tendon organs in muscle energy techniques (METs) and of the spindle in various positional release (PR) techniques, such as strain/counterstrain (SCS) (Jones, 1980; Stiles, 1984).

Many researchers and clinicians have recognized the importance of the fascial system in treatment of musculoskeletal pain syndromes as a fascia is connective tissue that connects and separates almost every structure of the human body (Hammer, 1999).

Chiropractic is one of the main branches of manual therapy. Historically, one of the major challenges of chiropractic has been to define and maintain its unique identity among the various manual therapy professions. This has often resulted in competitive stance toward other forms of manual therapy. Chiropractic has struggled with the dilemma of therapeutic diversity in a number of ways. Some chiropractors offer a blend of diversity manual therapy techniques in addition to complementary and alternative medicine option, including herbal medicine, nutrition, energy medicine and physiotherapy. Many of these clinicians use methods from the full spectrum of manual therapy, including soft tissue manipulation. Others limit their therapeutic methods to the hand-on adjustment but apply this method to both somatic and visceral complaints (Nelson *et al*, 2000).

Mechanoreceptor myomanipulation is in use in TMM. Mechanoreceptors are highly specialized neural structures that convert mechanical information into electrical information that is then relayed to the CNS. All of the structures of the KC are innervated with mechanoreceptors (Hammer, 1999). Chinese medicine developed as a concept of yin and yang, acupuncture and acupressure, and it has even been used in the modern medicine (Zuskin et al, 2008).To this point in time, acupuncture has been used primarily as an analgesic, a therapeutic intervention that controls pain under pathological conditions (Pelham, 2001). From an eastern perspective, it does much more. Acupressure is a relative of acupuncture it allows the stimulation of acupuncture meridian points without invasive needles. It involves localized finger/hand pressure (Sung, 1994). When the effects are felt in the immediate area, it is known as local point (Gash, 1990). When the effects are felt or cause a reaction in a distant area, it is commonly known as trigger point. Although trigger points are not always the same as an acupressure meridian points, as many as 71-80% of them coincide to meridian points (Sung, 1994).

Autogenic biofeedback. The term “Autogenic” literally means generated from within and refers to two aspects of the process. Firstly there is the basic shift from the “Stressed State” in which most people now live, to a specific, restorative, healing “Autogenic State” which in many important ways differs from the apparently similar phase of hypnosis, and in which the brain is better able to bring about a wide range of self-regulated readjustments of many systems within the body The process involves the active participation of each person and is a form of self-help. It works on the important principle that, given the basic techniques and a degree of advice and encouragement, the trainee can proceed safely to apply the method for himself and make it part of a health-promoting life-style (Carruthers, 1979).

Modern Western neurophysiology. The spinal cord serves two basic functions. Its first role is as a dual transmission pathway to carry both input information from the sensory receptors to the brain and output information, in the form of motor commands, from the brain to the muscles. Its second role is to support reflexes at the local spinal level to provide rapid, essentially automatic responses to noxious (or potentially dangerous) stimuli and to ensure the successful execution of movements already underway (Abbrnety, 1997).

Literature concerning the theoretical role of spinal reflex circuits and their sensorimotor signals in proprioceptive neuromuscular facilitation (PNF) muscle stretching techniques was examined. Reviewed data do not support the assertion commonly made in PNF literature that contraction of a stretched muscle prior to further stretch, or contraction of opposing muscles during muscle stretch, produces relaxation of the stretched muscle. Further, following contraction of a stretched muscle, inhibition of the stretch reflex response lasts only 1 s (Chalmers, 2004).

Acute adaptations to use have been shown to occur in both the muscle spindle and Golgi tendon organ pathways. It is thought that the intrafusal muscle fibres reset to a higher gain after contraction and that the tendon organ pathway undergoes a brief desensitisation. These phenomena could be important clinically when trying to stretch muscles, i.e. a contraction before a stretch should make the stretch more difficult. Also, this could affect the amount of muscle force generated, thereby altering motor behaviours requiring fine accuracy (Hutton, 1992).

Reciprocal inhibition is a neurological response in which excitation of the group of muscles (the agonists) is associated with the inhibition of a second, opposing group of muscles (antagonists). This response allows for the smooth coordination of muscular activity. Without it, co-contraction of opposing muscle group could lead to a rigor that might impede movement and place undue stress on joints. Sherington (1909) was the first person to take note of the phenomenon of reciprocal inhibition. He found that when he simulated the motor cortex of a cat, some muscles contracted and others relaxed. Those muscles showing relaxation, inhibition, were those that were antagonists of the simulated group.

Ikai *et al* (1996) describe four pathways mediating reciprocal inhibition:

1) alpha - Ia loop,

2) gamma - Ia loop,

Co-activation of alpha and gamma motoneurons is referred to as alpha-gamma linkage.

3) direct corticospinal tract stimulation of the Ia inhibitory interneurons,

4) direct corticospinal tract stimulation of the antagonist alpha motoneurons.

One of the most studied and simplest examples of RI is seen in the stretch reflex. When muscle spindles are stretched they evoke (through fast Ia afferent fibres) at the level of spinal reflex:

a) an excitation of the homonymous alpha-motorneurons leading to contract of the muscle of origin (agonist),
b) stimulation of synergist muscles,
c) inhibition of antagonist muscles via inhibitory interneurons.

These co-ordinations of the motor function are not restricted to spinal reflexes. Cortical stimulation of motorneurons (Betz cells) leads to the stimulation their primary targets (the agonists), the facilitation of synergistic muscles and inhibition of antagonists (Ikai *et al*, 1996).

It is known that the onset of dorsiflexion disynaptic reciprocal inhibition (DRI) of soleus motoneurons is increased to prevent activation of the antagonistic plantar flexors. This is caused by descending facilitation of transmission in the DRI pathway. Because the risk of eliciting stretch reflexes in the ankle plantar flexors at the onset of dorsiflexion is larger the quicker the movement, it was hypothesized that DRI may be increased when subjects are trained to perform dorsiflexion movements as quickly as possible (Geertsen, 2008).

Inverse Myotatic Reflex - a reflex (from a Latin word meaning `bending back`) is the simplest functional unit of integrated nervous system behaviour. The various reflexes scattered throughout the spial cord provide the foundation on which (directly) all involuntary and (indirectly) all voluntary movement is based. The best example of a monosynaptic reflex within the spinal cord is the simple stretch reflex, also known as the myotatic (muscle stretching) reflex (Abbrnety, 1997).

Inverse myotatic reflex is extensively employed in the common contract-relax technique known as proprioceptive neuromuscular facilitation (PNF) and is mediated through two pathways:

1) immediate (employing inverse myotatic reflex) – maximal contraction of the muscle (the agonist) stimulates the *Golgi tendon organs*, which will at the spinal level inhibit (and so relax) the agonist. *Golgi tendon organ* through its Ib afferents stimulates interneurons, which inhibit the agonist and synergist and stimulates the antagonist.

When the *Golgi tendon organ* is stretched to a point that might compromise the integrity of the muscle tendon, the inverse myotatic reflex is activated by inhibiting the contraction of the agonist, protects the muscle tendon.

2) delayed – Renshaw cells are intermediateneurons that cause a delayed reversal of primary effects, that is the inhibition of the agonist and stimulation of the antagonist. Renshaw cells are stimulated by co-lateral of alpha motoneuron and in turn innervate the same alpha motoneuron (and other motoneurons of the same muscle) in an inhibitory fashion. They also inhibit reciprocal inhibition by inhibiting the Ia inhibitory interneurons (Enoka, 1988).

Proprioceptive neuromuscular facilitation (PNF) stretching techniques are commonly used in the athletic and clinical environments to enhance both active and passive range of motion (ROM) with a view to optimising motor performance and rehabilitation. PNF stretching is positioned in the literature as the most effective stretching technique when the aim is to increase ROM, particularly in respect to short-term changes in ROM The superior changes in ROM that PNF stretching often produces compared with other stretching techniques has traditionally been attributed to autogenic and/or reciprocal inhibition, although the literature does not support this hypothesis (Sharman, 2006).

Within Taiwan's current medical and social environment, elite athletes prefer a combination of Eastern and Western treatments for sports injuries. Each of the medical approaches are widely accepted by elite athletes and their coaches At the time of the survey, 74.8% had sporting injuries and were being treated with Chinese and/or Western medicine. Among injured athletes, 14.5% chose Western treatment, 8.1% chose Chinese medicine, and 75.4% received combined treatment (Chen, 2005).

The sports-physician sees the necessity of a holistic view resulting out of the wishes of top ranking athletes in contrast to a quick temporary recovery of unsatisfying duration. On the other hand one must consider the short active period of the athlete and adapt less time consuming diagnosis and therapy (Riedmann, 1988).

1.3.2. TMM manipulation in athletes

A recent study investigating management models in elite athlete injuries discovered that their qualified ability for sports injury prevention was 70%. This ability was significantly correlated with age, education and sports experience. Within Taiwan's current medical and social environment, elite athletes prefer a combination of Eastern and Western treatments for sports injuries. Each of the medical approaches is widely accepted by elite athletes and their coaches (Chen *et al*, 2005). Depending upon the source, upper and lower extremity problems have been reported to account for up to 20% of all of chiropractic care, with lower extremity pain and injury specifically accounting for up to 10% of common chiropractic practice and with most practitioners using extremity manipulative therapy based upon location, methodology, training, and philosophy (Nelson *et al*, 2005). Extremity treatment is the second most frequently applied procedure within the chiropractic profession, with 76.1% reportedly using spinal and extremity procedures as compared with 18.7% who limit their practice to the spine only (Christensen *et al*, 2005).

There are two aspects of TMM in sport applications. One is the application in sport injury and prevention, the second component is the sport performance enhancement protocol. Several observations have been brought forward in athletic world. For instance, preliminary trial study using TMM in speed skaters was conducted. Improvement in lap times of the skaters was noted in athletes after receiving *Trigenics Sport Augmentation* protocol. In injury prevention TMM was tested on Estonian cross-country team. After using TMM procedure athletes suffered “no debilitating overuse or strain injuries for the first time in history” during the 18-month period of care preceding the Olympic Games in Turin. Unfortunately the above mentioned study is based on observations at present so further research is required before the technique's scientific credibility can be established.

In a pilot study by Vahimets *et al*, 2006, on young basketball players, six TMM manipulations were conducted during two weeks period and muscle viscous-elastic properties were registered before and after six TMM manipulation. After six TMM manipulations significant decrease in tone and stiffness of *m. gastrocnemius* was noted in the majority of young basketball players as compared to the pre-therapy condition. Thus the improvement of the functional condition of muscular tissue had occurred. The measurement of muscle tone characteristics is an additional tool for the observation of neuromuscular system condition of athletes and for the individualisation of procedures for increasing their effect.

Doctors and practitioners trained in Western medicine should learn these alternative treatment methods and apply them effectively in athletes, so that a better medical network can be established (Chen *et al*, 2005).

A permanent, interested, integrative cooperation between sports-medicine, science of sports, psychology of sports, organization and last but not least athletes themselves leads not only to better results but also to better human value of every day life before, during and post active period (Riedmann, 1988).

2. THE AIM AND TASKS

The aim of the study was to estimate the immediate effect of TMM manipulation on lower extremities muscles tone and viscous-elastic properties in male Estonian elite league basketball players.

Tasks

1. to analyse the influence of TMM manipulation on tone characteristics (frequency of muscle oscillation) of the lower extremity muscles (*m. tibialis anterior, m. gastrocnemius c. mediale*) before and after every procedure;
2. to estimate the influence of TMM manipulation on elasticity (logarithmic decrement of muscles´ damped oscillation amplitude) of the lower extremity muscles before and after every procedure;
3. to investigate the influence of TMM manipulation on stiffness of the lower extremity muscles before and after every procedure;
4. to assess the influence of five TMM procedures on lower extremity muscles´ tone and viscous-elastic properties according to the FAOS test;
5. to analyse correlations between lower extremities muscles´ tone and viscous-elastic properties and FAOS test.

Hypothesis

Previously it has been found that muscle tone and viscous-elastic properties can be influenced by TMM procedure. A positive effect has been demonstrated in the previous pilot study of tone characteristics of lower extremity muscles before and after five TMM procedures on basketball players (Vahimets *et al*, 2006). At present time there are no studies devoted to investigation of lower extremities muscles´ tone and viscous-elastic properties before and after a single TMM procedure.

The hypothesis of the present study is that TMM procedure has a positive influence on muscle tone characteristics and leads to decreasing of muscle tone (frequency of muscle oscillation).

3. METHODS

3.1. Subjects

Eleven male basketball players of an Estonian team (elite league) aged of 21.7±1.4 years (mean ± SD) (ranged 19 – 24 years) with BMI 23.8±1.1 kg·m^{-2} (ranged 21.3 – 25.2) participated in the study. Their training load was 12-15 h per week and duration of sports training 10.5±2.9 years (ranged 6 – 15 years). Anthropometrical characteristics of the subjects and data of the FAOS test (Roos *et al*, 2001, Appendix 1) are shown in tables 1 and 2. Athletes were divided into two groups: athletes with worse (group I) and better ankle conditions (group II) by FAOS Pain subscale.

Table 1. Antropometrical data of subjects (mean ± SD)

Athlete (n=11)	Age (years)	Height (cm)	Body mass (kg)	BMI (kg·m^{-2})	Duration of sports training (years)	Training load (h/week)	Domi-nant leg
GROUP I							
1	21	188	84	23,7	9	12-15	left
2	23	190	90	24,9	13	12-15	left
3	21	199	100	25,2	10	12-15	left
4	23	198	91	23,2	12	12-15	left
5	22	186	82	23,7	12	12-15	left
6	21	190	90	24,6	6	12-15	left
Mean± SD	**21,8±0,8**	**191,8±4,9**	**89,5±5,7**	**24,2±0,7**	**10,3±2,3**	**12-15**	**left**
GROUP II							
7	19	192	88	23,8	12	12-15	left
8	22	202	95	23,6	6	12-15	left
9	23	187	84	24	8	12-15	left
10	20	202	97	23,7	12	12-15	left
11	24	197	83	21,3	15	12-15	left
Mean±SD	**21,6±1,8**	**196±5,8**	**89,4±5,6**	**23,2±0,9**	**10,6±3,2**	**12-15**	**left**

Table 2. Data according FAOS scoring test questionnaire (mean ± SD)

Athlete (n=11)	FAOS Pain	FAOS Symptoms
GROUP I		
1	77,8	71,5
2	77,8	67,9
3	88,9	46,5
4	88,9	67,9
5	88,9	57,2
6	88,9	69,4
Mean±SD	**85,2± 5,7**	**63,4± 9,6**
GROUP II		
7	91,7	89,3
8	94,5	53,6
9	97,3	71,5
10	97,3	78,6
11	100	71,5
Mean±SD	**96,2± 3,1**	**72,9 ±13**

3.2. Intervention

3.2.1. Trigenics Myoneural Medicine

Trigenics Myoneural Medicine (TMM) combined with Eastern manual medicine and modern neurophysiology is based upon a neurological rather than mechanical model of treatment. The procedures involve synergistic, simultaneous application of three treatment techniques that strongly facilitate neurological pathways involved with muscle relaxation and pain reduction. An appealing aspect of Trigenics is that it also functions as an active resisted exercise involving direct therapeutic interaction between the patient and the *Registered Trigenics Practioner* (RTP). There are three main components used in Trigenics which strongly facilitates neurological pathways involved with muscle relaxation and pain reduction while localized pressure is applied to the Trigenics "*Myopoints*":

- neurogenics (reflex neurology),
- myogenics (mechanoreceptor manipulation),
- autogenics (biofeedback)

Neurogenics. The utilization of reflexogenic neuromyology in TMM is to create an immediate muscular relaxation response with consequent unloading and reduction in the target muscles resting tonicity. The principles of reciprocal inhibition (Sherington, 1909) are applied to allow deeper access into the muscle with reduced pain and resistance. Using the inverse myotatic reflex (Ikai, 1996), muscles are then lengthened to re-establish healthy neuromusculoskeletal dynamics and prevent further injuries.

Myogenics. During the treatment a specific form of manual contact called *Propriceptive Distortional Myoneuromanipulation* (PDM) is applied in a similar yet different manner to the work by Travell and Simons (1998). It is a specific localized transverse pressure on a moving muscle area and/or acupuncture meridian point to create a state of enhanced muscular relaxation or accentuated meridian "myopoint" stimulation.

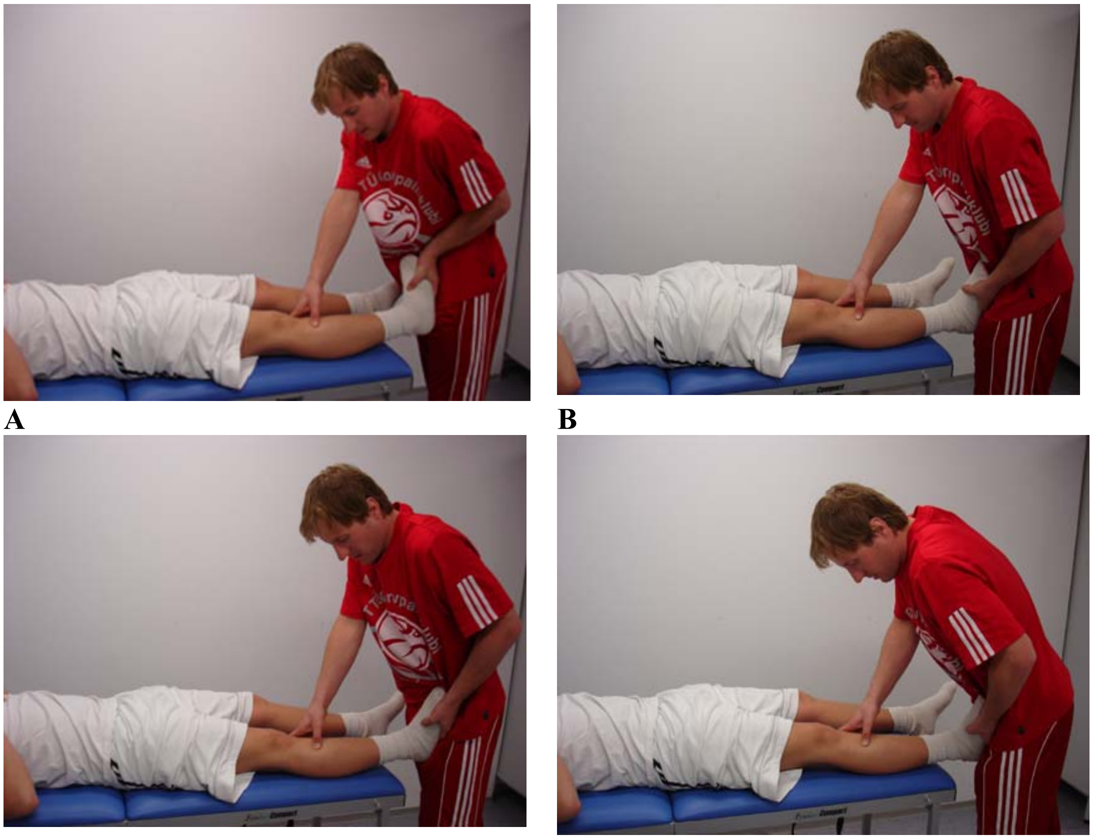
Autogenics also involves active participation of the patient in the treatment. It is controlled and focused deep breathing to create an autonomic muscular relaxation response in order to enhance treatment outcome.

In the present work the following TMM procedures have been used: muscle test, strengthening and lengthening procedures. Muscle tests were performed before procedures (Kendall *et al*, 1993).

M. tibialis anterior muscle test: patient is in supine position, knee extended, with foot resting off the end of the table. The foot is dorsiflexed and inverted. Pressure is applied by the therapist on the involved foot from the medial/superior side, the patient attempting to evert and plantarflex the foot (Kendall *et al*, 1993).

Strengthening procedure: patient is in supine position. The legs are extended along the table with the feet hanging off the end of the table. Therapist stands near the foot facing cephalad (Fig. 1A and B). The furthest hand from the involved side makes a thumb contact on the muscle supporting hand supports the involved foot by placing the hand on the plantar surface and is positioned to resist ankle plantarflexion. The patient will first evert, then fully plantarflex the foot. The therapist will lightly resist this movement, yet allowing full range of motion.

Lengthening procedure: patient is in supine position; legs are in the same position (Fig. 1C and D). Therapist stands in the same way as in case of the strengthening procedure, supporting hand is placed on the dorsum of the foot, across the metatarsals and brings the foot into plantarflexion and eversion to begin the procedure. The patient will attempt to dorsiflex and invert the foot and therapist will resist this movement, allowing for minimal range of motion.



A B C D

FIGURE 1. Strengthening (A – start, B - finish) and lengthening (C – start, D – finish) TMM procedures for *m. tibialis anterior*.

M. gastrocnemius c. mediale muscle test: the involved leg is flexed at the knee by 110° with the foot resting on the table. The lower leg is internally rotated to test the medial head of the muscle. Therapist is standing on the involved side, the furthest hand is placed on the knee to stabilize it the other hand cups the calcaneus on the involved side. Pressure is applied with this hand to extend the knee along the horizontal plane of the table.

Strengthening procedure: patient is in prone position, knee flexed by 90° (Fig. 2A and B). Therapist is standing at the foot off the table; the nearest arm reaches under and around the patient´s foot and ankle, so that the dorsum of the foot rests against the forearm. The patient dorsiflexes and inverts the ankle while lightly extending the knee allowing the patient to extend the knee to a relatively small degree.

Lengthening procedure: patient is in prone position, knee fully extended, and the foot resting off the end of the table (Fig. 2C and D). Therapist supports the patient´s foot so that the plantar aspect of the foot is resting against the distal thigh of the instructor. The patient attempts to plantarflex the ankle by pushing against the therapist´s supporting leg, contracting the muscle approximately for 5-6 seconds. Therapist allows minimum range of motion.

FIGURE 2. Strengthening (A – start, B - finish) and lengthening (C – start, D – finish) TMM procedures for *m. gastrocnemius c. mediale*

3.3. Methods

3.3.1. Myometry

Myometer Myoton-3 and the method of myometry were elaborated at the University of Tartu (Vain, 1979; Vain 1995, Vain, 2001). The working principle of the device is based on the dosed impact on muscle belly, after which muscle as viscous-elastic structure replies with damped oscillation. The apparatus consists of a semiautomatic myometrical transducer with a connecting cable, an analog-digital converter and a personal computer with the software necessary for the visualization, processing and storage of the experimental data (Fig 3) (Vain,1995).The muscle tone is characterized by frequency of muscle oscillation [Hz] at rest (or at relaxation). The muscle elasticity, i.e. the ability of the muscle to restore its initial shape after contraction, is characterized by logarithmic decrement of oscillations' amplitude damping (Vain, 1993; Vain, 1999). The decrement of the decay of the oscillations obtained with the proposed measuring tool is a new indicator of biomechanical tissue that can be used in practical diagnoses (Vain, 1995). Stiffness of muscle characterizes the ability of tissue to restore its shape after removing of external force acting on muscle [N/m] (Vain, 1995). The mass of the testing end of Myoton-3 is 18 g and the kick time of testing end during all measurements was 15 ms.

FIGURE 3. Myoton-3 – device for the measurement of muscle tone, elasticity and stiffness.

Two muscles of lower extremities were tested bilaterally: foot dorsal flexor (*m. tibialis anterior*), foot plantar flexor (*m. gastrocnemius c. mediale*):

1. *m. tibialis anterior* - originated from lateral tibial condyle, interosseus membrane to plantar surface: 1st cuneiform, base of the 1st metatarsal; action – dorsiflexion and inversion (Fig. 4A);

2. *m. gastrocnemius c. mediale* - originated from popliteal surface of femur, superior to medial condyle to posterior surface of calcaneus via Achilleus tendon; action – ankle plantarflexion, knee flexion (Fig. 4B).

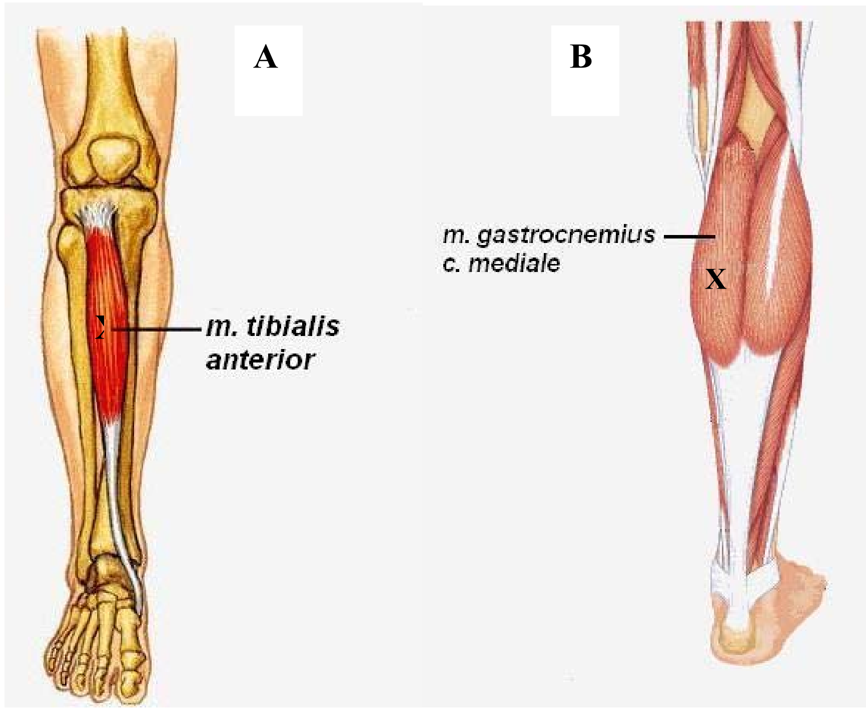


FIGURE 4. Schematic localization of measurement point (x) for *m. tibialis anterior* (A) and *m. gastrocnemius c. mediale* (B).

The muscle tone characteristics were evaluated at rest using MultiScan mode of myometer performing 20 measurements in each muscle point before and after TMM procedure. The point for measurements (the middle part of muscle belly) was identified by manual palpation at muscle during contraction (Kendall *et al*, 1993). The testing end of myometer was placed on previously palpated muscle belly (Fig. 4A and B). The points for measurements were marked symmetrically for muscles of right and left body side. While registering the tone characteristics of foot dorsal flexor and knee extensor muscles, the subject was in supine position; in case of foot plantar flexor and knee flexor muscles measurements the subject was in prone position (Fig. 5 A, B). All myometrical measurements were taken in standard condition according to the muscles. Data were analysed using software Myoton.

A **B**

FIGURE 5. Testing of muscle tone and viscous.elastic properties of lower extremity muscles using Myoton-3; A - *m. tibialis anterior,* B - *m. gastrocnemius c. mediale*.

3.3.2. Foot and ankle outcome score (FAOS) questionnaire

FAOS was developed to assess the patient opinion about a variety of foot and ankle-related problems (Roos *et al*, 2001).

FAOS has this far been used in patients with lateral ankle instability, Achilles tendonitis, and plantar fasciitis. FAOS consists of 5 subscales; Pain, other Symptoms, Function in daily living (ADL), Function in sport and recreation (Sport Rec), and foot and ankle-related Quality of Life (QOL) (Appendix 1). The last week is taken into consideration when answering the questionnaire. Standardized answer options are given (5 Likert boxes) and each question gets a score from 0 to 4. A normalized score (100 indicating no symptoms and 0 indicating extreme symptoms) is calculated for each subscale. The result can be plotted as an outcome profile.

At the present study Pain and Symptoms subscales were taken into consideration to assess the influence of TMM procedure.

3.4. Study arrangement

Five TMM manipulations were performed during the season in practice free days in low intensity training period. The tone, elasticity and stiffness of muscles of lower extremity were evaluated at rest bilaterally, before and after every single TMM manipulation by Myoton-3 and software Myoton.

The first muscle tests and TMM manipulation were conducted at the end of September 2007 in the end of the pre-season period. The rest four TMM manipulations were performed during the basketball season from October 2007 to May 2008. The first two manipulations were performed every month, the rest of procedures and measurements were performed in every two months recess, in every practice free day at the same time, 3-6 pm. All TMM manipulations were conducted in Tallinn Technical University. All the TMM manipulations were performed initially on the right an then on then left body side. The sequence of implications was carried out in the exact same way in every procedure (see section 3.2.1). The duration of each TMM manipulation for one athlete was 15 minutes. Between the TMM manipulations the subjects were having routine muscle care (active and passive stretching, massage, sauna *etc*). No additional drugs or any food supplement were prescribed during this period. Before the first procedure the FAOS questionnaire was completed by all 11 subjects and they were divided into two groups according to their outcomes.

All procedures and measuring were performed under the room temperature of 23°C.

3.5. Statistical analysis

Data are mean and SD. Data were analysed using Myoton (mean and SD) and MS Excel XP software. Changes of data after TMM procedures were calculated in percentage, where characteristics of muscle tone, elasticity and stiffness before each procedure were accepted as 100%. Spearman correlation analysis was performed to estimate relationship between FAOS test and characteristics and muscle tone and viscous-elastic properties. The level of $p<0.05$ was selected to indicate statistical significance.

4. RESULTS

4.1. Frequency of tone of *m. tibialis anterior* and *m. gastrocnemius c. mediale* before and after TMM manipulation

The first muscle tone and viscous-elastic properties of *m. tibialis anterior* and *m. gastrocnemius c. mediale* muscles were measured instantly prior to season (Fig. 6A and 7A). Increased muscle tone was observed in *m. tibialis anterior* and *m. gastrocnemius c. mediale*. There was significant difference between body sides extending up to 12% in *m. gastrocnemius c. mediale*, but no significance in *m. tibialis anterior*, up to 3%.

Significant decrease ($p<0.05$) in tone of left *m. tibialis anterior* was observed in the second and fifth case before and after TMM manipulation, 7% and 10% respectively (Fig. 5A). Greater decrease in tone after single TMM manipulation was found in right *m. tibialis anterior* in the third and fifth case (by 7% and 12%, respectively).

Changes in muscle tone of *m. gastrocnemius c. mediale* muscle (Fig. 7A) showed significant increase ($p<0.05$) in the right leg in the third case compared to the situation before the TMM procedure (9%). At the same time there was 25% increase noted in the left *m. gastrocnemius c. mediale* muscle after the TMM manipulation.

All other results demonstrated a tendency to decrease in the majority of cases, extending on average up to 4%.

4.2. Elasticity *m. tibialis anterior* and *m. gastrocnemius c. mediale* before and after TMM manipulation

Changes in elasticity (characterized by logarithmic decrement) of muscles before and after TMM manipulation is shown in Fig. 6B and 7B. A decrease in decrement (improvement of elasticity) was observed in the majority of cases in the right side of *m. tibialis anterior* (average of 6%), except the third case (increasing 2%). A contrary effect of TMM manipulation was established in the left side, after which the decrement was increasing on average 5%. The same tendencies were noted in *m. gastrocnemius c. mediale*. A decrease in decrement of right *m. gastrocnemius c. mediale* extended up to 11% after the TMM procedure. Changes in the left side demonstrated the increase in the second and third case (9% on average) and decrease in the fourth and fifth case (6% on average).

4.3. Stiffness of *m. tibialis anterior* and *m. gastrocnemius c. mediale* before and after TMM manipulation

As illustrated in Fig. 6C, there was a decrease in stiffness of *m. tibialis anterior* in the majority of cases, extending over 10% in the fifth case after TMM manipulation. A significant decrease was noted in the left side of *m. tibialis anterior* after the third case.

Changes in stiffness of *m. gastrocnemius c. mediale* are shown in Fig. 7C. A decreasing tendency has been demonstrated in most cases (4% on average), but an increasing effect was noted in the third case in the right and left leg, the increase of stiffness was 16% and 21%, respectively, after TMM manipulation.

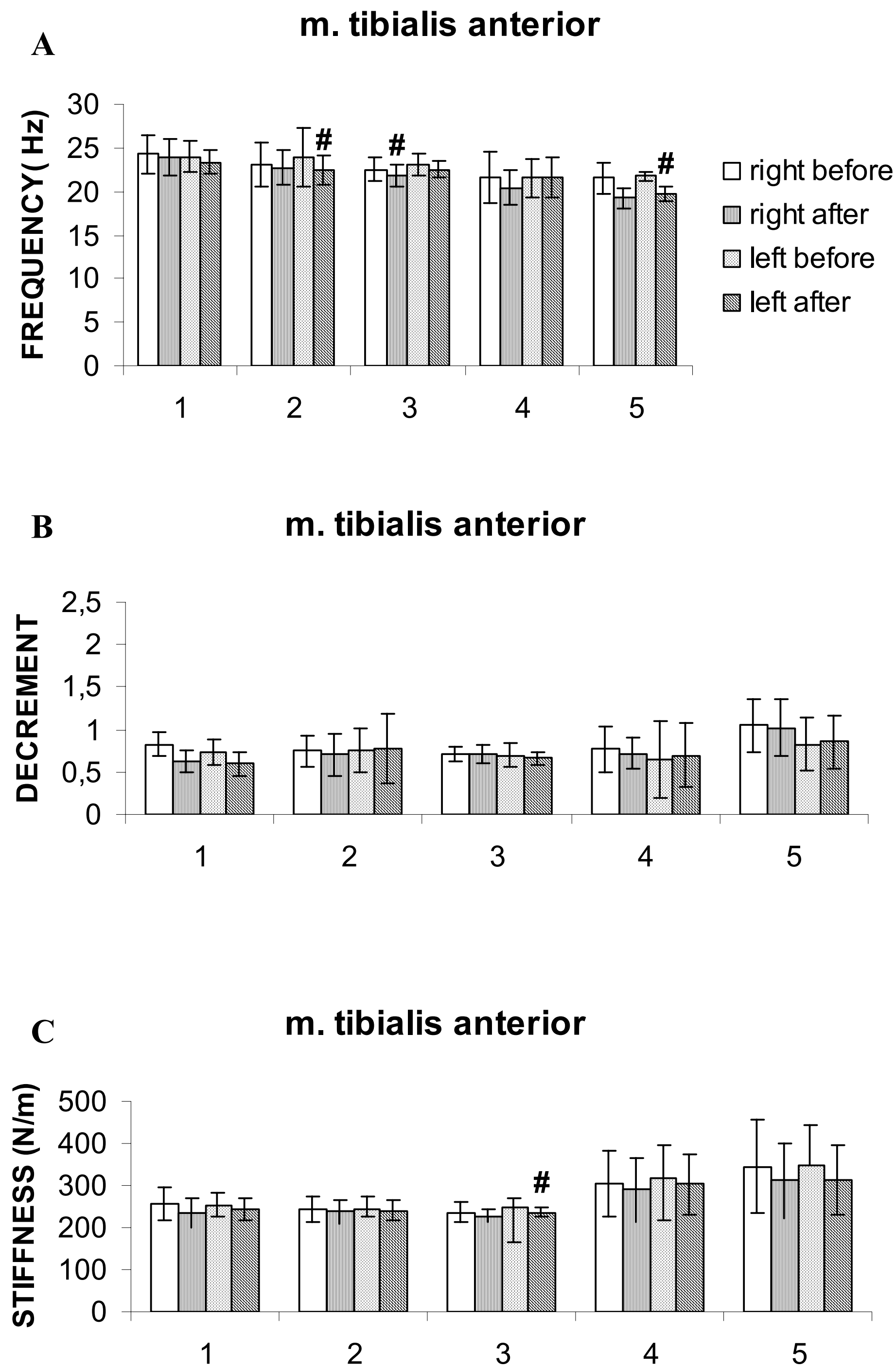


FIGURE 6. Tone (A), elasticity (B) and stiffness (C) of *m. tibialis anterior* before and after TMM manipulation. #- $p<0.05$ compared to data before TMM manipulation.

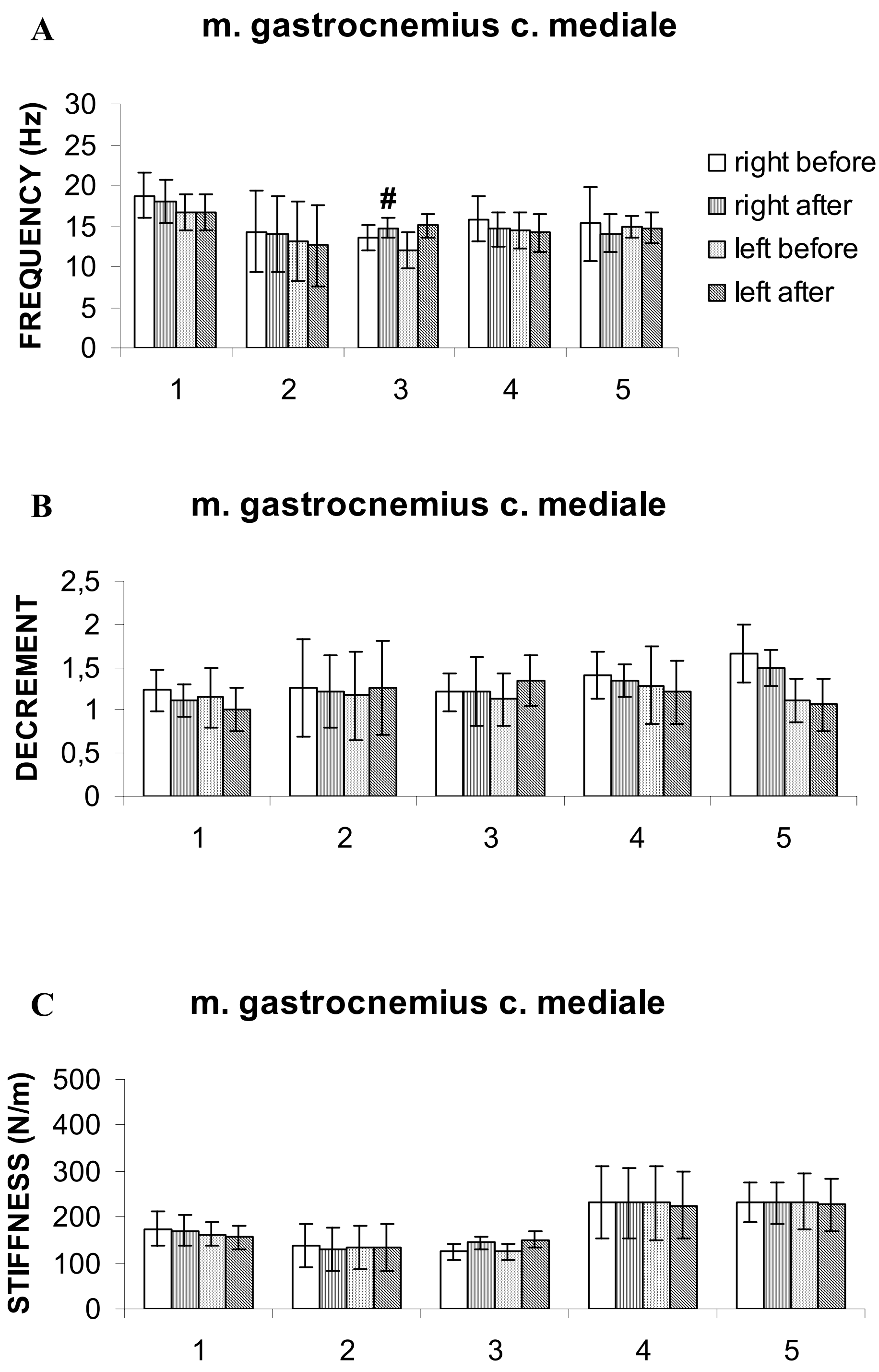


FIGURE 7. Tone (A), elasticity (B) and stiffness (C) of *m.gastrocnemius c. mediale* before and after TMM manipulation. #- $p<0.05$ compared to data before TMM manipulation.

4.4. Individual analysis of immediate effect of TMM on muscle tone, elasticity and stiffness of *m. tibialis anterior* and *m. gastrocnemius c. mediale* according to FAOS test.

Different individual changes in muscle tone, elasticity and stiffness of lower extremity muscles were established for right and left body side according to the FAOS test (total of 22 legs). According to the results of FAOS Pain subscale athletes were distributed into two groups with worse (6 atheletes) and better (5 athletes) ankle condition.

Changes in *m. tibialis anterior* muscle tone after TMM manipulation are shown in Fig. 8A and 9A. A significant decrease (9%, $p<0.05$) in the muscle tone of right *m. tibialis anterior* was noted in athlete 8 in the group with better ankle condition. In other cases the decrease in the muscle tone was found after TMM manipulation in both leg with worse and better ankle condition, 16% and 8% on average respectively.

After TMM manipulation the muscle tone of *m. gastrocnemius c. mediale* showed a tendency to decrease (Fig. 10A and 11A) in the majority of cases in both groups. Greater decrease (13%) was found in the right *m. gastrocnemius c. mediale* muscle in athlete 11 in the group with better ankle condition.

Changes in elasticity are demonstrated in Fig. 8B, 9B, 10B and 11B. A significant decrease in decrement ($p<0.05$) of *m. tibialis anterior* (Fig. 8B and 9B) was established in both groups, in the left side (10%) of athlete 2 with worse and in the right side (21%) of athlete 9 with better ankle condition.

The increase in decrement of *m. gastrocnemius c. mediale* (Fig. 10B and 11B) was noted in the majority of cases. Greater changes were found in the group with worse ankle condition, extending up to 55% in the right side of athlete 2 after TMM manipulation, but more extensive changes (on average 10%) can be found in the left side, compared with the data of the right side.

Changes in stiffness of *m. tibialis anterior* are shown in Fig. 8C and 9C. A significant decrease ($p<0.05$) in stiffness of *m. tibialis anterior* was noted in the left side of athlete 1 and right side of athlete 4 of the group with worse ankle condition after TMM manipulation (3% and 5% respectively). In the group with better ankle condition significant decrease ($p<0.05$) was observed in the right *m. tibialis anterior* muscle of athlete 9 (8%).

After TMM procedures the stiffness of right *m. gastrocnemius c. mediale* (Fig. 10C and 11C) significantly increased (3%, $p<0.05$) in athlete 5 of the group with worse ankle condition, at the same time a decrease in left *m. gastrocnemius c mediale* (2%) was noted.

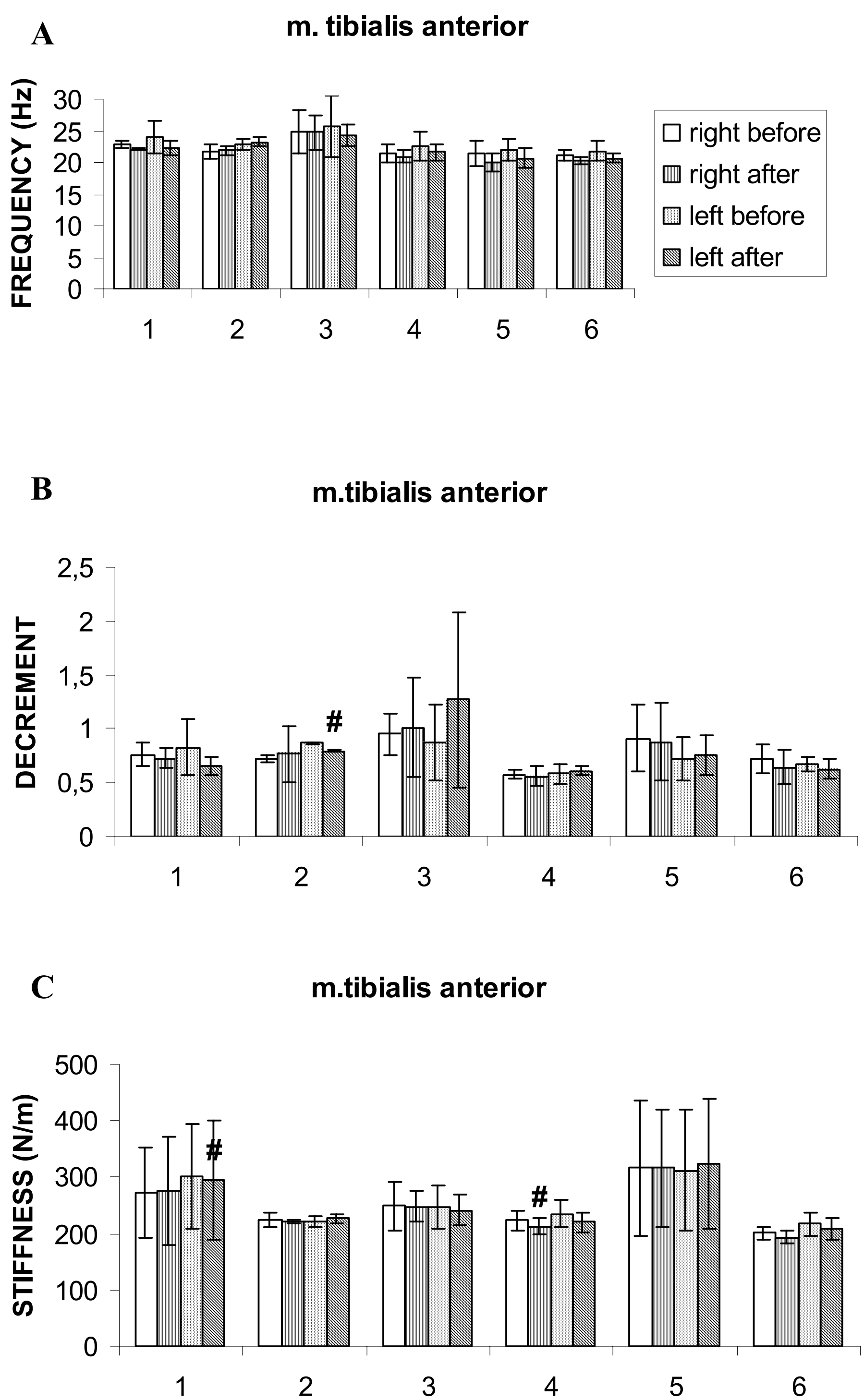


FIGURE 8. Tone (A), elasticity (B) and stiffness (C) of *m. tibialis anterior* before and after TMM manipulation according to FAOS test in athletes of group I with worse ankle condition. #- $p<0.05$ compared to data before TMM manipulation.

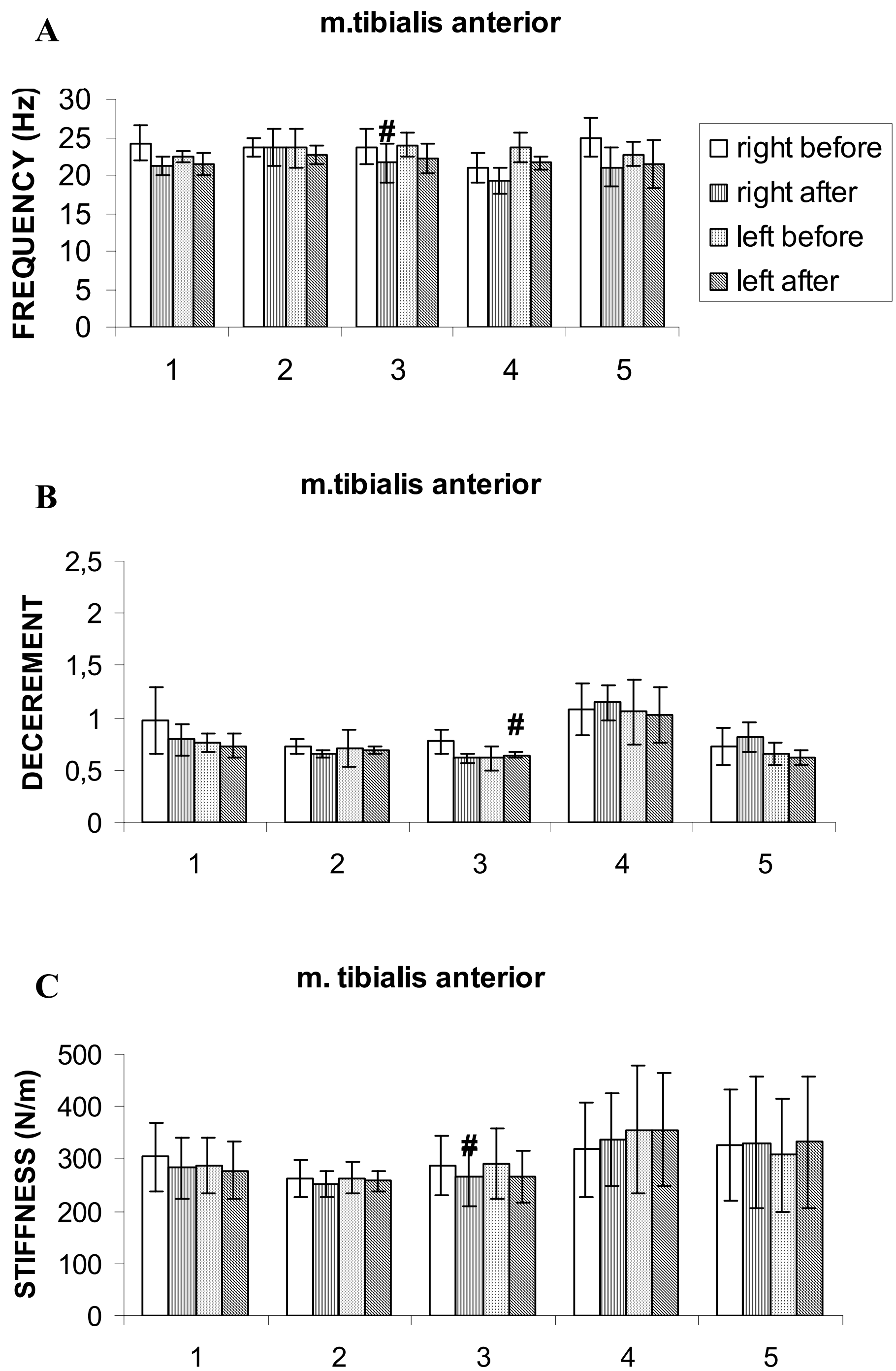


FIGURE 9. Tone (A), elasticity (B) and stiffness (C) of *m. tibialis anterior* before and after TMM manipulation according to FAOS test in athletes of group II with better ankle condition. #- $p<0.05$ compared to data before TMM manipulation.

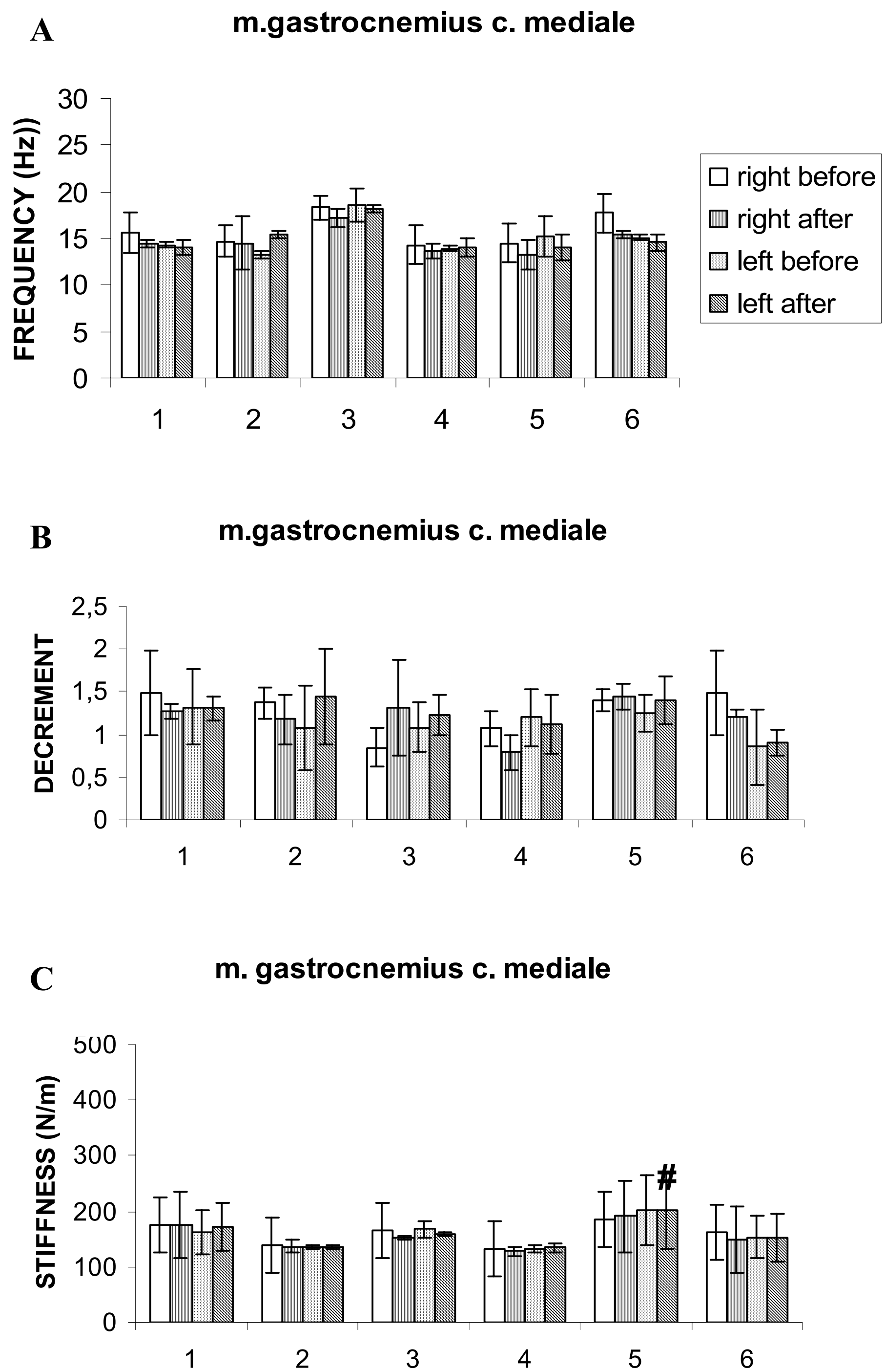


FIGURE 10. Tone (A), elasticity (B) and stiffness (C) of *m. gastrocnemius c. mediale* before and after TMM manipulation according to FAOS test in athletes of group I with worse ankle condition. #- $p<0.05$ compared to data before TMM manipulation.

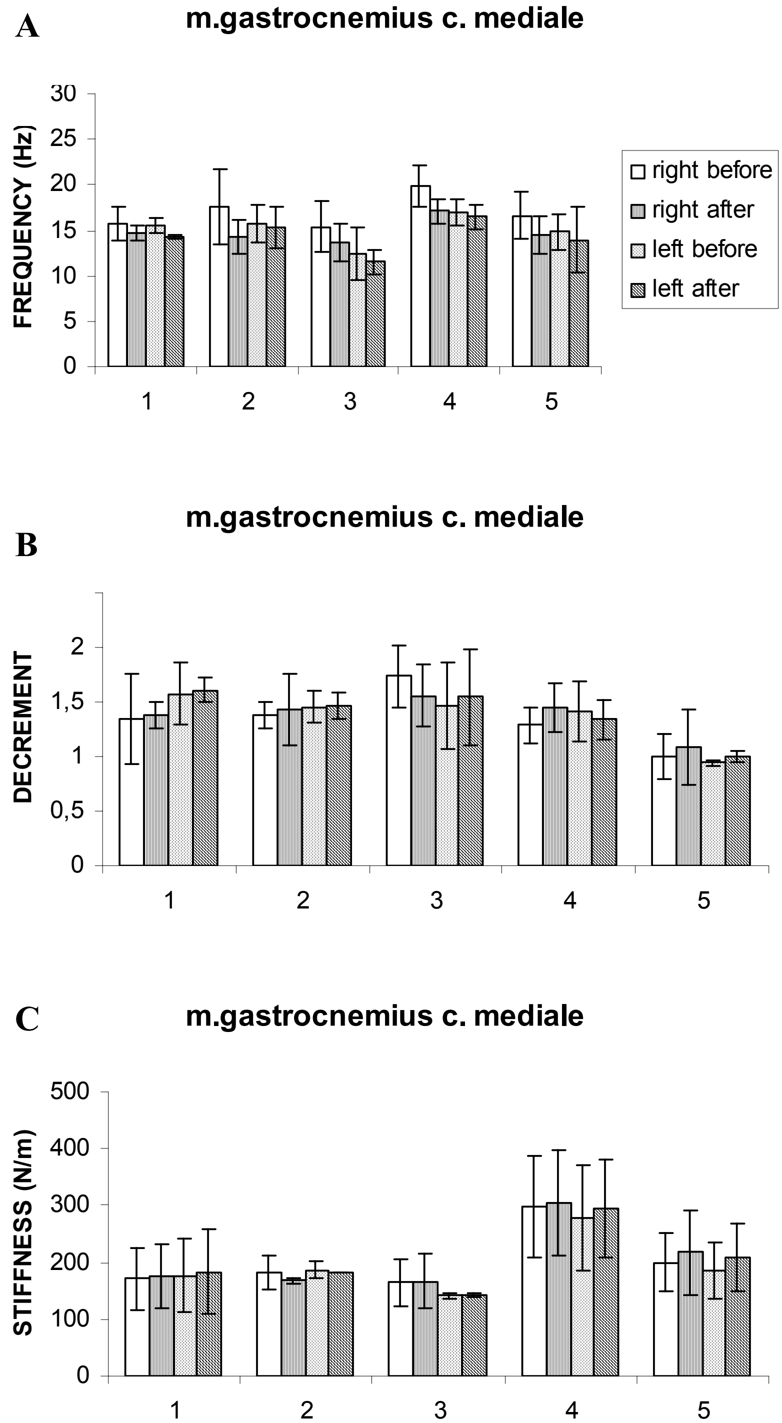


FIGURE 11. Tone (A), elasticity (B) and stiffness C) of *m. gastrocnemius c. mediale* before and after TMM manipulation according to FAOS test in athletes of group II with better ankle condition. #- p<0.05 compared to data before TMM manipulation.

4.5. Relative changes (in percentages) in muscle tone, elasticity and stiffness of *m. tibialis anterior* and *m. gastrocnemius c. mediale* after a single TMM manipulation in comparison with the data before TMM manipulation.

After TMM manipulation a statistically significant decrease ($p<0.05$) in tone *m. tibialis anterior* (Fig. 12A) was found in the left side of the second and fifth case and a significant decrease ($p<0.05$) in tone was observed in the right side of the third case. The decrement of *m. tibialis anterior* (Fig. 12B) showed a tendency to decrease in the majority of cases in the right side, however there was a slight increase in the left side in the second, fourth and fifth case after TMM manipulation, as compared to the characteristics before TMM manipulation. There was a significant decrease ($p<0.05$) in stiffness in *m .tibialis anterior* (Fig. 12C) after TMM manipulation in the left side in the third case and a tendency to decrease in all other cases.

Relative changes in *m. gastrocnemius c. mediale* are shown in figure 13A, B and C. A significant increase ($p<0.05$) in tone (Fig. 13A) was noted in the right muscle after the third TMM manipulation. Decrement's tendency to increase (Fig. 13B) was found in the left side after the second and third TMM manipulation as compared to the characteristics before TMM manipulation. In other cases the decrement showed a tendency to decrease. In the majority of cases a tendency to decrease was noted in stiffness but after the third TMM manipulation the stiffness of *m. gastrocnemius c. mediale* showed an increasing tendency in comparison with the data before TMM manipulation.

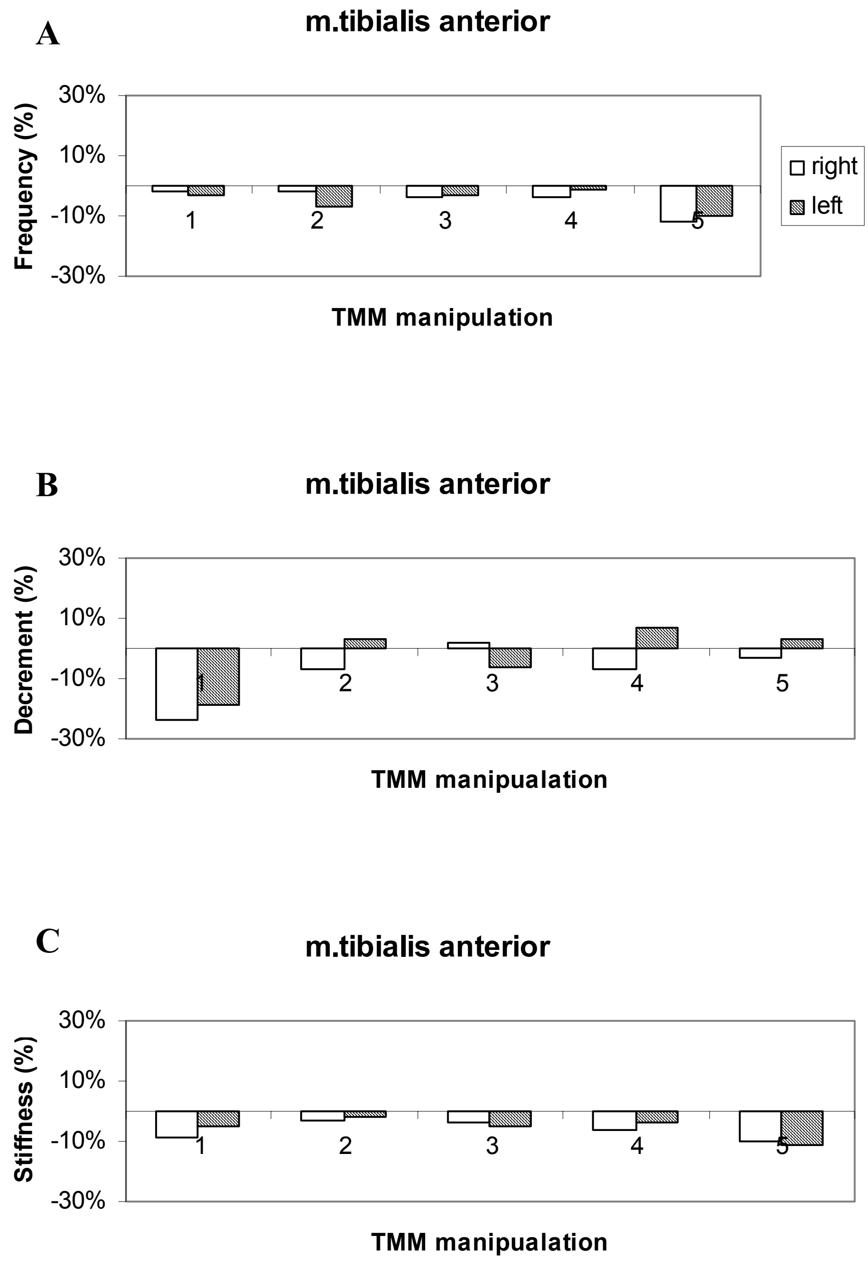


FIGURE 12. Relative changes (%) of tone (A), elasticity (B) and stiffness (C) of right and left *m.tibialis anterior* after TMM manipulation as compared to before TMM manipulation in athletes ($p<0.05$). Data before each TMM manipulation is 100%.

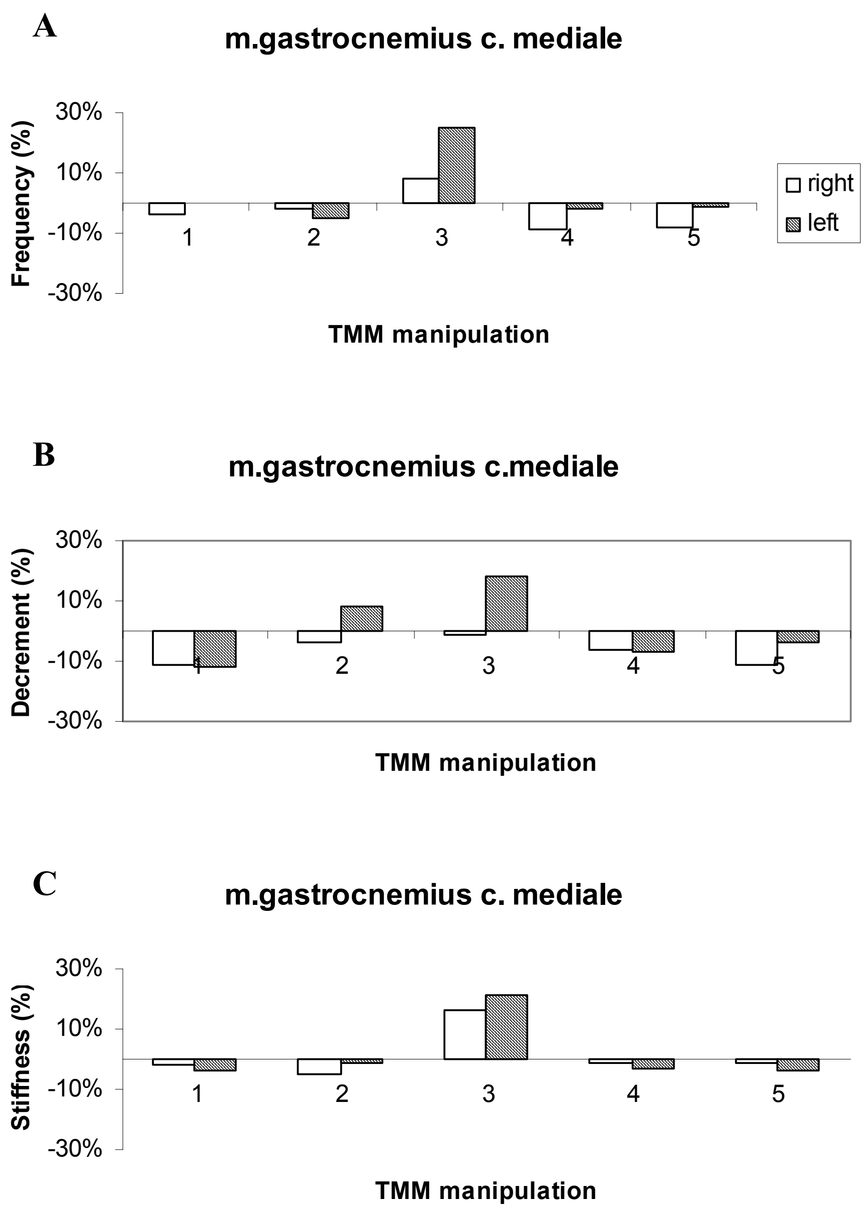


FIGURE 13. Relative changes (%) of tone (A), elasticity (B) and stiffness (C) of right and left *m.gastrocnemius c. mediale* after TMM manipulation as compared to before TMM manipulation in athletes ($p<0.05$). Data before each TMM manipulation is 100%.

4.6. Correlation analysis between lower extremities muscle tone and viscous-elastic properties and FAOS test, duration of sports and anthropometrical parameters.

Correlation between lower extremities muscle tone and viscous-elastic properties and FAOS test (subscales Pain, Symptoms) are shown in Table 3. A significant correlation is found between relative changes in tone of right *m. gastrocnemius c.mediale* ($p<0.05$) and FAOS test (Pain). Other characteristics of viscous-elastic properties showed medium or low correlation with FAOS test. There was a medium correlation between most viscous-elastic properties and FAOS test (Symptoms) noted.

A significant correlation ($p<0.05$) between age and elasticity of right *m. tibialis anterior* before TMM manipulation was found.

A significant correlation was noted between body mass of athletes and the tone of left *m. gastrocnemius c. mediale* before and after TMM manipulation ($p<0.05$ and $p<0.001$, respectively) and right *m. gastrocnemius c. mediale* after TMM manipulation ($p<0.01$). Medium correlations were discovered between relative changes in stiffness of right *m. gastrocnemius c. mediale* and BMI and relative changes in stiffness of left *m.gastrocnemius c. mediale* and BMI.

Table 3. Correlations between characteristics of lower extremity muscles tone and viscous-elastic properties and FAOS test, anthropometrical parameters

	Age	*Height*	*Body mass*	*BMI*	*dur of sports*	FAOS Pain	FAOS Symptoms
Age	1					0,09	-0,25
Height	-0,08	1				0,45	0,08
Body mass	-0,36	0,76**	1			0,06	-0,22
BMI	-0,41	-0,21	0,48	1		-0,52	-0,42
dur of sports	0,22	0,07	-0,22	-0,45	1	0,05	0,3
TA tone bef right	0,08	0,16	-0,04	-0,25	0,04	0,32	0,09
TA tone after right	0,07	0,24	0,4	0,33	-0,32	-0,2	-0,33
TA tone bef left	-0,09	0,34	0,5	0,3	-0,18	0	-0,21
TA tone after left	0,08	0,31	0,55	0,44	-0,07	-0,28	-0,23
GM tone bef right	-0,43	0,65*	0,68*	0,1	-0,26	0,44	-0,09
Gm tone after right	-0,51	0,54	0,76**	0,35	-0,03	0,13	-0,19
GM tone bef left	-0,55	0,61*	0,70*	0,2	-0,01	0,2	-0,29
GM tone after left	-0,38	0,61*	0,83***	0,41	0,08	-0,15	-0,35
TA decr bef right	-0,70*	0,12	0,29	0,24	0,17	0,23	0,16
Ta decr after right	-0,43	0,34	0,4	0,11	0,4	0,17	-0,03
TA decr bef left	-0,54	0,28	0,5	0,35	0,2	-0,2	0,13
TA decr after left	-0,4	0,41	0,72*	0,5	0,12	0	-0,33
GM decr bef right	-0,08	- 0,64*	-0,46	0,21	-0,49	-0,12	0,28
GM decr after right	-0,4	-0,2	0,01	0,3	-0,36	0,24	0,12
GM decr bef left	-0,42	0,05	0,01	0,01	-0,13	0,19	0,66*
GM decr afetr left	-0,27	-0,19	-0,05	0,26	-0,01	-0,06	0,5
Ta stiff bef right	-0,11	0,03	-0,35	-0,57	0,46	0,53	0,48
TA stiff after right	-0,1	0,11	-0,26	-0,56	0,5	0,48	0,39
TA stiff bef left	-0,23	0,08	-0,23	-0,48	0,32	0,45	0,48
TA stiff after left	-0,13	0,1	-0,27	-0,55	0,45	0,42	0,4
GM stiff bef right	-0,36	0,42	0,22	-0,26	0,16	0,5	0,3
GM stiff after right	-0,29	0,34	0,08	-0,37	0,3	0,51	0,38
GM stiff bef left	-0,44	0,44	0,27	-0,22	0,2	0,45	0,25
GM stiff after left	-0,37	0,42	0,16	-0,35	0,29	0,48	0,35
TA tone % right	0,04	0,13	0,54	0,68*	-0,46	- 0,61*	-0,51
TA tone % left	0,26	0,02	0,22	0,35	0,18	-0,46	-0,2
TA decr % right	0,18	0,31	0,29	-0,05	0,26	-0,1	-0,49
TA decr % left	-0,05	0,31	0,56	0,39	-0,01	0,19	-0,59
TA stif % right	-0,02	0,32	0,18	-0,19	0,37	-0,01	-0,16
TA stif % left	0,26	0,08	-0,2	-0,41	0,64	0,01	-0,07
GM tone % right	0	-0,45	-0,08	0,44	0,31	-0,71	-0,24
GM tone % left	0,3	-0,02	0,22	0,39	0,14	-0,65	-0,14
GM decr % right	-0,29	0,44	0,54	0,2	0,08	0,27	-0,35
GM decr % left	0,32	-0,33	-0,07	0,37	0,32	-0,43	-0,25
GM stif % right	0,14	-0,44	- 0,74**	-0,57	0,55	0,23	0,37
GM stif % left	0,08	-0,02	-0,45	- 0,71*	0,36	0,33	0,41

Notes: BMI-body mass index; TA - *m. tibialis anterior*; GM – *m. gastrocnemius c. mediale*; decr – decrement; stiff – stiffness; bef – before; dur - duration
* - p<0.05; ** - p<0.01; *** - p<0.001.

5. DISCUSSION

From TMM point of view, it is important for any athlete to possess structural efficiency. Studies by Shambaugh *et al* (1991), Power *et al* (1995), Watson (2001), and Cowan (1996) indicated that deficiencies in posture are important predictors of specific types of sport injury. Watson (2001) noted that posture evaluation must be quantitative, precise and carefully carried out if it is to be of value in the prediction of sport injury. Furthermore, the athlete must also possess functional efficiency, which permits the neuromuscular system to perform functional tasks with the least amount of energy and will create the least amount of stress on the kinetic chain.

Many modern textbooks consider muscle tone as entirely reflex in origin and resulting from a myotatic *(a stretching)* reflex in the muscle spindles. Normal passive muscle tone helps maintain relaxed standing body posture with minimally increased energy costs (*circa* 7% over supine), and often for prolonged durations without fatigue (Masi *et al*, 2008). Norris (2005) brings out the factors affecting flexibility, dividing them under internal and external factors. Internal factors include muscle tone and elasticity. Muscle tone is defined as a descriptive measure for the period of muscle recovery between trainings. Increased tone equals worsened condition for recovery (Vain, 1995).

The subjects of the present study were basketball players with the mean age of 21.7. They are rather young players in the world of basketball, yet they should be experienced and aware of dangers (injuries) that might jeopardise their career as a basketball player. The first data of present study were collected at the end of preseason period; hence it demonstrated slightly higher tone of the muscles. There was a tendency of decrease of tone in both studied muscles after a single TMM manipulation in the majority of cases. A significant decrease (12%) was found in the right *m. tibialis anterior* of athlete 9 which might indicate the insufficient muscle care during the preparation period or inadequate recovery period between trainings. However, it might also derive from the inadequate posture and functional efficiency during the period. Because of that, athletes need to pay more attention to muscle care or more specific follow-up supervision to avoid imbalances. Considering the background of athletes and the training intensity, it might be considered a normal tone level, never the less proper development of muscles is crucial for daily musculoskeletal stability and any athlete performance, particularly those who participate in power sports. In addition there has to be an adequate recovery period between intensive practises.

Previous findings (Vahimets, 2005) in a study of highly qualified basketball players showed the increased muscle tone during the preparation period because of the gradual growth of exercise intensities and working load towards the end of preseason.

In the previous pilot study by Vahimets *et al* (2006) of six TMM manipulations before and after a two weeks period in basketball players aged 15.3±0.5 (mean ± SD), significant changes in muscle tone characteristics were established in athletes who had higher muscle tone before TMM manipulations. A significant decrease was found in the majority of muscles after six TMM procedures conducted in a short period (2-weeks period during the season) for athletes.

TMM is a good alternative for athletes with a considerable potential, accelerating the rehabilitation process among the other manipulative therapy models. Any kind of muscle manipulation is beneficial for athletes' muscle care.

Prevention and intervention of injury have become focal points for researchers and clinicians. Before these studies can be used, the risk factors for injury must be clearly established (Williams, 1971). As a result, a warm-up and stretching protocol should be implemented prior to physical activity. The routine should allow the stretching protocol to occur within the 15 minutes immediately prior to the activity in order to receive the most benefit (Woods *et al*, 2008). McKay *et al* (2001), performed an ankle injury risk factor study on elite and recreational basketball players and found that those athletes who did not stretch during warm up were at a significantly increased risk (OR = 2.62, 95% CI = 1.01 to 6.34) of injury compared with those who did stretch.

There is general consensus in the literature that the incidence of injury is greater during competition than practice. This finding suggests that athletes may be more prone to aggressive, risk taking behaviours during competition, which may in turn increase the potential for injury (Murphy *et al*, 2003).

In a prospective study of recreational sports (Australian football, field hockey, basketball, and netball) injuries, Stevenson *et al* (2000), found that incidence of injuries to the lower extremity or back was greatest in the first four weeks of the season. An injury was defined as an incident that resulted in any decrease in activity level, the need for advice or treatment, or adverse economic or social effects. These findings indicate that there may be a training effect that reduces the incidence of injury later in the season. More attention has to pay to the importance of preseason period using variety of musculoskeletal manipulations focusing on athlete's condition. Most manipulative therapy applied to extremity disorders is delivered as multimodal therapy, blending exercise, soft tissue treatment, modalities, or multiple extremity joint and/or combined spinal and extremity joint manipulative therapy, and is usually condition and patient specific (Brantingham *et al*, 2009).

Many authors have demonstrated significant correlation between the muscles biomechanical characteristics and the working capacity of CNS (Aruin *et al*, 1978). The energy recuperation mechanism of elastic deformations is the most effective. It has been shown in track-and-field events like running, jumps and throws (Komi, 1978).

In the present study, the changes in elasticity were observed in athletes before and immediately after TMM manipulation. Decrement characterizes muscle elasticity, i.e. the ability of the muscle to restore its initial shape after contraction. According to Norris (2005), muscle elasticity considering connective tissue framework of the muscles and provides passive resistance. The lower the decrement, the better is the elasticity and ability of contraction. The results of this study demonstrated the increase in muscle elasticity in the majority of cases, but not in all cases. The decrement of *m.tibialis anterior* was significantly decreased in two athletes out of eleven (athlete 2, 9), 10 % and 21% respectively. More extensive changes considering two groups were taking place in the group with better ankle condition.

One of the possible explanations to these quite controversial findings could be the difference in the backgrounds of athletes. Differences in muscle tone properties might occur considering their early experiences. There could be an increase in training intensities implementing higher demands on a neuromuscular system which has not been adapting adequately. Previous inadequate rehabilitation programs could be a more likely explanation to these findings as the majority of athletes have suffered from ankle injury. It now has restrictive barriers to normal alignment of ankle and it hence transmits wrong output to neuromuscular system and functional efficiency is thus not possible, as already stated previously. The issue of examining research on muscular injury and physical adaptations to muscular injury and training is important. The other thing that could change the muscle tone properties in different directions could be the influence of TMM procedure. Further investigation in this field must be conducted in order to establish the influence of TMM procedures in different conditions.

Muscular injury is one of the major problems facing today's athletes, both recreational and professional. Injuries to skeletal muscle represent more than 30% of the injuries seen in sports medicine clinics (Woods *et al*, 2008). The same can be said to the ankle joint. It is the most common peripheral joint injury (Pollard *et al*, 2002). As a result, it is imperative to utilize the most effective means to aid in deterring these injuries. The sports that most commonly produce high ankle injury rates in their participating athletes include: basketball, netball, and the various codes of football. This area appears to be under-researched however it was found that movement therapy and its various forms appear to be the most efficient and most effective method of treating uncomplicated ankle injury. Future investigations should involve a study to determine the effect chiropractic treatment (manipulation) may have on the injured ankle (Pollard *et al*, 2002).

Many injury risk factors, both extrinsic (those outside of the body) and intrinsic (those from within the body), have been suggested (Taimela *et al*, 1990). Extrinsic risk factors include the level of competition, skill level, and shoe type, use of ankle tape or brace and playing surface. Intrinsic risk factors include age, sex, previous injury and inadequate rehabilitation, aerobic fitness, body size, limb dominance, flexibility, limb girth, muscle strength, imbalance and reaction time, postural stability, anatomical alignment, and foot morphology (Murphy *et al*, 2003).

Injuries not only compromises important static and dynamic stabilisers of the lower extremity, but may also be associated with deafferentiation of a joint. For example, disruption of the ACL not only creates an increase in anterior knee laxity, and may be associated with repeated episodes of giving way, but it also compromises a portion of neuroreceptors that innervate the joint and may result in worsened proprioception. There is strong evidence that previous injury, especially when followed by inadequate rehabilitation, places an athlete at increased risk of suffering an injury to the ankle, knee, and all injuries as a group (Murphy *et al*, 2003).

One piece of tissue physiological information that can be obtained from the body surface of patients is tissue stiffness. Stiffness is associated with the ability of the tissue to distort therefore may provide important tissue biological information (Kimura *et al*, 2007). Stiff muscles are also important predictor of injuries. The less elastic and stiffer the muscle, the smaller is a range of motion. Norris (2005), states that stiffness occurs when a muscle tissue is less elastic. Frontera *et al* (2006), demonstrated that the stiffness rather than range of motion (typically known as flexibility) is more properly associated with risk and severity of injury.

It is well known that neuromuscular or metabolic disorders change soft tissue stiffness. Previous studies have reported that soft tissue stiffness can be changed mainly by the internal pressure within soft tissue due to blood congestion and muscle swelling (Arokoski *et al*, 2005). Due to fact that so far there is insufficient previous literature on examining musculoskeletal manipulation on muscle tone properties. There are some previous writings on muscle stiffness, but their authors have failed to correlate the stiffness to muscle flexibility. Halbertsma *et al* (1994) evaluated the effects of stretching exercises on flexibility, stiffness and electromyographic activity of the hamstring muscles. It was concluded that stretching exercises do not make hamstring any longer or less stiff, but only influence the stretch tolerance. He also found no changes in elasticity. Some conclusions were made by that after evaluating a single 10 minutes stretch on hamstring muscle, significant effect on hamstring flexibility was found (Halbertsma *et al*, 1996).

In the current study the changes of stiffness were established after TMM procedure. The tedency to decrease was noted in majority of cases of *m.tibialis anterior* (mean of 3%). Significant decrease was found of right *m. tibialis anterior* in athlete athlete 9 (8%).

Some authors (Kellis, Kouvelioti 2009), noted that agonist and antagonist co-activation plays an important role for stabilizing the knee joint, especially after fatigue. However, whether selective fatigue of agonists or antagonist muscles would cause different changes in muscle activation patterns is unknown. Research demonstrated that fatigue responses during landing are highly dependent on the muscle which is fatigued.

The need for objective evaluation of general muscle properties and condition is widely accepted in sports medicine to avoid injuries and over training and in clinical use to evaluate the treatment effect or progression of the pathology. Several research teams have tried to develop and validate a simple noninvasive technique with appropriate equipment. Clear and simple numerical values will help to interpret the results. This kind of equipment will be useful for the objective assessment of the condition of the skeletal muscles or soft tissue, or for the evaluation of treatment efficacy (Vain, 1995). Patients with neuromuscular disorders that originate from muscle tone such as myofascial pain syndrome (MPS), tension-type headache, Parkinson’s disease, stiff-man syndrome and hemiplegia have soft tissue that became stiff (Arokoski *et al* 2005).

Also, in the current study statistical correlations were found between FAOS test (subscale Pain) and muscle viscous elastic properties. High correlation was noted between FAOS scoring test and relative changes in the tone of right *m. gastrocnemius c.mediale* ($p<0.05$). The worse ankle condition the greater relative changes took place in the muscle tone. Additionally high correlations between athletes´ body mass and muscle tone of *m. gastrocnemius c.mediale* before and after TMM manipulation ($p<0.05$) were established.

Findings by Ebersole *et al* (2009), suggest that the presence of patellofemoral pain (PFP) influenced mechanical aspect of muscle function as measured by mechanomyographic

(MMG), but not the electrical properties (EMG). MMG may provide unique insight into the intrinsic effects on muscle function due to PFP.

A commonly used method for warm-up before exercise is to stretch muscles. After a period of eccentric exercise, there is muscle damage accompanied by an increase in passive tension, perceived as a sensation of increased stiffness in the exercised muscles. Stretch reduces passive tension. Benefits from the lower tension are reduced sensations of stiffness and soreness. This represents a new proposal for the mechanism for passive stretches as a warm-up strategy (Reisman *et al*, 2005).

Study by Lichtwark *et al* (2007) showed difference length changes of muscle fascicles from those of the whole muscle tendon complex during real life movements. Muscle fascicles perform the same actions along the length of the human *gastrocnemius medialis* muscle during locomotion. However the distal fascicles tend to shorten more and act at greater pennation angles than the more proximal fascicles. Muscle fascicles acted relatively isometrically during the stance phase during walking, however during running the fascicles shortened throughout the stance phase, which corresponded to an increase in the strain of the series elastic elements (SEEs) (consisting of the Achilles tendon and aponeurosis). Measurement of the fascicle length changes at the midbelly level provided a good approximation of the average fascicle length changes across the length of the muscle.

Manual adjustive techniques of the foot and ankle have been receiving increased interest in the podiatry profession in recent times. However, the scientific basis of manipulation of the lower extremity has not been adequately evaluated. As such, in its current form the practice of foot and ankle manipulation must be viewed as a non-standard or alternative therapy (Menz, 1998). A detailed knowledge of the anatomy of the muscles and joints as well as the early recognition of factors that may delay the rate of healing are important considerations when developing a management plan for inversion (Pollard *et al*, 2002). The ability of acute PNF stretching procedures to often produce a joint range of motion greater than that observed with static stretching must be explained by mechanisms other than the spinal processing of proprioceptive information. Studies reviewed indicate that changes in the ability to tolerate stretch and/or the viscoelastic properties of the stretched muscle, induced by PNF procedures, are possible mechanisms (Chalmers, 2004).

In sports enhancement, previous study has shown that static stretching (SS) can diminish the peak force output of stretch-shortening cycle actions while performing a dynamic warm-up (DW) protocol has been shown to enhance performance in similar activities (Winchester *et al*, 2008).

Other findings suggest that dynamic stretching may increase acute muscular power to a greater degree than static and PNF stretching. These findings may have important implications for athletes who participate in events that rely on a high level of muscular power (Manoel *et al*, 2008).

Research on the adaptations of proprioceptors during free movement, using locomotion as a model, has found that the hypothesis of consistent alpha-gamma coactivation during motor behaviours is much more complicated and adaptable, depending on the environmental circumstance and the specific motor task. These research findings support the use of selective training, i.e. training to the task, for optimal motor learning. The results of the relatively limited research on chronic adaptations of proprioceptors due to exercise has shown that on a microlevel, the intrafusal muscle fibres may show some metabolic changes but do not show any hypertrophy. However, on a more macro level, with extended training, the latency of the stretch reflex response is found to be decreased and the amplitude is found to be increased in both animals and humans (Hutton, Atwater, 1992). These findings have important implications both for rehabilitation of persons with abnormal reflex activity and in the training of athletes.

Contraction intensities between 10 and 100% maximal voluntary contraction (MVC) have been proposed in varying muscle energy technique (MET) and proprioceptive neuromuscular facilitation (PNF) post-isometric relaxation (PIR) protocols. The study was undertaken to determine if athletes were able to comply with differing therapist requested contraction intensities during PNF stretching protocols. These findings indicate that this group of athletes displayed a poor level of compliance to varying therapist requested contraction intensities with respect to both accuracy and consistency (Sheard *et al*, 2008).

It is demonstrated that disynaptic reciprocal inhibition (DRI) at the onset of movement may be increased in healthy subjects following explosive strength training to ensure efficient suppression of the antagonist muscles as the dorsiflexion movement becomes faster. Because the risk of eliciting stretch reflexes in the ankle plantar flexors at the onset of dorsiflexion is larger the quicker the movement, it was hypothesized that DRI may be increased when subjects are trained to perform dorsiflexion movements as quickly as possible (Geertsen, 2008).

Although some of the mechanisms of acupuncture as it applies to pain relief have been studied, little is known of the positive and/or negative effects of this procedure on the physical performance parameters of healthy people, particularly highly trained athletes. After introducing acupuncture from historical and technique viewpoints, preliminary studies of the effects of acupuncture on strength, aerobic conditioning, flexibility, and sport performance are discussed, as well as concerns regarding the direction of research investigating the potential benefit and/ or adverse effects of this practice. Finally, an argument is put forward for the establishment of guidelines for the use of acupuncture in the sports community (Pelham, 2001). There is evidences that electric stimulation method could significantly increase athlete's performance ($p<0.05$), and the biomechanical indexes, maximal peak moment of force ($p<0.05$), force moment accelerating energy ($p<0.05$) and average power ($p<0.05$). It can be concluded that electrical acupoint stimulation can enhance athlete's rapid strength (Yang, 2006).

There is the evidence hat electromyostimulation (EMS) and voluntary muscle contraction (VC) constitute different modes of muscle activation and induce different acute physiological effects on the neuromuscular system. Long-term application of each mode of muscle activation can produce different muscle adaptations. It seems theoretically possible to completely or partially cumulate the muscle adaptations induced by each mode of muscle activation applied separately (Paillard, 2008). Combined technique (CT) induced greater muscular adaptations than VC whether in sports training or rehabilitation. This efficiency would be due to the fact that CT can facilitate cumulative effects of training completely or partially induced by VC and EMS practiced alone. CT also provides a greater improvement of the performance of complex dynamic movements than VC. However, EMS cannot improve coordination between different agonistic and antagonistic muscles and thus does not facilitate learning the specific coordination of complex movements. Hence, EMS should be combined with specific sport training to generate neuromuscular adaptations, but also allow the adjustment of motor control during a voluntary movement. Likewise, in a therapeutic context, CT was particularly efficient to accelerate recovery of muscle contractility during a rehabilitation programme. Strength loss and atrophy inherent in a traumatism and/or a surgical operation would be more efficiently compensated with CT than with VC. Furthermore, CT also restored more functional abilities than VC. Finally, in a rehabilitation context, EMS is complementary to voluntary exercise because in the early phase of rehabilitation it elicits a strength increase, which is necessary to perform voluntary training during the later rehabilitation sessions.

In generally CAM usage is common among collegiate student athletes and rates are higher than in adults nationwide and within the state of Hawai'i. This study and future investigations will increase the awareness of CAM use patterns by collegiate athletes, and hopefully improve allopathic physicians' abilities to provide optimal athletic health care (Nichols, Harrigan, 2006).

Study of sports injury cases recorded at Iowa Junior Olympics in 1985, 34% required attention only from coaches, 46% were referred to local physicians, and 20% were referred to specialists (Martin *et al*, 1987). This study found that out of patients who sought Western medical help, 17% required treatment from orthopaedic surgeons to correct or treat outstanding injury and 74.6% were treated by orthopaedic doctors or physical therapists. More than half of patients sought treatment from Eastern medicine, including traditional massage (64%), acupuncture (58%), and Chinese treatment applications (65%).

The completely different medical approaches of the Eastern and Western medicine are widely accepted by elite athletes and coaches. Mainstream Western medicine doctors should not overlook the traditional Eastern medicine, and they should learn more about these alternative treatment methods and apply them effectively. If Western doctors can work together with Eastern traditional doctors, we can improve our medical network (Chen *et al*, 2005). The individual choice of the duration and techniques of manipulations must be applied for athletes' muscle care to attain maximal positive effect.

6. CONCLUSIONS

1. After TMM manipulation changes in muscle tone were established in both *m. tibialis anterior* and *m. gastrocnemius c. mediale* muscle. A significant decrease in frequency was noted in *m. tibialis anterior* after TMM manipulation. The tendency of decrease was noted in the majority of cases.
2. Changes in decrement showed a tendency to decrease in the right side of both *m. tibialis anterior* and *m. gastrocnemius c. mediale* muscle and a tendency to increase in the left side of muscles after TMM manipulation in season period.
3. Changes in stiffness demonstrated the tendency to decrease in the majority of cases in both *m. tibialis anterior* and *m. gastrocnemius medialis* muscle after TMM manipulation.
4. Changes in muscle tone and viscous-elastic properties were established in *m. tibialis anterior* muscle according to FAOS test. A tendency of decrease in tone frequency was observed in all athletes with worse and better ankle condition. The decrement of *m. tibialis anterior* decreased in the majority of cases, similar changes were noted in stiffness of both groups according to FAOS test. More extensive changes in tone, elasticity and stiffness were observed in athletes with better ankle condition; especially in the right side. A decrease in muscle viscous-elastic properties was observed in *m. gastrocnemius c. mediale* in the majority of athletes in the group with worse ankle condition but in the group with better ankle condition, the increase in decrement and stiffness was noted but tone decreased. Greater mean changes were observed in group with better ankle condition.
5. High statistical correlations were found between FAOS test (Pain subscale) and relative changes in tone of right *m. gastrocnemius c.mediale*, and elasticity of right *m. tibialis anterior* before TMM manipulation and also high correlation was noted between athletes´ body mass and tone of *m. gastrocnemius c. mediale* before and after TMM manipulation.

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***Trigenics Myoneural Medicine* manipulatsiooni vahetu mõju meeskorvpallurite alajäsemete lihaste toonusele ja viskoos-elastsete omaduste karakteristikutele.**

Martin Vahimets

KOKKUVÕTE

Viimasel ajal on spordivigastuste preventsioon ning efektiivne rehabilitatsioon nii teadlaste kui ka praktikute jaoks muutunud järjest kesksemaks teemaks. *Trigenics Myoneural Medicine* (*TMM*) eesmärk ja põhimõte on tagada skeletilihassüsteemi võimalikult tõhus töö tekitades võimalikult vähe stressi kineetilisele ahelale. Eduka sporditulemuse saavutamisel mängib suurt rolli skeletilihaste tasakaal. Mitmetes uuringutes on läbi viidud erinevate manuaalteraapia võimaluste mõju skeleti-lihassüsteemile. Vähe on uuritud selle mõju lihase toonuse ja viskoos-elastsete omaduste karakteristikutele (elastsus ja jäikus).

Käesoleva töö eesmärgiks oli uurida *TMM* närvi-lihasaparaadi manipulatsiooni mõju lihase toonuse, elastsuse ja jäikuse karakteristikutele kõrgelt kvalifitseeritud korvpalluritel. Uuringus osalesid üksteist Eesti meistriliigas mängivat korvpallurit vanuses 21,7±1,4 (noorim 19, vanim 25 a.) ja treenivad 12-15 tundi nädalas ning, kes on korvpalli mänginud 10,5±2,9 aastat.

Käesolev uuring viidi läbi Tallinna Tehnikaülikooli spordihoones ajavahemikul 2007 a. septembri lõpust kuni 2008 a. mai lõpuni. Selle aja jooksul viidi läbi viis *TMM* närvi-lihasaparaadi manipulatsiooni, mille põhimõte seisneb närvi-lihasaparaadi mõjutamisel pigem KNS-i ja seljaaju reflekside mõjul, kui mehhaaniliselt. Lihastoonust, elastsust ja jäikust mõõdeti vahetult enne ja kohe pärast *TMM* manipulatsiooni müomeetriga Myoton-3. Esimene mõõtmine viidi läbi nädal enne hooaja algust, et määrata lihastoonuse, elastsuse ja jäikuse algparameetrid. Uuritavaid lihaseid oli kaks, *m. tibialis anterior* ja *m. gastrocnemius c. mediale*. Määrati kustuvate lihase omavõngete sagedus, sumbuvate võngete logaritmiline dekrement ja jäikuse parameetrid, mis iseloomustavad vastavalt lihase toonust, elastsust ning jäikust. Lisaks määrati eelpool mainitud meetoditele kasutati uuringus *FAOS*´e testi (*Foot and Ankle Outcome Score*). *FAOS* testi alusel jagati sportlased kahte gruppi Valu alaskaala järgi: I grupp (halvema hüppeliigese seisundiga sportlased) ja grupp II (parema hüppeliigese seisundiga sportlased).

Uuringu tulemustest selgus, et pärast *TMM* närvi-lihasaparaadi mõjutamist lihastoonus vähenes, elastsus paranes ning jäikus vähenes enamikul juhtudel. Olulisi muutusi täheldati samuti, kui kasutati *FAOS* testi, millega määrati hüppeliigese seisundit. Parema seisundiga sportlastel olid suhtelised muutused lihastoonuse parameetrites pärast *TMM* manipulatsiooni suuremad, kui halvema seisundiga sportlastel. Lisaks leiti korrelatiivseid seoseid hüppeliigese valu ning lihase toonuse vahel.

Tulemuste põhjal järeldati:

1. pärast *TMM* manipulatsiooni langes mõlema uuritava lihase toonus. Olulist toonuse vähenemist täheldati *m. tibialis anterior´l* pärast 2., 3. ja 5 manipulatsiooni, samuti *m. gastrocnemius c. mediale´*l pärast 3. manipulatsiooni;
2. logaritmiline dekrement vähenes (elastsus paranes) paremal kehapoolel mõlemal lihasel ning suurenes vasakul kehapoolel mõlemal uuritaval lihasel enamusel juhtudel vahetule pärast *TMM* manipulatsiooni;
3. olulist jäikuse vähenemist täheldati *m. tibialis anterior´*l pärast 3. *TMM* manipulatsiooni. *M. gastrocnemius c. mediale* puhul täheldati tendentsi selle parameetri vähenemisele;
4. kõigil sportlastel täheldati *m. tibialis anterior* lihase toonuse vähenemist mõlemas grupis *FAOS* testi alusel. Sama tendentsi täheldati viskoos-elastsetel parameetritel. Olulisi muutusi leiti dekremendi ning jäikuse puhul. Parema hüppeliigese seisundiga sportlastel (grupp II) täheldati olulist vähenemist ka lihase toonuses. Samuti täheldati kõigi parameetrite muutusi *m. gastrocnemius c. mediale* puhul mõlemas grupis, sealjuures oluline vähenemine saavutati lihase jäikuses halvema hüppeliigese seisundiga sportlasel (grupp I);
5. leiti oluline korrelatiivne seos *FAOS* alaskaala valu ning *m. gastrocnemius c. mediale* suhtelise muutuse vahel, lisaks leiti olulisi seoseid kehakaalu ning *m. gastrocnemius c. mediale* lihase toonuse muutuste vahel.

Antud uuringu tulemuste põhjal võime järeldada, et vahetu *TMM* närvi-lihasaparaadi manipulatsiooni mõju lihastoonuse ja viskoos-elastsete omaduste karakteristikutele oli erinev. Enamusel juhtudel lihase toonuse ja viskoos-elastsete karakteristikute näitajad langesid. Mõnedel üksikutel juhtudel täheldati ka vastupidist efekti. See omakorda sõltub treeningute intensiivsusest, skeleti-lihaste seisundist, väliskeskkonna tingimustest jne. *TMM* manipulatsiooni mõju hindamiseks ja tulemuste adekvaatsemaks tõlgendamiseks peaks enam keskenduma nendele sise- ja väliskeskkonnast tulenevatele mitmesuguste faktoritele, et viia läbi edasisi uuringuid.

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APPENDIX 1.

Foot and Ankle Outcome Score (FAOS) (Roos, 2001)

FAOS FOOT & ANKLE SURVEY

Todays date: _____/______/______ Date of birth: _____/______/______

Name: ____

INSTRUCTIONS: This survey asks for your view about your foot/ankle. This information will help us keep track of how you feel about your foot/ankle and how well you are able to do your usual activities.
Answer every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can.

Symptoms
These questions should be answered thinking of your foot/ankle symptoms during the **last week**.

S1. Do you have swelling in your foot/ankle?

Never	Rarely	Sometimes	Often	Always
□	□	□	□	□

S2. Do you feel grinding, hear clicking or any other type of noise when your foot/ankle moves?

Never	Rarely	Sometimes	Often	Always
□	□	□	□	□

S3. Does your foot/ankle catch or hang up when moving?

Never	Rarely	Sometimes	Often	Always
□	□	□	□	□

S4. Can you straighten your foot/ankle fully?

Always	Often	Sometimes	Rarely	Never
□	□	□	□	□

S5. Can you bend your foot/ankle fully?

Always	Often	Sometimes	Rarely	Never
□	□	□	□	□

Stiffness
The following questions concern the amount of joint stiffness you have experienced during the **last week** in your foot/ankle. Stiffness is a sensation of restriction or slowness in the ease with which you move your joints.

S6. How severe is your foot/ankle stiffness after first wakening in the morning?

None	Mild	Moderate	Severe	Extreme
□	□	□	□	□

S7. How severe is your foot/ankle stiffness after sitting, lying or resting **later in the day**?

None	Mild	Moderate	Severe	Extreme
□	□	□	□	□

Pain

P1. How often do you experience foot/ankle pain?

Never	Monthly	Weekly	Daily	Always
☐	☐	☐	☐	☐

What amount of foot/ankle pain have you experienced the **last week** during the following activities?

P2. Twisting/pivoting on your foot/ankle

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P3. Straightening foot/ankle fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P4. Bending foot/ankle fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P5. Walking on flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P6. Going up or down stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P7. At night while in bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P8. Sitting or lying

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P9. Standing upright

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, daily living

The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your foot/ankle.

A1. Descending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A2. Ascending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your foot/ankle.

A3. Rising from sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A4. Standing

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A5. Bending to floor/pick up an object

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A6. Walking on flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A7. Getting in/out of car

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A8. Going shopping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A9. Putting on socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A10. Rising from bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A11. Taking off socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A12. Lying in bed (turning over, maintaining foot/ankle position)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A13. Getting in/out of bath

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A14. Sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A15. Getting on/off toilet

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your foot/ankle.

A16. Heavy domestic duties (moving heavy boxes, scrubbing floors, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A17. Light domestic duties (cooking, dusting, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, sports and recreational activities

The following questions concern your physical function when being active on a higher level. The questions should be answered thinking of what degree of difficulty you have experienced during the **last week** due to your foot/ankle.

SP1. Squatting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP2. Running

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP3. Jumping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP4. Twisting/pivoting on your injured foot/ankle

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP5. Kneeling

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Quality of Life

Q1. How often are you aware of your foot/ankle problem?

Never	Monthly	Weekly	Daily	Constantly
☐	☐	☐	☐	☐

Q2. Have you modified your life style to avoid potentially damaging activities to your foot/ankle?

Not at all	Mildly	Moderatly	Severely	Totally
☐	☐	☐	☐	☐

Q3. How much are you troubled with lack of confidence in your foot/ankle?

Not at all	Mildly	Moderately	Severely	Extremely
☐	☐	☐	☐	☐

Q4. In general, how much difficulty do you have with your foot/ankle?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Thank you very much for completing all the questions in this questionnaire.