T.C.
YEDİTEPE UNIVERSITY
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DEPARTMENT OF SPORTS PHYSIOTHERAPY

EFFECTS OF ISOMETRIC EXERCISE ON DELAYED ONSET MUSCLE SORENESS

MASTER THESIS
RAMAZAN KURTULMUŞ, PT

ISTANBUL, 2019

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APPROVAL

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APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated 31.07.2019 and numbered 2019/13-1

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DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

RAMAZAN KURTULMUŞ

DEDICATION

I dedicate my thesis to my beloved nephews Ömer and Meryem Kurtulmuş.

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I would first like to thank my thesis advisor Assistant Professor Şule DEMİRBAŞ. The door to her office was always open whenever I ran into a trouble spot or had a question about my research or writing.

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LIST OF SYMBOLS/ABBREVIATIONS

DOMS : Delayed onset muscle soreness

CK : Creatine Kinase

ROM : Range of Motion

LDH : Lactate Dehydrogenase

CRP : C Reactive Protein CRP

HHD : Hand held dynamometer

VAS : Visual Analog Scale

PPT : Pressure Pain Threshold

BMI : Body Mass Index

SD : Standart Deviation

m : meter

cm : centimeter

kg : kilogram

N : Newton

Δ : Difference

ABSTRACT

Kurtulmuş, R. (2019) Effects of Isometric Exercise On Delayed Onset Muscle Soreness. Yeditepe University, Institute of Health Sciences, Department of Physiotherapy and Rehabilitation, MSc thesis. Istanbul

The aim of this study was to investigate the effects of isometric exercise on delayed muscle pain. Forty people participated in the study. Participants were selected from Yeditepe University Physiotherapy and Rehabilitation Department students on a voluntary basis. Participants who were eligible to participate in the study according to inclusion and exclusion criteria were divided into two groups as isometric exercise group and control group by lot. In order to cause delayed onset muscle soreness, an exercise program used in the literature was applied. The group selected for the isometric exercise was taught by the physiotherapist about the isometric exercise program they will perform throughout the process. Muscle soreness, pressure pain threshold, edema, range of motion and muscle strength were evaluated before, immediately after exercise, on the 1st, 3rd, and 5th days. As a result we found that, isometric exercise reduced soreness on day 1 ($p=0.000$) and day 3 ($p=0.000$), and improvement in pressure pain threshold was faster in isometric exercise group, pressure pain threshold was higher in the isometric exercise group on day 3 ($p=0.050$), increase in range of motion was found to be higher in the isometric exercise group from Day 3 to Day 5 ($p=0.025$).. In the other parameters, there was no difference between the isometric exercise group and the control group.

Key Words: Isometric exercise, Delayed onset muscle soreness, pain, pressure pain threshold, edema.

ÖZET

Kurtulmuş, R. İzometrik Egzersizlerin Gecikmiş Kas Ağrısı Üzerine Etkisi. Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Fizyoterapi ve Rehabilitasyon ABD, Master Tezi. İstanbul.

Bu çalışmanın amacı gecikmiş kas ağrısında izometrik egzersizin etkilerini araştırmaktır. Çalışmaya 40 kişi katıldı. Katılımcılar Yeditepe Üniversitesi Fizyoterapi ve Rehabilitasyon bölümü öğrencilerinden gönüllülük usulüne göre seçildi. Dahil edilme ve edilmeme kriterlerine göre çalışmaya katılmak için uygun olan katılımcılar kura ile izometrik egzersiz grubu ve kontrol grubu olarak iki gruba ayrıldılar. Gecikmiş kas ağrısı oluşturabilmek için literatürde kullanılan bir egzersiz programı uygulandı. İzometrik egzersiz için seçilen gruba fizyoterapist tarafından süreç boyunca yapacakları izometrik egzersiz programı öğretildi. Bireylerin egzersiz öncesi, egzersizden hemen sonra, 1. gün, 3. gün ve 5. gün kas hassasiyeti, basınç ağrı eşiği, ödem, eklem hareket açıklığı ve kas kuvveti değerlendirildi. İzometrik egzersizin sorenessi 1. günde ($p=0.000$) ve 3. günde ($p=0.000$) azalttığı, basınç ağrı eşiğindeki iyileşmenin izometrik egzersiz grubunda daha hızlı olduğu, basınç ağrı eşiğinin 3. günde izometrik egzersiz grubunda daha yüksek olduğu ($p=0.050$), eklem hareket açıklığı artışının 3. gün ila 5. gün arasında izometrik egzersiz grubunda daha fazla olduğu tespit edildi ($p=0.025$). Diğer parametrelerde izometrik egzersiz grubuyla kontrol grubu arasında anlamlı bir fark bulunmadı.

Anahtar Kelimeler: İzometrik Egzersiz, Gecikmiş Kas Ağrısı, Hassasiyet, Basınç Ağrı Eşiği, Ödem.

1.INTRODUCTION

Today, with the appeal of sports to a wider audience, increasing competition in this field and the economic expansion in the sports sector in a professional sense, the performance pressure on the athletes is gradually increasing. Due to the intense competition and training programs, from time to time loads are made above the athlete's capacity; this leads to delayed muscle pain, which is uncomfortable and has a negative effect on the athlete's performance. The aim of this study was to investigate the therapeutic effect of isometric exercises on delayed muscle pain.

In recent studies, various training strategies have been developed in order to maximize the performance of the athletes. However, the athlete's performance is not only dependent on the load. An optimal period of rest and regeneration is needed to minimize the physiological and psychological negative effects of loading.

Delayed onset muscle soreness (DOMS) is a clinical condition characterized by a decrease in joint range of motion, strength and performance in addition to pain and tenderness, which peaks after 24–48 hours, usually occurring after an unusual exercise of intense eccentric type. These symptoms usually disappear after 5–7 days without treatment (1, 2). This clinical picture, which is frequently seen in athletes, may lead to a decrease in performance and inability to participate in training or competition (3, 4). There may also be a risk of injury due to pain, loss of function, and impaired joint mechanics (2). Therefore, individuals with delayed muscle pain after severe eccentric exercises should be treated as soon as possible.

Experimental studies have been conducted to reduce the symptoms of delayed muscle pain. These studies include drug treatments including non-steroidal anti-inflammatory drugs and oral analgesics, as well as different physiotherapy applications (5, 6). Physiotherapy applications used in these studies was; superficial hot and cold application (7), massage (8), stretching (9), transcuteneal electrical nerve stimulation (10, 11), ultrasound (11-14), interferential flow (15, 16) and various exercise treatment (3).

Previous studies shown that isometric exercise found effective in thermal (17), mechanic (18) and electrocutoneus (19) pain. Isometric exercises are also used in the treatment of various orthopedic disorders (20-22). However, there are no studies investigating the effects of isometric exercise on DOMS in the literature.

The aim of this study is to investigate the effects of isometric exercises on pain, pressure pain threshold, edema, range of motion and strength in DOMS.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1. Muscles

Like nerve cells, muscle cells are stimulated electrically, chemically and mechanically. Unlike nerve cells, muscle cells respond to stimulation with a contraction Actin and myosin, the main components of contraction, are abundant in these cells.

Muscles are divided into skeletal muscle, cardiac muscle and smooth muscle. Most of the muscles in the human body are skeletal muscles. The skeletal muscle has highly developed cross lines. They are not activated when there is no stimulation from the nervous system. Skeletal muscles work voluntarily and their fibers are anatomically independent. The cardiac muscle cells also have diagonal lines. Unlike skeletal muscle, it produce its own stimulation with its own pacemaker cells and can work with external stimuli. Unlike other muscle cells, smooth muscles do not contain cross lines and work slowly. They are usually found in the internal organs and have pacemaker cells that can produce their own stimuli (23).

2.1.1.Smooth Muscles

Smooth muscles work with involuntary contractions. Electrical stimuli are regulated by the autonomic nervous system Since the actin and myosin are randomly distributed, they do not have a striped structure. They take an active role in systems such as digestion and excretion in the body (24). Smooth muscle fibers are usually arranged in parallel. Smooth muscles are divided into single and multi-unit types according to the contraction types (25).

2.1.2. Cardiac Muscle

The cardiac muscle is found only in the heart. In terms of involuntary work, it resembles smooth muscles and due to its striated structure, it is anatomically similar to skeletal muscle It has a large number of mitochondria. muscle fibers are branched and intertwined (26). Stimulation of the heart muscle is controlled by the autonomic nervous system (27).

2.1.3.Skeletal Muscle

Skeletal muscle is composed of bundled fibrils. A membrane called sarcolemma surrounds the muscle cell. The part of the muscle responsible for contraction is myofibrils.

Among myofibrils is a cell fluid called sarcoplasm. This fluid carries various enzymes and vital substances such as ATP. Mitochondria are also present in proportion to the amount of use of skeletal muscle. Skeletal muscles have more than one cell nucleus and are located just below the sarcolemma (28).

Skeletal muscles work voluntarily. They cannot produce their own stimuli and receive all stimuli from the nervous system. The nerve cells that stimulate skeletal muscles are somatic nerves (27). Each muscle fiber contains several hundred to several thousand myofibrils. Each myofibril has about 1500 myosin filaments and about 3000 actin filaments. These are large polymerized proteins responsible for muscle contraction. When examined longitudinally, myofibrils are divided into numerous compartments called sarcomere. The myofibril section between the two Z lines is called sarcomere. Sarcomere is the smallest unit of muscle cell contractions. The myofibrils are therefore composed of sarcomere, myofilaments with protein structure. Myosin and actin form consecutive dark and light bands due to the intertwining of filaments. The light bands contain only actin filaments and are called I bands. The dark bands contain the myosin filaments and the ends of the actin filaments interposed between them and are called the A band. Small protrusions from the sides of the myosin filaments are cross-bridges. The interaction between cross bridges and actin filaments causes contraction. The end of the actin filaments adhere to the Z lines. The actin filaments extend from this line in both directions and enter the myosin filaments. The Z line moves along the muscle fiber to connect one myofibril to the other. Thus, as in a single myofibril, light and dark bands along the entire muscle fiber give the skeletal and heart muscle a striated appearance. When muscle fibers contract, the sarcomere length is about 2 micrometers. In this size, the actin filaments cover the myosin filaments and the ends of the actin filaments begin to overlap one another. Sarcomere can produce the greatest contraction force in this size. Many filamentous molecules called titin provide the relationship between myosin and actin filaments (29).

2.2. Types Of Muscle Contractions

40-50% of human body weight consists of muscle tissue. The muscle contractes when stimulated and can stretch beyond its normal length and returns to its normal length when the stretching function disappears. Since the formation of a movement depends on the contraction of skeletal muscles, skeletal muscles are of particular importance in exercise physiology (30).

With the contraction of the muscles, the movements of the skeletal system, the pumping of blood from the heart, and organic activities such as breathing and digestion are

performed. Skeletal muscles are of particular importance in terms of exercise. Because all kinds of physical work and sports activities are created by these muscles. Almost all of the organic activities are performed by muscle contraction. Muscle contraction types are examined under three main headings as isometric, isotonic and isokinetic (31).

2.2.1. Isometric Contraction

Isometric contraction is a static contraction. Muscle contractions without any length changes, increase in muscle tension (Figure. 2.1.). In other words, the tension of the muscle increases while the length of the muscle remains constant.

In isometric contraction, the reason for not shortening of the muscle is due to the fact that the internal force against the external resistance is greater (32). Isometric contraction would not have done a mechanical work according to the laws of physics (33).

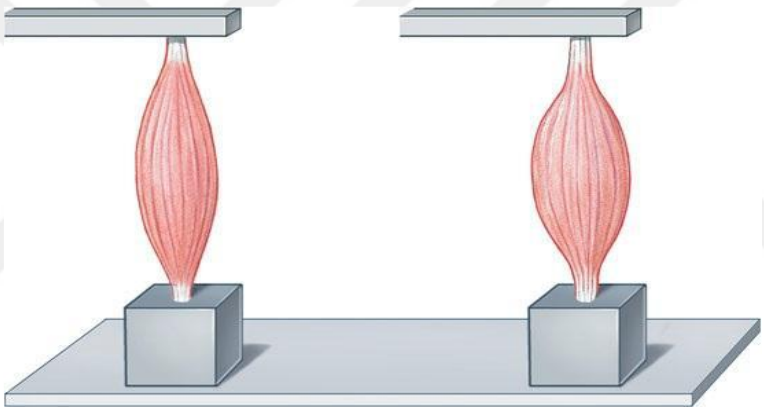

Figure 2.1. Isometric Contraction (34).

2.2.2. Isotonic Contraction

Isotonic contraction is a form of dynamic contraction. Dynamic contractions in which there is a change in the length of the muscle but the tension remains constant is called isotonic contraction. Contraction creates a movement and a mechanical soot (30).

2.2.2.1.Concentric Contraction

During muscle contraction, the muscle's tension (tone) remains constant, while the muscle's length becomes shorter (Figure 2.2.). Contraction occurs with movement and a mechanical soot is done. Lifting a weight from place to place (30)**.** In the type of concentric contraction, the contractile element shortens, while the elastic element maintains a certain tension and length in an order. If we flex the elbow joint with a weight we received, the

biceps brachii muscle will contract concentrically. The muscle length is shortened, the forearm makes a mechanical work towards the upper arm (31).

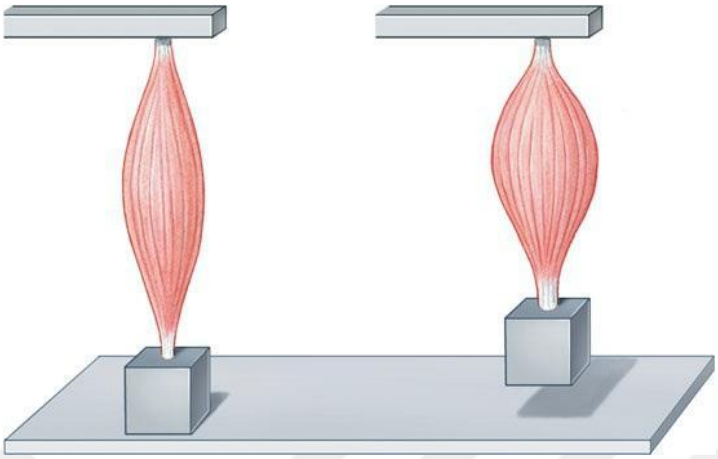

Figure 1.2. Concentric Contraction (34).

2.2.2.2.Eccentric Contraction

Eccentric contraction is a dynamic contraction. As the tone of the muscle increases, its length increases (Figure 2.3.). In eccentric contractions, the soot is negative, such as stair descent or landing from a height.

While the tension of the muscle remains constant during the eccentric contraction, the muscle elongation occurs in contrast to the concentric contraction. Extension of the Biceps Brachii muscle is seen eccentrically if the elbow extends with a weight after elbow flexion (31).

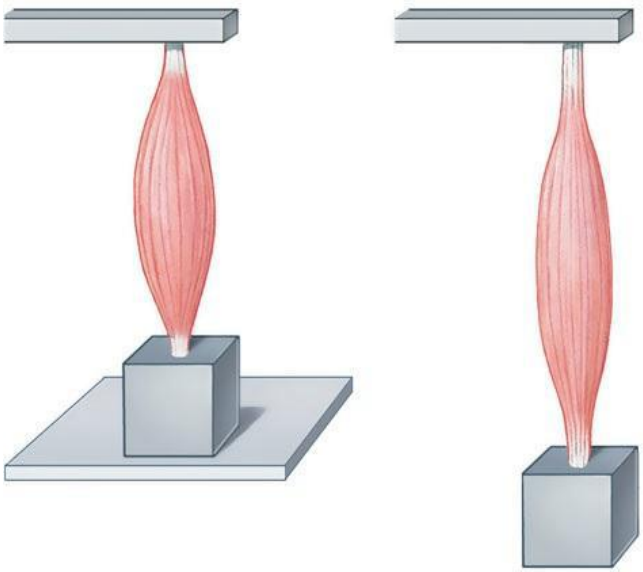

Figure 2.3. Eccentric Contraction (34).

2.2.3.Isokinetic Contraction

In isokinetic contraction, movement is performed at a constant speed, while the resistance or load differs according to the force produced by the muscle at that angle (30). Isokinetic contraction; is a maximal contraction in which the muscle contraction speed is kept constant. As the muscle contracts at a constant speed, the tension in the muscle is kept maximal at all angles of the joint throughout the entire movement. Such movements can be performed in laboratory environments with very expensive and laborious instruments such as isokinetic dynamometers (31).

2.3. Delayed Onset Muscle Soreness (DOMS)

DOMS is pain and tenderness after unusual exercises, often involving eccentric contraction (35). This tenderness, which usually begins in the distal part of the muscle and is intense, progressively spreads through the entire muscle 24–48 hours after exercise. The reason for this localization of pain is the high level of pain receptors in the connective tissue of the muscle-tendon junction. The muscle-tendon junction has a continuous membrane where the muscle cells are intertwined. The oblique arrangement of the muscle fibers just before the muscle-tendon junction reduces their ability to withstand high tensile forces. Because of these properties, contractile elements of muscle fibers at the muscle-tendon junction become susceptible to microscopic damage (3).

DOMS occurs as a result of eccentric loading in amounts that the person cannot tolerate. In eccentric activities, the muscle is forced to contract while at the same time lengthening. Consequently, if the amount of the load exceeds the tissue capacity, the muscle is forced to elongate and a high tension occurs. This causes strain or injury to the muscle tendon junction (3, 36)**.**

Exercises, often involving eccentric loads, present a high risk of DOMS formation. Examples of these exercises are running downhill (3, 37, 38), cycling (39, 40), isokinetic exercises (3, 9, 12, 14) and step exercises (3, 13).

DOMS usually increases within 12-24 hours after exercise and reaches its highest pain level between 24-72 hours. DOMS temporarily causes the following conditions with pain (41). These are swelling, pressure sensitivity, decreased range of motion, loss of strength, increase of creatin kinase (CK).

Although DOMS does not normally require medical treatment, medical intervention is recommended if the pain level is abnormal, the swelling of the limbs is high, or if the urine is dark (41).

2.3.1. Theories on Mechanisms of Delayed Onset Musle Soreness

To date, various theories have been proposed about the possible mechanisms of DOMS. These are; lactic acid theory, muscle spasm theory, connective tissue damage theory, muscle damage theory, inflammation theory and enzyme theory (3, 12).

2.3.1.1. Lactic Acid Theory

It is based on the hypothesis that lactic acid will continue to be produced following the end of exercise. The accumulation of toxic metabolic residual products is thought to cause a disturbing stimulation and perceived pain as a delayed stage. However, this theory is not accepted by many authors. Because metabolic products are released in higher amounts after concentric muscle contractions, they do not cause delayed pain and tenderness similar to those in eccentric exercise (3, 12).

2.3.1.2. Muscle Spasm Theory

This theory has been proposed as an increase in resting muscle activity after eccentric exercise. Increased resting muscle activation indicates tonic localized spasm of motor units. This causes local blood vessels to become stuck, ischemia and pain relievers accumulating in the area. Thus, a vicious cycle begins and more stimulation of pain-related nerve endings leads to more reflex muscle spasms and prolonged ischemia (3, 12, 42).

2.3.1.3. Connective Tissue Damage Theory

Connective tissue is a sheath-shaped structure around the muscle mass. The arrangement and structure of the connective tissue varies depending on the type of muscle fiber. Type I (slow contracting) fibers are more durable than type II (fast contracting) fibers. Therefore, type II fibers have a higher rate of damage due to any tension (3, 43).

The high tension caused by eccentric exercise causes disruption of the structural proteins in the muscle fiber. This creates excessive tension at the muscle tendon junction, connective tissue and around the muscle fiber. This damage to the connective tissue causes muscle pain and tenderness. As a result of DOMS, the presence of amino acids such as

hydroxyproline and hydroxylysine in the natural structure of collagen tissue is an indicator of both increased collagen synthesis and degradation of collagen structure (3).

2.3.1.4.Muscle Damage Theory

After the eccentric exercise, the contractile structure of the muscle deteriorates with the elongation of the muscle under tension. Myofibrillary deterioration is observed especially in the Z band. During eccentric exercise, a 1/3 - 1/5 reduction in motor unit activation occurs. Therefore, the increased load per fiber in each unit causes mechanical deterioration (37). Type II fibers are less susceptible to fatigue and are more prone to damage after eccentric exercise (35). In addition to mechanical degradation of muscle structure, it is stated that this theory is important in some enzymes. One of these enzymes, CK, is responsible for maintaining an adequate level of adenosine triphosphate during muscle contraction. The increase in serum levels of this enzyme is indicative of permeability or deterioration of the membrane surrounding the muscle cell. According to most studies, a significant increase in serum CK levels is observed 24–48 hours after exercise. This value peaks between 3–7 days depending on the nature of the exercise and returns to normal level within 7–14 days (44). However, there is no consensus on how long after the exercise the serum CK level increases. It is stated that this enzyme level may continue to increase until the 5th day. The theory of muscle damage is considered to be partially explanatory for the onset of DOMS (3).

2.3.1.5. Inflammation Theory

Although inflammation is a pathological event, it may also develop due to exercise. With rapid destruction of damaged muscle fibers and connective tissue, bradykinin, histamine and prostoglandins are increased and neutrophils and monocytes transfer to the damaged area. A few hours after exercise, the number of circulating neutrophils increases significantly as an indicator of muscle damage, supporting acute inflammation (3). Pain is one of the main symptoms of inflammation. Although histamine, seratonin, bradykinin and potassium are substances, prostaglandin E is the best parameter to sensitize pain receptors. Painful stimulus is carried to upper centers by type III and type IV afferent nerves (35).

2.3.1.6. Enzyme Theory

Calcium, normally found in the sarcoplasmic reticulum, accumulates in the sarcoplasm following muscle damage. This leads to inhibition of cellular respiration at the mitochondrial level, which leads to regeneration of adenosine triphosphate. Adenosine triphosphate is

required for active transport of calcium into the sarcoplasmic reticulum. In addition, the accumulation of calcium in the sarcoplasm activates protease and phospholipase enzymes. These enzymes produce damage to the sarcoplasm by producing leukocytes and prostoglandins. As a result, disruption of muscle and protein structure increases in Z-band terminations and causes chemical stimulation of pain in nerve terminations. After eccentric exercise, the tissue is exposed to a high degree of tension, causing damage to the muscle and connective tissue. This is followed by edema and inflammatory cell infiltration, which are responses to acute inflammation. When all these theories are considered, DOMS cannot be explained by a single theory. As a result, the mechanism of occurrence of DOMS is a sequence of successive events (3).

2.3.2. Symptoms Of Delayed Onset Muscle Soreness

Eccentric exercise causing muscle damage may result in pain and tenderness, decreased muscle strength, increased plasma CK level, deterioration of cell structure and inflammation (45)**.** Muscle damage and pain are associated with intensity of exercise (35). The most prominent symptoms are edema, stiffness, pain and tenderness with decreased range of motion, strength and performance (46).

2.3.2.1. Pain and Soreness

Although the mechanism of acute muscle pain after exercise is known, the etiology of DOMS has not been fully elucidated. Pain and tenderness in 8–72 hours following exercise peaks in 24–48 hours and disappears within 5–10 days. After a strong eccentric activity, DOMS symptoms such as pain and tenderness occur at the muscle-tendon junction at the distal part of the muscle and along the muscle belly (47).

Inflammation due to damage to muscle and connective tissues in DOMS sensitizes mechanoreceptors. Therefore, mechanoreceptors are more easily activated when a safe arrives or when that zone moves (48). Harmful chemicals such as histamine, bradykinin and prostaglandin E released as a result of inflammation also cause pain (49).

2.3.2.2. Edema

According to studies on DOMS, edema occurs in the affected extremity and environmental measurement values increase (46). Edema occurs after 48 hours of eccentric exercise, gradually increasing to the highest value in about 10 days (40). Edema after DOMS develops as a result of fluid and cell movement from the circulation to the intercellular space

with inflammation, activating the free nerve endings in the muscle, causing pain and muscle stiffness (46).

2.3.2.3. Decrease in Muscle Strength

It is stated that the decrease in muscle strength after eccentric exercise reached its highest value in the first 48 hours and returned to normal in 5-10 days (38). The decrease in muscle strength after concentric exercise returns to normal within a few hours and is generally thought to be the result of metabolic or neural fatigue (50). It is reported that muscle strength decreases by 10-30% immediately after the downhill running exercise with eccentric contraction causing muscle damage and the recovery period lasts longer than the concentric protocol (51). High resistance exercises cause greater loss of strength (50-65%) and recovery period lasts longer (46).

Studies have shown that the decrease in muscle strength after eccentric exercise is associated with initial muscle length. Longer muscle length is indicated by more contraction of muscle strength (46).

2.3.2.4. Decreased Range of Motion (ROM)

In the studies, after the eccentric exercise, joint range of motion decreases in individuals and even after 10 days, it cannot reach pre-exercise values. Connective tissue extending parallel to muscle fibers after DOMS has been suggested to be effective in decreasing joint range of motion (3). It has also been reported that decreased ROM is associated with edema at the muscle-tendon junction (52).

2.3.4.5. Decrease in Sports Performance

Eccentric exercise causes changes in muscle pain and joint mechanics as well as structural changes in muscle pain and muscle tissue (53). These changes are characterized by decreased range of motion, muscle strength, pain and voluntary muscle activity, depending on the type of exercise, the structure of the person. Due to all these factors, performance losses are seen as a result of DOMS, leading to significant losses and risk of injury during competitions. Loss of performance is a condition that restricts individuals individually. The recovery of the lost force is not as easy as the return of pain or normal joint movement (46).

Pain in elite athletes can result in reduced performance and inability to achieve optimal training intensity (52). Impaired performance as a result of muscle damage after eccentric

exercise is most often characterized by a reduction in maximal isometric voluntary contraction force (54). Most of the studies on this subject have been performed on sedentary or individuals who have not participated in resistant training in the last 6 months. Although there is no evidence of differentiation of muscle damage, the degree and effect of muscle damage is likely to be more severe in sedentary individuals (55). It is also stated that fatigue, which causes the disruption of proprioceptive sensors in muscles and tendons, may cause a decrease in performance (56).

2.3.2.6. Biochemical Parameters

Serum CK, lactate dehydrogenase and myoglobin levels are used indirectly to show muscle damage in DOMS, and C reactive protein level and neutrophil count are used to determine inflammation.

2.3.2.6.A. Creatine Kinase

Many studies have evaluated the presence of muscle protein in the blood to show indirect muscle damage after eccentric exercise (57)**.** The most accepted protein with increased muscle damage after exercise is CK (43). This may be due to the fact that the increase in CK level is higher than other proteins. Most studies have shown that serum CK levels increase at 24-48 hours after exercise and remain elevated for 3-6 days. Plasma CK is an intramuscular enzyme that is responsible for keeping Adenosine Triphosphate at an appropriate level during muscle contraction. An increase in CK's blood indicates that the membrane surrounding the muscle cell ruptures or increases permeability. Although the increase in serum CK level is thought to be related to the severity of muscle damage, this potential correlation has not been fully established (58).

2.3.2.6.B. Lactate Dehydrogenase

Another enzyme used to assess muscle damage is lactate dehydrogenase (LDH), which catalyzes the conversion of pyruvate to lactate in anaerobic glycolysis. There are 5 different isoforms called LDH1, LDH2 (myocardium, kidney), LDH3 (lung, spleen, kidney), LDH4, LDH5 (skeletal muscle, liver) according to the tissues. In post-exercise muscle damage, serum LDH level reaches its highest level in the first 6 hours and returns to baseline before exercise 48-72 hours later (59).

2.3.2.6.C. Myoglobin

Myoglobin is a protein in the skeletal muscle that allows oxygen to be stored and transported to the muscle cell mitochondria (30). Skeletal muscle has three different isoforms

of myoglobin (60). After heavy exercise, myoglobin is released as a result of disruption of protein structures within the muscle and myoglobin may increase within 30 minutes. This increase may continue for 5 days due to inflammation (61).

2.3.2.6.D. C Reactive Protein

C Reactive Protein (CRP) is an acute phase reactant synthesized from the liver. It is a sensitive indicator of acute and chronic inflammation. CRP levels show a significant increase in acute myocardial infarction, stress, trauma, infection, inflammation, postoperative or neoplastic proliferation. Elevated CRP in muscle damage after exercise begins within 6-8 hours and reaches peak levels in 24-48 hours (62). CRP methods used in clinical laboratories have measurement limits of 3-5 mgr / lt. These methods respond to the measurement of CRP as an acute phase reactant. High precision (hs-CRP) that measures CRP precisely and specifically at lower concentrations measurement methods are also available (63)

2.3.2.6.E. Neutrophils

Neutrophils are a leukocyte cell and the most common type of leukocytes. Neutrophils are responsible for cellular and humoral protection of the body against foreign substances. The function of neutrophils involved in acute inflammation occurs in six steps. Movement along the vascular endothelium, adherence along the endothelial sequence, migration to the inflammation site (chemotaxis), adherence to microorganisms, bacterial uptake (phagocytosis) and intracellular killing (42).

2.3.3. Treatment

Various treatment modalities are used to reduce symptoms and restore muscle function. Treatment options can be grouped into 4 groups (45).

- Prevention
- Medical Treatment
- Physiotherapy
- Hyperbaric Oxygen Therapy
- Magnetic Field Therapy

2.3.3.1. Prevention

There is no preventive treatment with proven efficacy in DOMS. However, various methods have been tried to date. Some of these are exercise, stretching, warming, massage and the use of antioxidants (64).

One of the methods known to prevent DOMS is regular exercise. Repeated use of an activity involving eccentric muscle movements can prevent muscle damage (45).

One of the other preventive treatment methods is stretching. While some studies have shown that stretching before eccentric exercise is protective, some studies have reported that stretching has no effect, especially on serum CK level and strength parameters (65).

2.3.3.2. Medical Treatment

If there is pain due to inflammation after exercise, anti-inflammatory or analgesic drugs are useful. To date, no medication has been reported to reduce DOMS symptoms, except calcium blockers and protease inhibitors given to patients with intermittent claudication in the event of exercise-induced pain. (45).

2.3.3.3. Physiotherapy

Various physiotherapy methods have been used until now. Some of those; cold application, stretching, massage, compression, immobilization, vortex bath, microelectric nerve stimulation, transcutaneal electrical nerve stimulation, interference current, magnetic field therapy, ultrasound and exercise (66).

2.3.3.3.A. Cold Application

Because of its cold treatment, easy application and cheapness, it is frequently used in DOMS is one of the treatment methods. Cold application of skin, subcutaneal tissue, changes in intramuscular structure and joint temperature occur. Decrease of tissue temperature local arteriole through sympathetic adrenergic fibers, stimulating superficial skin receptors and the construction of venules. In this way, edema and membrane permeability reduction, slowdown in metabolism occurs. DOMS and inflammatory responses due to muscle damage were improved with ice treatment (67).

2.3.3.3.B. Stretching

Stretching before and after exercise is recommended in order to reduce the symptoms of DOMS. By increasing stretching flexibility, it can prevent injuries (3)**.** There are conflicting results in the literature regarding stretching in DOMS. It is reported that static stretching after exercise may cause edema accumulation in the tissue, and repeated stretching may reduce tension at the muscle tendon junction (68). Similarly, it is stated that ballistic stretching exercises may cause DOMS formation (69). McGlynn et al. (70) argue that static stretching reduces the electromyographic activities of muscles, DOMS formation and muscle spasm.

2.3.3.3.C Massage

Massage has the effects of softening scar tissue, opening adhesions, reducing muscle tension, improving microcirculation, tissue elasticity, membrane permeability and peripheral blood. This increase in blood flow accelerates healing by excretion of toxic substances such as lactate and hydrogen ions in the muscles (71). There are controversial results about the therapeutic properties of massage for DOMS. It is stated that massage application increases neutrophil margination by increasing blood flow in inflammation and thereby decreases prostoglandin production and reduces DOMS symptoms due to inflammation (72). However, it is stated that massage application has no effect on physiological parameters such as neutrophil count and serum CK level in DOMS (3).

2.3.3.3.D. Compression

One of the treatment methods used in the treatment of DOMS is compression. Kraemer et al (73) found that the use of continuous compression garments in the treatment of DOMS was particularly effective in preventing loss of range of motion, reducing pain associated with edema, movement or palpation, and increasing strength.

2.3.3.3.E. Immobilisation

Immobilization is recommended in the early period of recovery in musculoskeletal disorders. Short-term immobilization accelerates the formation of granulation tissue in the damaged area and improves muscle function. It is stated that short-term immobilization after intensive eccentric exercise facilitates muscle fiber regeneration and increases tension strength and isometric strength and has positive results on edema and muscle function (74).

2.3.3.3.F. Whirlpool

Hydrotherapy is the application of water to the body for therapeutic purposes. Vortex bath treatment is used to warm or cool tissues depending on the situation. Recommended water temperatures are 12.8 ℃ - 18.3 ℃ or 35.0 ℃ - 43.3 ℃ ’. It is stated that vortex bathing can be used to reduce the symptoms associated with the inflammatory process. Kuligowski et al. (75) stated that vortex bathing has beneficial effects in the treatment of DOMS.

2.3.3.3.G. Microwave

Microwave treatment; It is an electrotherapy method which is used for healing soft tissue and nonunion fractures with current intensity between 1 - 999 microamps (76). Lambert et al. (77) reported that microcurrent therapy reduces pain and has no effect on loss of strength. Rapaski et al. (78) reported that there was a significant decrease in serum CK level, which is one of the important physiological parameters of DOMS when microcurrent therapy is applied after eccentric exercise. The mechanism of action of the positive effects of microfluidic therapy indicated on some clinical features of DOMS is partly explained by the decrease in intracellular calcium homeostasis disorder (77).

2.3.3.3.H.Transcutaneal Electrical Nerve Stimulation

Transcutaneal electrical nerve stimulation is one of the electrotherapy methods used in the treatment of DOMS. Transcutaneal electrical nerve stimulation is used to reduce pain and improve functional disorders in DOMS (10). Denegar et al. (79) compared low- and high-frequency transcutaneous electrical nerve stimulation, indicating that both frequencies may have only systemic effects on DOMS but have no effect on other symptoms. In another study by the same investigator, transcutaneal electrical nerve stimulation was used in combination with cold administration. According to the results of the study, the combination of these two treatment methods has been shown to be effective in reducing pain (10).

2.3.3.3.I. Interferential Current

Interferential current is used to reduce inflammation, pain and edema in DOMS. The main mechanism of action of interference flow in pain treatment is based on Melzack and Wall's theory of gate control (80). There are conflicting results in the literature regarding interferential flow therapy in DOMS. Some studies have shown that the application of interferential current in DOMS is effective in reducing pain (15).
O'Connor et al. (64). Interferential flow does not affect pain, range of motion, muscle strength and physiological parameters.

2.3.3.3.J. Ultrasound

Ultrasound is used to reduce inflammation, pain and edema in DOMS and increase the healing rate of damaged tissues. In literature, contradictory results are seen in studies related to this subject (11, 13, 14).

Hasson et al (13), shown that ultrasound treatment in DOMS reduces pain and sensitivity and increases muscle strength. Some studies suggest that thermal dosages of ultrasound can increase pain and stiffness(11, 12)

2.3.3.3.K. Exercise

Exercise is one of the most important treatments in reducing the symptoms of DOMS. The relief of pain during exercise is temporary and after the end of the exercise, the symptoms recur rapidly. Pain reduction during exercise; It is stated that the adhesions in the muscle are caused by the dissolution, waste products excretion and the increase in endorphin release. As a result of these effects, analgesic effect decreases sensitivity due to DOMS. Stimulation of the afferent fibers of Group Ia, Ib and II with thick myelin and low thresholds reduces pain by inhibiting the sense of pain carried by group III and IV fibers (3). In the studies examining the effects of therapeutic exercise after DOMS, different exercise protocols were applied. These protocols operate the arm with an ergometer for 8–10 min (81)**,** 25 submaximal eccentric exercise (82)**,** eccentric exercise including downhill running and repeated exercises after 3-6 weeks (83). From these studies, it was found that eccentric exercise repeated for 3-6 weeks only after DOMS was effective.

2.3.3.3.L. Hyperbaric Oxygen Therapy

Hyperbaric oxygen therapy allows oxygen to be dissolved and transported to the damaged tissue in plasma. It also increases blood flow and muscle strength (84).Studies have reported that hyperbaric oxygen therapy has no effect on pain, tenderness, edema, isometric strength, cross-sectional area of the muscle, and serum CK levels after DOMS (85, 86).

2.3.3.3.M. Magnetic Field Therapy

Although it is thought that static magnetic field therapy may reduce pain in the treatment of DOMS, it was found that static magnetic field treatment on DOMS is not more effective than placebo (69)**.**

2.4. Effects of Isometric Exercise on Pain

Today, physical exercise is known to have a positive effect on various types of pain. However, the mechanism of hypoalgesia is not known. The most widely accepted theory is the reduction of pain perception by activation of the endogenous opioid system during exercise. Exercises of the right intensity produce beta endorphins and decrease pain sensitivity (19). This is called exercise induced hypoalgesia in the literature.

Exercise induced hypoalgesia is defined as a decrease in sensitivity to painful stimuli after physical activity. (87). Many studies have been conducted on this subject. While these studies were conducted on healthy individuals in the early days, they were also applied to the patient population in recent years. In the first period studies, it was shown that exercise induced hypoalgesia provided by high tempo running and cycling ergometer was eliminated with naloxone, this supports the role of opioids in exercise-related pain reduction. Using a strenuous isometric contraction, there was a decrease in pain threshold accompanied by a decrease in cortical excitability and motor evoked potentials assessed by transcranial magnetic stimulation. (88).

Exercise-induced hypoalgesia is distinguished from conditioned pain modulation by the temporal relation between exercise and pain and the innocuous quality of exercise. Conditioned pain modulation involves endogenous inhibition of one form of pain when two painful stimuli are administered simultaneously, and is often impaired in those with chronic(89). In exercise-induced hypoalgesia, pain induction occurs after exercise is completed.

According to the severity of isometric exercise studies (18), thermal (17) (19) and electrocutenous (19) was found to be effective in pain. It has been shown that the effect of hypoalgesia provided by isometric exercises is observed not only in the exercise muscle but also in other parts of the body (17, 87, 88). In this respect, it supports the beta-endorphin theory of analgesia mechanisms.

Studies in the literature show that isometric exercises have shown analgesic effect in various orthopedic disorders such as tendinopathies (90), back pain (91) whiplash syndrome (92), kronik ağrı (93). And in a study isometic exercises found more beneficial on hypoalgesia when compared to aerobic exercise on chronic whiplash syndrome (92).

3. MATERIALS AND METHODS

Forty healthy subjects participated in the study. Participants were selected from Yeditepe University Physiotherapy and Rehabilitation Department students on a voluntary basis. Participants who were eligible to participate in the study according to inclusion and exclusion criteria were divided into two groups as isometric exercise group and control group by lot.

Inclusion Criterias

- Being between the ages of 18-30.
- Not to exercise the lower extremity in daily life.

Exclusion Criterias

- Orthopedic disorders
- Neurological disorders
- Cardiopulmonary disorders
- Open Wounds
- Pregnancy
- History of Surgery

In addition, participants were asked not to use painkillers, to pay attention to caffeine use, not to drink alcohol, not to use medication and not to engage in activities that are difficult in normal daily life during the 5-day period. In addition, participants were asked to note that they ate and drank during the 5-day period.

3.1. Exercise Protocol to Establish DOMS

In order to establish DOMS, a proven exercise protocol that previously demonstrated this effect in the literature was chosen. According to this protocol, after the initial assessments, the participants will jump over (Figure 3.1) feet on a 60 cm high box and were asked to jump (Figure 3.2.) upwards with all their strength immediately after touching the ground (Figure 3.3). After first trial, participant was asked to go back to the box and repeat the movement. The participants performed the exercise in 20 repetitions and 5 sets and a 2 minute rest period was applied between each set. After the exercise, the quadriceps muscle isometric exercise program was taught to the treatment group. Exercise training was given by a physiotherapist. According to this program, participants were asked to do their exercises in

3 sets of 10 repetitions, 5 times a day. Exercises were performed with 50% of maximum voluntary muscle strength (94).

Figure 3.1. Starting Position

Figure 3.2. Landing Position

Figure 3.3. Jumping

3.2. Outcome Measures

In our study, 5 evaluation criteria were determined as outcome measure in order to measure the effect of DOMS. These; isometric muscle strength measurement, muscle

sensitivity measurement, pressure sensitivity measurement, joint ROM measurement and thigh area measurement.

The measurements were performed by the same physiotherapist in the same order. These measurements were performed five times, immediately before, immediately after the exercise protocol, on the first, third and fifth days after administration.

3.2.1.Measuring Quadriceps Isometric Strength

Hand held dynamometer (HHD) was used to measure isometric muscle strength. Measurements were made by a physiotherapist. At the beginning of the measurement, the participant was asked to sit with a knee and hip angle of 90°. After this procedure, physiotherapist placed the dynamometer on the lower 1/3 of the tibia. The participant was asked to push the physiotherapist with maximum force (Figure 3.4.).

After three repetitions, the recording phase was started. Three repetitions were performed for recording and the highest value seen on the dynamometer was maintained for at least half a second. During the test, the participant was given commands at high volume for motivation purposes.

Figure 3.4 Measuring Isometric Strength of Quadriceps Muscle

3.2.2. Measuring Muscle Soreness

In order to measure muscle soreness, the participant was asked to come to the squat position with the knee 90 °. In this position, the participant was asked to rate the overall muscle sensitivity over 10 according to the Visual Analog Scale (VAS) (Figure 3.5.).

Figure 3.5. Squat Position

3.2.3. Measuring Pressure Pain Threshold (PPT)

PPT was measured by the physiotherapist using an algometer. The center of the distance between the knee cap and the sias was marked before the test. The trunk was seated vertically with the knee and hip flexed at 90 °. Algometry was then placed at the marked point. From this moment, the pressure was slowly increased to 1 kg / cm 2 each time. The value seen on the algometer was recorded when the participant raised his hand or said ouch. This procedure was repeated 3 times and 5 minute intervals were given between each repetition (Figure 3.6.).

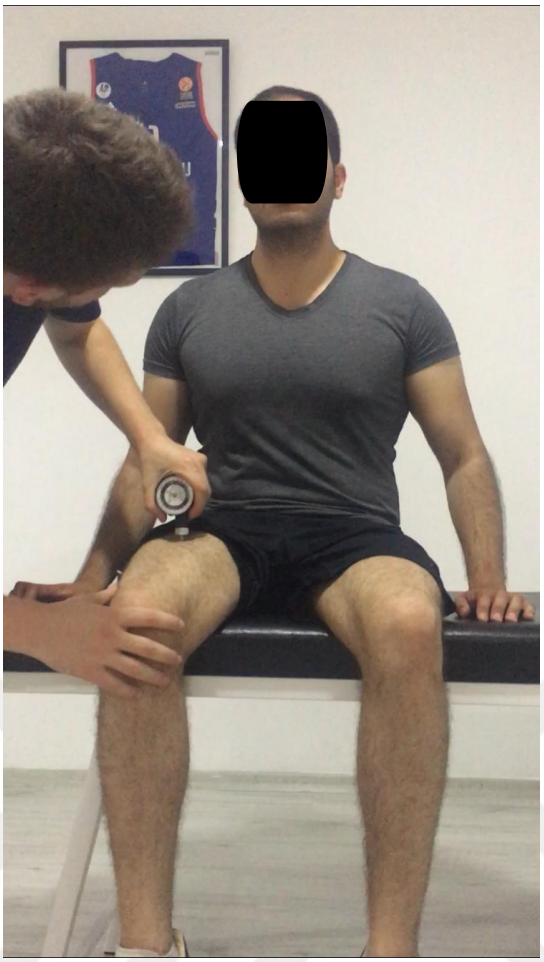

Figure 3.6 Pressure Pain Threshhold Measurement

3.2.4. Measuring ROM

The ROM was measured by a physiotherapist using a standard goniometer. The participant was placed prone on the treatment bed to measure the knee flexion angle. The subject was asked to bend the knee as far as he could and the measured value was recorded. During measurements, the fixed arm of the goniometer was positioned to follow the femur line, the pivot point being the lateral condyle of the femur, and the movable arm following the fibular line (95) (Figure 3.7.).

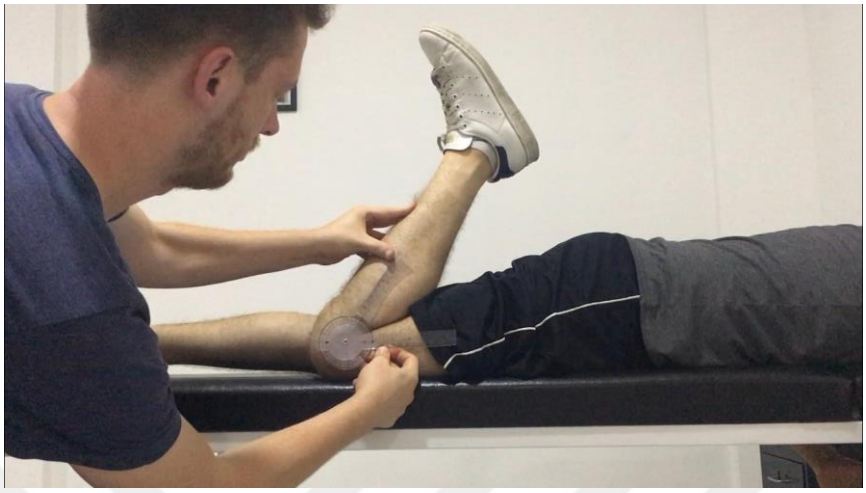

Figure 3.7. Measuring Range of Motion

3.2.5. Measuring Thigh Circumference

Measurements were performed by a physical therapist with a classic tape measure. The distance between Spina Iliaca Anterior Superior of pelvis and patella was measured to determine the location of the measurement. The point corresponding to 40% of this distance (close to the patella) was marked. Perimeter measurement was made on the line passing through this point (Figure 3.8.)

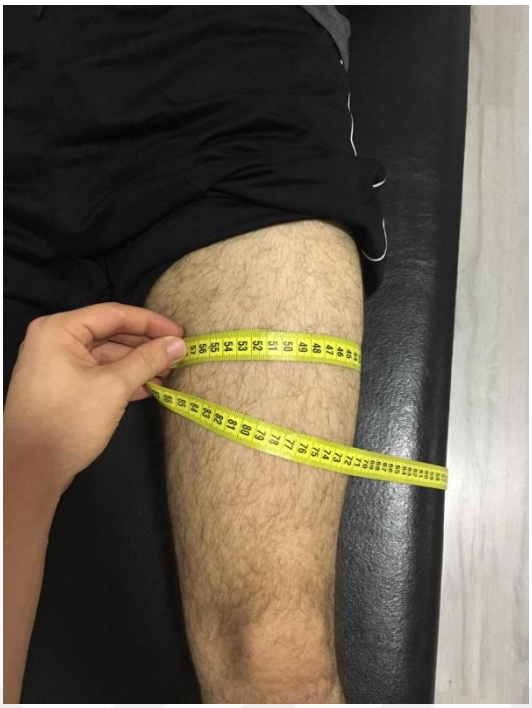

Figure 3.8. Measuring Thigh Circumference

3.3. Tools Used in the Study

The participants completed a form to learn demographic information before participating in the study (FORM1).

3.3.1. Visual Analogue Scale

The adequacy of the use of VAS for pain and sensitivity measurement has been demonstrated by the literature (96). The VAS scale includes numbers from 0 to 10. Accordingly, 0 points have no pain / tenderness; 10 points represent the highest imaginable pain. Based on these, the participant is asked to rate his / her pain / sensitivity out of 10 (Figure 3.9.)

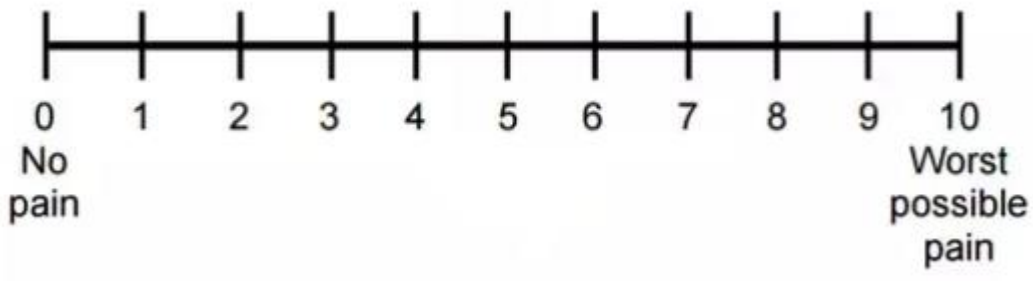

Figure 3.9. Visual Analog Scale

3.3.2. Algometry

Algometry is used to measure pain sensation caused by pressure. using an algometer may be a useful way to quantify pains and possibly track recovery / healing. Its reliability has been proven in the literature (97).

3.3.3. Hand-Held Dynamometer

HHD is a frequently used device for measuring muscle strength. It is frequently used both in clinics and scientific studies. It has been proven to be a reliable instrument for measuring muscle strength in many studies (98-100).

3.3.4.Goniometer

In our study, a standard goniometer was used to measure the knee flexion angle before and after the application.

3.3.5.Statistical Analysis

In order to evaluate the data obtained from the study and form the tables SPSS (Statistical Package for Social Sciences) was used. For quantitative variables, mean and standard deviation values were used. For compatibility of quantitative variables with normal distribution Kolmogorov-Smirnov test was used. Student's paired or independent sample t test for normally distributed variables and Wilcoxon test were used for non-normally distributed variables. Significance value was accepted as $p < 0.05$.

4.RESULTS

In order to investigate the effects of isometric exercise on pain, pressure pain, edema, ROM and strength in delayed muscle pain, a total of 40 individuals (20 female and 20 male) were included in the study.

The mean age of all individuals included in the study was 22.07 ± 2.02 years, average height was 1.69 ± 0.08 m, body weight average was 65.25 ± 13.61 kg, and BMI average was 22.82 ± 2.69 kg. / m2.

There was no difference between the groups in terms of age, height, body weight and BMI(Body Mass Index) (p> 0.05) (Table 4.1).

Table 4.1. Demographics

	Isometric Exercise (Mean ± SD)	**Control (Mean ± SD)**	**p**
Sex (Male/Female)	**10/10**	**10/10**	
Age (Year)	**21.78 ± 1.9**	**22.36 ± 2.15**	**0.13**
Height (m)	**1.67 ± 0.91**	**1.71 ± 0.69**	**0,81**
Weight (kg)	**64.5 ± 14.12**	**66.01 ± 13.11**	**0,77**
BMI (kg/m2)	**23.05 ± 2.72**	**22.60 ± 2.66**	**0,75**

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05.

4.1. Thigh Circumference Assessments

4.1.1. In Group Assessment of Thigh Circumference

A statistically significant difference was found between the values measured before and after the exercise in both groups (isometric: p = 0.000; control: p = 0.000). When analyzing the post-exercise period with Day 1 significant increase was observed in the control group (p = 0.029), but not in the isometric group (p = 0.644).

Between 3rd day and 1st day, a significant decrease was detected in both the isometric exercise group (p = 0.000) and the control group (p = 0.002). Between day 1 and day 3, values continued to decrease significantly in both groups (isometric: p = 0.001; control p = 0.002).

A significant difference was found between the 5th day values and the pre-exercise values in both groups (isometric: p = 0.010; control: p = 0.006) (Table 4.2.)

Table 4.2. In Group Assessment of Thigh Circumference

		Mean (cm)	SD (cm)	p
Isometric	***Postex***	55.45	3.63	**0.000***
	Preex	52.75	3.68	
	Day1	55.35	3.95	0.644
	Postex	55.45	3.63	
	Day3	54.25	3.74	**0.000***
	Day1	55.35	3.95	
	Day5	53.35	3.98	**0.001***
	Day3	54.25	3.74	
	Day5	53.35	3.98	**0.010***
	Preex	52.75	3.68	
Control	***Postex***	56.70	3.88	**0.000***
	Preex	53.90	4.56	
	Day1	56.25	4.02	**0.029***
	Postex	56.70	3.88	
	Day3	55.50	3.98	**0.002***
	Day1	56.25	4.02	
	Day5	54.60	4.41	**0.002***
	Day3	55.50	3.98	
	Day5	54.60	4.41	**0.006***
	Preex	53.90	4.56	

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.1.2. Between-Groups Assessment of Thigh Circumference

No significant difference was found between the groups at any time period in thigh circumference measurement (Table 4.3.)

Table 4.3. Between-Groups Assessment of Thigh Circumference

	Isometric (mean±SD)	Control (mean±SD)	p
Preex	52.75±3.68	53.90±4.56	0.413
Postex	55.45±3.63	56.70±3.88	0.237
Day 1	55.35±3.95	56.25±4.02	0.362
Day 3	54.25±3.74	55.50±3.98	0.173
Day 5	53.35±3.98	54.60±4.41	0.216

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.1.3. Assessment of Thigh Circumference Differences

There was no difference between the groups in terms of changes in the circumferential measurements of at all time periods. (Table 4.4.)

Table 4.4.Assessment of Thigh Circumference Differences

	Isometric (mean±SD)	Control (mean±SD)	p
Δpost-pre	2.70±1.17	2.80±1.40	0.801
Δday1-post	-0.10±0.97	-0.45±0.83	0.226
Δday3-day1	-1.10±0.79	-0.75±0.79	0.168
Δday5-day3	-0.90±0.79	-0.90±0.91	1.000
Δday5-pre	0.60±0.88	0.70±0.92	0.728

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.2. Assessment of Muscle Soreness

4.2.1. In Group Assessment of Muscle Soreness

There was no significant difference in muscle soreness in both isometric exercise group (p = 0.716) and control group (p = 0.330) between before and after the exercise. Muscle soreness was significantly increased in the isometric exercise group on Day 1 (p = 0.000). Muscle soreness was significantly increased on the first day in the control group (p = 0.000). There was a significant decrease in the VAS values of the isometric exercise group in the 3rd day measurements (p = 0.000), while no significant change was observed in the control group (p = 0.408). In the 5th day measurements, there was a significant decrease in VAS values in both groups compared to Day 3 (p = 0.000, p = 0.000). At the 5th day, no significant difference was observed in the isometric exercise group when compared with the values

before exercise (p = 0.262). Similarly, no significant difference was observed in the control group (p = 0.053) (Table 4.5.)

Table 4.5. In Group Assessment of Muscle Soreness

		Mean	**SD**	**p**
Isometric	***Postex***	0.60	0.82	0.716
	Preex	0.55	0.89	
	Day1	2.60	0.50	**0.000***
	Postex	0.60	0.82	
	Day3	3.45	0.69	**0.000***
	Day1	2.60	0.50	
	Day5	0.80	0.89	**0.000***
	Day3	3.45	0.69	
	Day5	0.80	0.89	0.262
	Preex	0.55	0.89	
Control	***Postex***	0.75	1.12	0.330
	Preex	0.55	0.76	
	Day1	5.15	0.99	**0.000***
	Postex	0.75	1.12	
	Day3	5.35	0.67	0.408
	Day1	5.15	0.99	
	Day5	1.10	1.02	**0.000***
	Day3	5.35	0.67	
	Day5	1.10	1.02	0.053
	Preex	0.55	0.76	

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.2.2. Between Group Assessment of Muscle Soreness

There was no significant difference between the groups in terms of muscle soreness in the pre-exercise evaluation (p = 1,000). There was no significant difference between the groups in terms of muscle soreness in the evaluation performed immediately after exercise (p = 0.631). On day 1 and 3, there was a significant difference in muscle soreness between the groups (p = 0.000, p = 0.000, respectively). However, there was no significant difference between the groups on the 5th day (p = 0.329) (Table 4.6.)

Table 4.6.Between Group Assessment of Muscle Soreness

	Isometric (mean±SD)	**Control (mean±SD)**	**p**
Preex	0.55±0.89	0.55±0.76	1.000
Postex	0.60±0.82	0.75±1.12	0.631
Day 1	2.60±0.50	5.15±0.99	**0.000***
Day 3	3.45±0.69	5.35±0.67	**0.000***
Day 5	0.80±0.89	1.10±1.02	0.329

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.2.3. Assessment of Muscle Soreness Differences

There was no significant difference between the groups in terms of VAS changes before and after exercise (p = 0.538). When the differences between day 1 and post-exercise values were compared, it was determined that VAS increase of the control group was statistically higher (p = 0.000). When the differences between Day 3 and Day 1 measurements were compared, the decrease in VAS was higher in the isometric exercise group (p = 0.03). The decrease between Day 3 and Day 5 was also higher in isometric exercise. (p = 0.000). There was no significant difference between the groups at the difference between 5th day values and the pre-exercise values (p = 0.387) (Table 4.7.)

Table 4.7. Assessment of Thigh Circumference Differences

	Isometric (mean±SD)	**Control (mean±SD)**	**p**
Preex	0.55±0.89	0.55±0.76	1.000
Postex	0.60±0.82	0.75±1.12	0.631
Day 1	2.60±0.50	5.15±0.99	**0.000***
Day 3	3.45±0.69	5.35±0.67	**0.000***
Day 5	0.80±0.89	1.10±1.02	0.329

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.3.Strength Assessment

4.3.1. In Group Assessment of Muscle Strength

A significant decrease in muscle strength was observed in both groups before and after exercise protocol application (p = 0.000, p = 0.000). In the isometric exercise group, a significant increase was found between the 1st day and the post-exercise period (p = 0.002). In the isometric exercise group, a significant increase was found between the 1st day and the

post-exercise period (p = 0.002). In the isometric exercise group, there was no significant difference both between Day 1 and Day 3 (p = 0.100) and Day 3 and Day 5 (p = 0.119). In the control group, muscle strength on Day 3 was significantly higher than Day 1 (p = 0.042), and muscle strength on Day 5 was significantly higher than Day 3 (p = 0.043). A significant difference was found between the 5th day and pre-exercise muscle strength in both groups (isometric: p = 0.001; control: p = 0.008) (Table 4.8.).

Table 4.8. In Group Assessment of Muscle Strength

		Mean (N)	**SD (N)**	**p**
Isometric	***Postex***	232.25	61.33	**0.000***
	Preex	264.25	62.80	
	Day1	242.50	61.60	**0.002***
	Postex	232.25	61.33	
	Day3	247.75	61.48	0.100
	Day1	242.50	61.60	
	Day5	253.25	62.29	0.119
	Day3	247.75	61.48	
	Day5	253.25	62.29	**0.001***
	Preex	264.25	62.80	
Control	***Postex***	238.25	61.33	**0.000***
	Preex	266.50	50.76	
	Day1	244.50	61.59	**0.027***
	Postex	238.25	61.33	
	Day3	249.50	61.48	**0.042***
	Day1	244.50	61.59	
	Day5	256.00	49.91	**0.043***
	Day3	249.50	61.48	
	Day5	256.00	49.91	**0.008***
	Preex	266.50	50.76	

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.3.2. Between Group Assessment of Muscle Strength

There was no significant difference in muscle strength between groups in any measurement period (Table 4.9.)

Table 4.9. Between Group Assessment of Muscle Strength

	Isometric (mean±SD)	Control (mean±SD)	p
Preex	264.25±62.80	266.50±50.76	0.903
Postex	232.25±61.33	238.25±61.33	0.839
Day 1	242.50±61.60	244.50±61.59	0.850
Day 3	247.75±61.48	249.50±61.48	0.978
Day 5	253.25±62.29	256.00±49.91	0.957

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.3.3. Assessment of Muscle Strength Differences

There was no significant difference between the groups in terms of changes in quadriceps isometric muscle strength measurement values at all time periods. (Table 4.10.)

Table 4.10. Assessment of Muscle Strength Differences

	Isometric (mean±SD)	Control (mean±SD)	p
Δpost-pre	-32.00±12.81	-28.25±11.73	0.311
Δday1-post	10.25±10.45	6.25±10.74	0.177
Δday3-day1	5.25±13.12	5.00±10.00	0.880
Δday5-day3	5.50±13.57	6.50±13.28	0.764
Δday5-pre	-11.00±10.95	-10.50±14.40	0.744

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.4. PPT Assessment

4.4.1. In Group Assessment of PPT

When the muscle PPT values were examined, a significant decrease was detected between both values before and after exercise (isometric: p = 0.000; control: p = 0.000). A statistically significant decrease was observed in both groups when post-exercise and Day 1 values were compared (isometric: p = 0.000; control: p = 0.000). When Day 1 and Day 3 values were compared, a significant decrease was detected in both groups (p=0.030). When Day 3 and Day 5 values were compared, a significant increase was detected in both groups

(isometric: p = 0.025; control p = 0.000). When the 5th day values were compared to the pre-exercise levels, a significant decrease was detected in both groups (isometric p = 0.000; control: p = 0.001) (Table 4.11.)

Table 4.11. In Group Assessment of PPT

		Mean (N)	**SD (N)**	**p**
Isometric	***Postex***	9.65	2.56	**0.000***
	Preex	10.85	2.71	
	Day1	9.00	2.29	**0.000***
	Postex	9.65	2.56	
	Day3	9.35	2.13	**0.030***
	Day1	9.00	2.29	
	Day5	9.60	2.11	**0.025***
	Day3	9.35	2.13	
	Day5	9.60	2.11	**0.000***
	Preex	10.85	2.71	
Control	***Postex***	9.50	2.19	**0.000***
	Preex	10.65	2.39	
	Day1	8.35	1.79	**0.000***
	Postex	9.50	2.19	
	Day3	8.15	1.95	
	Day1	8.35	1.79	
	Day5	9.50	2.19	**0.000***
	Day3	8.15	1.95	
	Day5	9.50	2.19	**0.001***
	Preex	10.65	2.39	

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.4.2. Between Groups Assessments of PPT

Comparison of PPT values at each measurement period revealed a significant difference between the groups only on Day 3 PPT. In this measurement, isometric group PPT values were found to be significantly higher than the control group (p = 0.050) (Table 4.12.)

Table 4.12. Between Groups Assessments of PPT

	Isometric (mean±SD)	**Control (mean±SD)**	**p**
Preex	10.85 2.71	10.65 2.39	0.816

Postex	9.65 2.56	9.50 2.19	0.806
Day 1	9.00 2.29	8.35 1.79	0.343
Day 3	9.35 2.13	8.15 1.95	**0.050***
Day 5	9.60 2.11	9.50 2.19	0.741

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.4.3. Assessment of PPT Differences

When the changes in PPT values of both groups were compared with each other, no significant difference was found between pre- and post-exercise changes (p = 0.828). When the difference between day 1 and post-exercise measurements were compared, it was found that the isometric exercise group showed less decrease than the control group (p = 0.017). When the 3rd day measurements were compared with the 1st day measurements, PPT values of the isometric exercise group were found to be increased while the control group had a decrease and the difference was statistically significant (0.021). When the Day 5 and Day 3 values were compared, the increase in the control group was statistically higher than the increase in the isometric group (p = 0.000). When the 5th day values of the groups were compared with pre-exercise values, no difference was found between the two groups (p = 0.733) (Table 4.13.).

Table 4.13. Assessment of PPT Differences

	Isometric (mean±SD)	**Control (mean±SD)**	**p**
Δpost-pre	-1.20±0.69	-1.15±0.74	0.828
Δday1-post	-0.65±0.48	-1.15±0.74	**0.017***
Δday3-day1	0.35±0.67	-0.20±0.77	**0.021***
Δday5-day3	0.25± 0.44	1.35±1.04	**0.000***
Δday5-pre	-1.25±0.85	-1.15±0.98	0.733

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.5. ROM Assessment

4.5.1. In Group Assessment of ROM

When the ROM was evaluated within the groups, a significant difference was detected in both groups before and after exercise (isometric: p = 0.013; control: p = 0.042). When day 1 and post-exercise values were compared, a significant decrease was detected in both groups (isometric: p = 0.000; control p = 0.000). There was no significant difference in the groups

between day 3 and day 1 (isometric: p = 0.907; control p = 0.351). When Day 5 and Day 3 values were compared, a significant increase was detected in both groups (isometric: p = 0.000; control: p = 0.005).

When the 5th day values were compared with the pre-exercise values, a significant difference was detected in both groups (isometric: p = 0.001; control p = 0.001) (Table 4.14.)

Table 4.14. In Group Assessment of ROM

		Mean (N)	**SD (N)**	**p**
Isometric	***Postex***	140.10	4.73	**0.013***
	Preex	140.90	5.27	
	Day1	137.25	4.58	**0.000***
	Postex	140.10	4.73	
	Day3	137.25	4.91	0.907
	Day1	137.25	4.58	
	Day5	139.60	4.76	**0.000***
	Day3	137.25	4.91	
	Day5	139.60	4.76	**0.001***
	Preex	140.90	5.27	
Control	***Postex***	140.65	4.01	**0.042***
	Preex	141.35	4.65	
	Day1	138.30	4.32	**0.000***
	Postex	140.65	4.01	
	Day3	138.85	3.24	0.351
	Day1	138.30	4.32	
	Day5	140.05	3.87	**0.005***
	Day3	138.85	3.24	
	Day5	140.05	3.87	**0.001***
	Preex	141.35	4.65	

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.5.2. Between-group Assessment of ROM

There was no significant difference between the groups at any time period in the evaluation of range of motion of the joints (Table 4.15.)

Table 4.15. Between-group Assessment of ROM

	Isometric (mean±SD)	**Control (mean±SD)**	**p**
Preex	140.90±5.27	141.35±4.65	0.807
Postex	140.10±4.73	140.65±4.01	0.816
Day 1	137.25±4.58	138.30±4.32	0.562
Day 3	137.25±4.91	138.85±3.24	0.260
Day 5	139.60±4.76	140.05±3.87	0.738

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

4.5.3. Assessment of ROM Differences

In the comparison of changes of range of motions, a significant difference was found between the groups only between the 5th day and the 3rd day. ROM increase in the isometric exercise group was significantly higher in this period than the control group (p = 0.025) (Table 4.16.)

Table 4.16. Assessment of ROM Differences

	Isometric (mean±SD)	**Control (mean±SD)**	**p**
Δpost-pre	-0.80±1.28	-0.70±1.45	0.857
Δday1-post	-2.85±2.45	-2.35±1.63	0.748
Δday3-day1	0.00±1.86	0.55±2.45	0.503
Δday5-day3	2.35±1.46	1.20±1.64	**0.025***
Δday5-pre	-1.30±1.41	-1.30±1.26	1.000

Data expressed as mean ± Standard Deviation. Significance was set as p≤0,05. *: p≤0,05

5. DISCUSSION

In this study we aimed to investigate the effects of isometric exercise on soreness, PPT, edema, ROM and strength in DOMS. As a result we found that, isometric exercise reduced soreness on day 1 and 3, and improvement in PPT was faster in isometric exercise group, PPT was higher in the isometric exercise group on day 3, increase in ROM was found to be higher in the isometric exercise group from Day 3 to Day 5. In the other parameters, there was no difference between the isometric exercise group and the control group.

There was no difference between the groups in terms of gender, age, height, weight and BMI. High et al. (65) in a study of 31 women and 31 men reported that there was no difference between men and women in DOMS. Similarly, Rinard et al. (101) reported no difference between genders in terms of motion-induced pain in DOMS. On the other hand, MacIntyre et al. (102) stated in a study conducted on 10 females and 12 males that pain assessments were different in individuals according to gender. In previous studies conducted to investigate the differences in pain complaints by DOMS, there was no consensus among the researchers. In this study, an equal number of male and female subjects were included in both groups in order to rule out possible DOMS changes by gender.

Different measurement and evaluation methods are used in the determination of experimental DOMS in the clinic and there is no consensus among the researchers yet. A systematic review conducted to investigate the effectiveness of physical therapy modalities in the treatment of DOMS suggests the use of 4 basic parameters to determine the occurrence of DOMS. These are pain, pain associated with activity, ROM, and muscle strength (64). In addition to these parameters, PPT, circumference measurement, performance tests and biochemical parameters can be used to determine the formation of DOMS (64, 103, 104). In this study, soreness, PPT, ROM, edema and muscle strength were used to determine experimentally induced DOMS.

Various exercise protocols have been used in the literature to generate experimental DOMS. These protocols include running downhill, cycling resistance, isokinetic exercises, jumping down, or resistant exercises (3, 104, 105). In this study, a 60 cm-high platform jumping method, which was reported to have created DOMS in the literature, was used. A significant difference between the parameters indicated before and after the exercise is an indication that the protocol used in this study constitutes DOMS.

In addition, the most affected muscle group in this protocol is reported to be quadriceps femoris (94, 104). For this reason, we evaluated the quadriceps femoris muscle group.

In previous studies, it has been reported that the severity of soreness associated with rest and activity increases after experimental muscle pain is established (11, 39, 47). Similarly, in this study, both groups showed an increase in soreness severity measured by VAS after exercise. Previous studies have reported that muscle pain occurs several hours after exercise, reaches its highest value after 24-48 hours, and its severity varies with the type of exercise (40, 103). In this study, the soreness measured using VAS was increased 1 day after exercise in both groups. Clarkson et al. (39) reported that muscle pain after eccentric exercise occurred in 24 hours and reached the highest value in 48 hours. Proske et al. (106) reported that muscle pain peaks in the first 24 hours after eccentric exercise. In this study, it was found that the muscle reached the highest soreness on Day 3. Muscle soreness was significantly lower in the isometric group on both Day 1 and Day 3. In both groups, muscle sensitivity decreased to pre-exercise level at the end of the 5th day.

Another parameter used to determine the occurrence of DOMS experimentally in previous clinical trials is PPT (68, 103). It is reported that pain and tenderness in the DOMS begin from the muscle-tendon junction in the distal part of the muscle and spread to the muscle belly. For this reason, the PPT assessment is based on the musculotendinous region and muscle belly (103). In our study, PPT measurements were made from muscle belly. It is reported that PPT values decrease in the affected extremity of individuals after the formation of DOMS (68). As a result of this study, it was determined that PPT decreased in both groups 1 day after exercise. These results are similar to previous study results. The time period at which the PPT is lowest and the period at which soreness intensity are consistent. This result shows that VAS in which pain is subjectively evaluated or pressure pain threshold in which it is evaluated objectively gives similar results. Studies on the reliability of the use of these two different assessment methods in the DOMS, one subjective and the other evaluating the pain, may clarify the subject. In our study, the pressure thresholds increased in the isometric exercise group in the first 3 days, whereas the increase in the control group was between 3 and 5 days.

Measuring circumference and volumetric measurements are among the methods used to evaluate inflammation-induced edema in DOMS (94, 103, 107). In this study, the circumference was measured with reference to the muscle belly in the evaluation of the edema. Experimental studies on individuals with DOMS have been reported to increase circumference measurement values in the affected extremity (36, 107). Sellwood et al. (103) reported that circumference measurement values did not change after eccentric exercise in a randomized controlled trial in which they investigated the effects of cold administration on

DOMS. According to the results of the study on DOMS, there is no consensus on the formation of edema in the affected extremity. As a result of this study, edema developed in both groups after exercise causing DOMS. This result supports studies indicating that edema develops in the affected limb in the DOMS. According to the results of this study, which is thought to reduce edema after DOMS, isometric exercise has no such effect.

Clarkson et al. (108) reported that exercise-induced muscle damage causes pain and a decrease in muscle's ability to contract, which reduces joint ROM. Jones et al. (63) reported that edema in the muscle-tendon junction and connective tissue around the muscle causes a decrease in the ROM. Studies suggesting decreased range of motion after DOMS have attributed the decrease in ROM to different causes. On the other hand, there are also studies showing that the ROM of the joints does not change after exercise causing muscle damage (104). There is a contradiction between the results of studies on whether the ROM of the joint changes in the affected extremity after DOMS. In this study, it was determined that passive flexion of the knee joint decreased immediately after exercise. This decrease reached the highest value on Day 1 and Day 3. These results support the studies suggesting that the ROM of the joint is altered due to factors that may lead to decreased ROM of the affected extremity.

Exercise-induced muscle damage has been reported to cause changes in the microstructure of the muscle and pain, and therefore a decrease in muscle strength (38, 50). It is stated that the exercise protocol used in the studies performed causes a decrease in quadriceps femoris and hamstring muscle strength (104). In this study, it was found that there was a decrease in muscle strength immediately after exercise and that the baseline level could not be reached at the end of 5th day. In both groups, the decreased muscle strength immediately after exercise began to increase on Day 1 and continued until Day 5. These results support previous studies and the isometric exercise program did not increase muscle strength.

6. CONCLUSION

The aim of this study was to investigate the effects of isometric exercise on soreness, PPT, edema, ROM and strength, DOMS. Clinical and laboratory findings obtained before and immediately after exercise, on day 1, day 3 and day 5. As a result of our statistical analysis we have reached the following results:

- Both groups had similar characteristics in terms of age, gender, height, body weight and BMI.
- After exercise, soreness occurred on day 1 we found that the muscle reached the highest soreness on Day 3.
- Muscle soreness was significantly lower in the isometric group on both Day 1 and Day 3. In both groups, muscle soreness decreased to pre-exercise level at the end of the 5th day
- It was determined that PPT decreased in both groups 1 day after exercise. The pressure thresholds increased in the isometric exercise group in the first 3 days, whereas the increase in the control group was between 3 and 5 days.
- Edema developed in both groups after exercise causing DOMS. According to the results of this study, which is thought to reduce edema after DOMS, isometric exercise has no such effect.
- In this study, it was determined that passive flexion of the knee joint decreased immediately after exercise. This decrease reached the highest value on Day 1 and Day 3.
- We found that there was a decrease in muscle strength immediately after exercise and that the baseline level could not be reached at the end of 5th day. In both groups, the decreased muscle strength immediately after exercise began to increase on Day 1 and continued until Day 5.

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8. APPENDIXES

Appendix 8.1. Ethical Approval

T.C. YEDİTEPE ÜNİVERSİTESİ

Sayı : 37068608-6100-15- 1686 **30/05/2019**
Konu: Klinik Araştırmalar
Etik kurul Başvurusu hk.

İlgili Makama (Ramazan Kurtulmuş)

Yeditepe Üniversitesi Sağlık Bilimleri Fakültesi, Fizyoterapi ve Rehabilitasyon Bölümü Yar. Doç. Dr.Feyza Şule Badıllı Demirbaş'in sorumlu araştırmacı olduğu **"İzometrik Egzersizin Gecikmiş Kas Ağrısı Üzerine Etkisi"** isimli araştırma projesine ait Klinik Araştırmalar Etik Kurulu (KAEK) Başvuru Dosyası **(1640)** kayıt Numaralı KAEK Başvuru Dosyası), Yeditepe Üniversitesi Klinik Araştırmalar Etik Kurulu tarafından **29.05.2019** tarihli toplantıda incelenmiştir.

Kurul tarafından yapılan inceleme sonucu, yukarıdaki isimi belirtilen çalışmanın yapılmasının etik ve bilimsel açıdan uygun olduğuna karar verilmiştir (**KAEK Karar No: 1036**).

Prof. Dr. Turgay ÇELİK
Yeditepe Üniversitesi
Klinik Araştırmalar Etik Kurulu Başkanı

Yeditepe Üniversitesi 26 Ağustos Yerleşimi, İnönü Mahallesi Kayışdağı Caddesi 34755 Ataşehir / İstanbul
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Appendix 8.2. Curriculum Vitae

ÖZGEÇMİŞ

A. KİŞİSEL BİLGİLER

Adı soyadı: Ramazan Kurtulmuş

Doğum tarihi: 23.03.1993

Yabancı dil bilgisi: İngilizce

Görev yeri: İstanbul

E-posta adresi: kurtulmusramazan@gmail.com

Telefon: 0507 036 75 93

B. EĞİTİM BİLGİLERİ

Mezun olduğu üniversite/fakülte: T.C. İstanbul Bilim Üniversitesi Sağlık Yüksekokulu Fizyoterapi ve Rehabilitasyon Bölümü

Mezuniyet tarihi: 2016

C. İŞ TECRÜBESİNE AİT BİLGİLER

Bugüne kadar çalıştığı kurum/kuruluşlar: 2018 – Halen 360 Terapi

Appenix 8.3. Participant Approval Form

İZOMETRİK EGZERSİZLERİN GECİKMİŞ KAS AĞRISI ÜZERİNE ETKİSİ

ARAŞTIRMAYA KATILIM ONAM FORMU

Bu çalışma Yeditepe Üniversitesi Sağlık Bilimleri Fakültesi Fizyoterapi ve Rehabilitasyon Bölümü tarafından yürütülen **"İzometrik egzersizlerin gecikmiş kas ağrısı üzerine etkisi"** başlıklı araştırma kapsamında planlanmıştır. Bu çalışmanın amacı gecikmiş kas ağrısına izometrik egzersizlerin etkisini araştırmaktır. Çalışmamıza katılmayı kabul eden gönüllü bireylerin; yaşı, cinsiyeti, sosyo-demografik koşulları, var olan kronik hastalıkları, geçirilen cerrahi operasyonları, yaralanmaları ve antrenman davranışlarına dair bilgiye ulaşılarak testlemelere dahil edilecektir. Deney grubuna katılan bireyler ilk uygulama sonrası 5 gün boyunca izometrik egzersiz protokolünü uygulayacaklardır. Bu amaçla kullanılan değerlendirmelerin sonuçları yalnızca araştırma kapsamındaki çalışmalarda kullanılacaktır.

Araştırma ile ilgili sizden doldurmanızı istediğimiz formları doğru bir şekilde doldurmanızı ve herhangi bir şikayetiniz veya rahatsızlığınız olduğunda bize bildirmeniz gerekmektedir. İstediğiniz zaman çalışma dışına çıkma hakkınız olduğunuzu bilmenizi isteriz. Bu araştırma kapsamında uygulanacak olan uygulama size zarar vermeyecektir. Bu araştırma dahilinde sizden herhangi bir ücret talep edilmemektedir. Bu araştırmada yer almanız nedeniyle size hiçbir ödeme yapılmayacaktır. Kişisel bilgileriniz herhangi bir amaçla kurum yöneticileri veya üçüncü kişilerle paylaşılmayacaktır.

Katılımınız için teşekkür ederiz.

Sorumlu Araştırmacı: Dr. Öğr. Üyesi Şule Demirbaş

Yardımcı Araştırmacı: Fzt. Ramazan Kurtulmuş

"İzometrik egzersizlerin gecikmiş kas ağrısı üzerine etkisi" isimli çalışmada katılımcıya verilmesi gereken bilgileri okudum ve katılmam istenen çalışmanın kapsamını ve amacını gönüllü olarak üzerime düşen sorumlulukları tamamen anladım. **Çalışma, hakkında yazılı ve sözlü açıklamada adı belirtilen araştırmacı tarafından yapıldı.** Bu çalışmayı istediğim zaman herhangi bir neden belirtmek zorunda kalmadan bırakabileceğimi ve bıraktığım takdirde herhangi bir olumsuzluk ile karşılaşmayacağımı anladım.

Bu koşullarda söz konusu araştırmaya kendi isteğimle, hiçbir baskı ve zorlama olmaksızın katılmayı kabul ediyorum.

Gönüllünün Adı – Soyadı – İmzası – Tarih

Açıklama yapan kişinin Adı - Soyadı – İmzası – Tarih