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Ph.D. THESIS

THE DETERMINATION OF RELATIONSHIP BETWEEN KINESIOTAPING AND CONTRALATERAL FORCE IRRADIATION

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FOREWORD

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Explanation
Nm	: Newton-meter
mV	: milivolt
Hz	: Hertz
ms	: milisecond
mm	: milimeter

Abbreviation	Explanation
EMG	: Electromyography
%EMG$_{max}$	: Normalized contralateral muscle EMG signals
RMS	: Root Mean Square
KT	: Kinesiotaping
ACL	: Anterior Cruciate Ligament
OA	: Osteoarthritis
TMS	: Transcranial Magnetic Stimulation
ROM	: Range of motion
M-Wave	: Muscle action potential
fMRI	: Functional Magnetic Resonance Imaging
MEP	: Motor evoked potential
MRI	: Magnetic Resonance Imaging
MMG	: Mechanomyography
MIVC	: Maximum isometric voluntary contraction
BOLD	: Blood-oxygenated level dependent
MVC	: Maximum voluntary contraction

ÖZET

DOKTORA TEZİ

KİNEZYOLOJİK BANTLAMA VE KONTRALATERAL KUVVET YAYILIMI ARASINDAKİ İLİŞKİNİN BELİRLENMESİ

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Kuvvet yayılımı güçlü veya sağlıklı bir kasın uyarılması sonucunda kontralateral kaslarda bir aktivite oluşmasıdır. Kontralateral kuvvet yayılımı etkisi rehabilitasyonda yaralanmış tarafın kuvvet kaybını azaltma, ağrılı ekstremitede kas aktivitesini devam ettirme, inme gibi nörolojik hastalıkların tedavisinde, spor ve ortopedik yaralanmalarda mobilite ve kuvvetin arttırılması gibi birçok alanda kullanılmaktadır. Bu sebeple kontralateral kuvvet yayılımı etkisini arttırmak klinik açıdan önemlidir. Kinezyolojik bantlama, derinin yapısal özelliklerine ve esnekliğine benzer bir bant ile mekanoreseptörleri uyarmak suretiyle kasların fasilitasyonunu ve inhibisyonunu sağlayan bir metottur. Bu tez çalışmasında, kinezyolojik bantlamanın kuvvet yayılımı üzerindeki olası etkisinin araştırılması amaçlanmıştır. Bunu gerçekleştirmek için 40 katılımcı kontrol ve kinezyolojik bantlama grubu olarak iki gruba ayrıldı. KB sadece KB grubuna deneyden 24 saat önce uygulandı. Bütün katılımcılar dominant kol biceps brachii kasının izometrik, konsentrik ve eksentrik kontraksiyonlarını izokinetik dinamometre cihazında gerçekleştirdi. Bu dirsek hareketleri sırasında dominant olmayan kol biceps brachii ve triceps brachii kaslarından yüzeyel elektromyografik ölçümler kaydedildi. Dirsek eklem torkları da kayıt altına alındı. Dominant ve non-dominant dirsek tarafından üretilen torklar açısından iki grup arasında fark bulunmadı ($p>0.05$). Tüm kontraksiyon tipleri sırasında oluşan biceps brachii kas elektriksel aktivitesi KB grubunda kontrol grubuna göre yüksekti ($p<0.05$). Kontralateral triceps brachii kas aktivitesi ise KB grubunda kontrol grubuna göre sadece eksentrik kontraksiyon sırasında yüksek bulundu ($p<0.05$). Eksentrik kontraksiyon sırasında oluşan kontralateral biceps brachii kas aktivitesi izometrik ve konsentrik kontraksiyona göre

KB grubunda yüksekti ($p<0.05$). Kontrol grubunda ise kontraksiyon tipleri kontralateral biceps brachii kas aktivitesinde değişikliğe sebep olmadı ($p>0.05$). Her iki grupta da kontraksiyon tipleri kontralateral triceps brachii kas aktivitesini etkilemedi ($p>0.05$). Sonuç olarak, hareketsiz kola KB uygulamasının kontralateral kas aktivitesini arttırdığı tespit edilmiştir. Aralık 2018, 79 sayfa.

Anahtar kelimeler: Kuvvet yayılımı, kinezyolojik bantlama, kontralateral kas aktivitesi, elektromyografi sinyalleri

SUMMARY

Ph.D. THESIS

THE DETERMINATION OF RELATIONSHIP BETWEEN KINESIOTAPING AND CONTRALATERAL FORCE IRRADIATION

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The force irradiation is that the contraction of strong muscle generates an activation in the contralateral muscles. The effect of contralateral force irradiation is used to prevent muscle weakness in injured extremity, treatment of neurological disease such as stroke, to increase mobility and force in early rehabilitation of sport and orthopedic injuries. For this reason, it is important to promote the effect of contralateral force irradiation. Kinesiotaping is a taping technique that facilitates or inhibits the muscle activity via stimulation of mechanoreceptors with a tape which demonstrates elasticity and thickness resembling that of human skin. In the thesis, the electromyographical activity of the contralateral muscles was compared between force irradiation group and force irradiation with the kinesiotaping group. Forty healthy volunteers were equally divided into the control and KT groups. KT was applied on the non-dominant biceps brachii 24 hours before the experiment in the KT group. All participants performed unilateral isometric, concentric, and eccentric contractions of the biceps brachii with their dominant upper limbs by using an isokinetic dynamometer. During the elbow movements, muscle electrical activities of the biceps brachii and triceps brachii muscles in the non-dominant limbs were recorded by surface electromyography. Elbow joint torques in both limbs were also recorded. Maximum torques exerted by dominant and non-dominant limbs were not different between groups (p>0.05). Higher muscle electrical activity determined in the KT group than in the control group during all contraction types for biceps brachii muscle (p<0.05). Only eccentric contraction produce higher contralateral triceps brachii activity in KT group than control group (*p*<0.05). Eccentric contraction created higher contralateral biceps brachii muscle activity than isometric and concentric contractions in the KT group (*p*<0.05). In the control group, the contraction type did not affect the contralateral biceps brachii muscle activities (*p*>0.05). There were no differences contralateral triceps brachii activity in both groups (*p*>0.05). In conclusion, KT application on the contralateral limb increased the contralateral muscle activation.

December 2018, 79 pages.

Keywords: force irradiation, kinesiotaping, contralateral muscle activity, electromyography signals

1. INTRODUCTION

1.1. FORCE IRRADIATION

1.1.1. The Definition of Force Irradiation

Physiotherapy and rehabilitation professionals are interested in preventing strength loss and promoting the recovery process after injuries. Physiotherapy techniques are generally focused on injured limb, but the active movements can be harmful or impossible in some cases such as subjects with burns, fractures, arthritis, or neurological problems, etc. The cross-education, which provides augmentation in the contralateral limb strength after unilateral exercise program, can be useful in these cases (Scripture et al. 1894). The force irradiation is an underlying mechanism of cross-education (Moore 1975; Munn et al. 2004; Panzer et al. 2011; Urbin et al. 2015; Kofotolis and Kellis 2007). The stimulation of strong muscles creates an activation on the contralateral muscles, which is called force irradiation (Pink 1981). Another definition of force irradiation is that an involuntary contralateral muscle activity which occurs during a strong unilateral muscle contraction. In the literature, force irradiation is also referred to as associated activity (Howatson et al. 2013), motor irradiation (Hendy et al. 2012) or contralateral muscle activity (Shinohara et al. 2003), motor overflow (Addamo et al. 2009), unintended muscle activity (Watanabe et al. 2017), cross-effect (Veldman et al. 2015). The contralateral muscle activity can be revealed by using surface electromyography (EMG) during a unilateral contraction (Cernacek 1961).

1.1.1. Underlying Mechanisms

The contralateral muscle activity is based on two main phenomena: stabilization and central neural mechanisms (Hellebrandt 1951; Cernacek 1961; Pohja et al. 2002; Reuter-Lorenz and Stanczak 2000; Hoy et al. 2004). If the contralateral muscle is acting as a contralateral antagonist or agonist, the stabilization mechanism would be effective during unilateral movements. Postural readjustments involving the trunk musculature occur during the unilateral exercise against heavy resistance for stabilization of the body (Hellebrandt 1951). Furthermore, the studies suggest that most of the muscle activation in the contralateral extremity occurred in the stabilizer muscles (Panin 1961; Abreu et al. 2015).

The corticospinal tract comprises ipsilateral and contralateral pathways is the primary motor pathway which controls the extremity movement. In the human cortex, the right and left hemispheres are continuedly communicating through facilitatory and inhibitory pathways and the maintenance of interhemispheric balance is important for normal brain function (Chen 2004). It is evident that in the healthy human brain, there exists a strong interhemispheric interaction between the primary motor cortices with inhibitory influences being more prominent than facilitatory pathways (Fecteau et al. 2006). For example, during control of a selective voluntary contraction, the ipsilateral tracts are inhibited by the contralateral hemisphere. According to one of the central neural mechanism theories, involuntary movement in the member movement is a result of non-projective activation of the ipsilateral corticospinal pathway, more generally due to the decrease or absence of contralateral hemisphere inhibition (Reuter-Lorenz and Stanczak 2000). That theory called Ipsilateral Activation Theory can happen due to the fibers that cannot cross in the medulla spinalis (Pohja et al. 2002). The name of another central neural mechanism theory is the bilateral activation theory or the transcallosal facilitation theory, suggested that intended contractions from contralateral cortical activity may facilitate the ipsilateral hemisphere, and it produce force irradiation (Cernacek 1961). It is thought that at the end of the first facilitation is altered to an inhibition when the cortical activity associating with voluntary contraction augments. If this activity goes on to increase because of maximal voluntary movement, secondary facilitation appears to be changed with inhibition (Muellbacher et al. 2000; Hoy et al. 2004; Meyer et al. 1995). Therefore, this theory modified to recommend that cross-effect could occur because of weak transcallosal inhibition, decreased inhibition or enhanced facilitation after the first excitation (Hoy et al. 2004).

The contralateral muscle activity does not arise directly from the contralateral motor cortex in the healthy subjects because the proof for an active ipsilateral tract or alternative pyramidal tract branches are just discovered in patients with neurological diseases (Reitz and Müller 1998). Additionally, although proof of cross-effects found at the segmental level, these are mostly inhibitory in nature, facilitatory interactions at the segmental level are not so expectable (Hortobágyi et al. 2003). Furthermore, a study presented that the ipsilateral motor cortex has a role in cross-effect in healthy subjects (Zijdewind et al. 2006a). The central neural mechanism related to cross-effect would be generally predominant if the muscle produces greater activation when the role of muscle is a contralateral agonist than a contralateral antagonist (Figure 1.1).

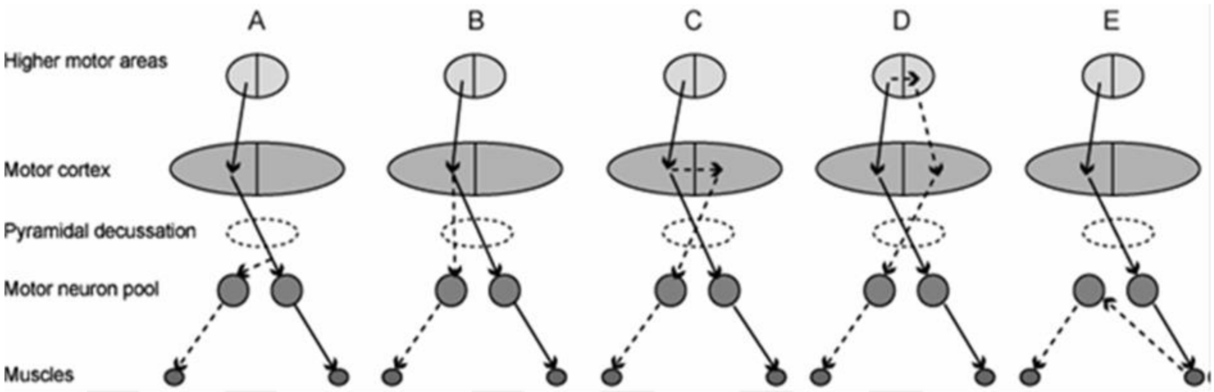

Figure 1.1: The central neural pathways theories for force irradiation. (A) Motor commands can follow the way from the contralateral motor cortex to the bilateral motoneuron pools go over the normal pyramidal tract or (B) on an active ipsilateral tract. (C) Another hypothesis is that the ipsilateral motor cortex creates a copy of the motor command by using neuronal links on the motor cortices or (D) via bilateral input which originated from higher motor centers synchronously affect bilateral motor cortices. (E) Additionally, motor commands could cross over via transfer of afferent feedback from the active limb. (Zijdewind et al., 2006; Carson, 2005; Hoy et al., 2004)

1.1.2. The Factors Affect Force Irradiation

The amount of force irradiation is affected by internal and external inputs. It is enhanced during strong or fatiguing contractions and can produce a movement or muscle activation in the contralateral limb. The contralateral activity occurring during such contractions could be owing to an enhancement in neuronal drive required to perform a strong contraction or a prolonged contraction during an increased level of muscular fatigue (Zijdewind and Kernell 2001; Zijdewind et al. 1998; Shinohara et al. 2003). Nevertheless, other factors such as suppression of facilitation or inhibition of cortical excitability may affect the force irradiation. If the neural drive is approximately at the maximum level during contraction, the cross-effect would increase (Zijdewind and Kernell 2001; Dimitrijevic et al. 1992; Zijdewind et al. 1998; Aranyi and Rosler 2002). Thus, studies showed that motor irradiation was higher during maximum voluntary contraction (MVC) than submaximal contractions (Abreu et al. 2015). It is suggested that alterations in the central nervous system such as the rate of motor unit recruitment underlie the alterations in contralateral activity.

Contraction types also affect the amount of contralateral activity. A study revealed that the contralateral EMG activation was greater during isometric contraction compared to isotonics (Shinohara et al. 2003). Furthermore, concentric contractions produced less contralateral activity than eccentric contractions. During cross education, strengthening was faster in eccentric than concentric exercise programme. The amount of strength gain resulted from the cross-education is as below;

- The concentric and isometric strength gains are 30% and 22% following a concentric exercise training, respectively.

- The eccentric and isometric strength gains are 77% and 39% following an eccentric exercise programme, respectively (Hortobagyi et al. 1997).

Different types of contralateral activity were presented during unilateral exercise (Duque et al. 2005; Muellbacher et al. 2000; Post et al. 2009; Uematsu et al. 2010). Interhemispheric asymmetries in the ability for the ipsilateral cortex to control the unilateral motor activity were presented. The left hemisphere mostly obtained higher effect in controlling the left hand than does the right hemisphere in controlling the right hand for the subjects with right-hand dominancy (Verstynen et al. 2005; Kawashima et al. 1993; Fadiga et al. 1999). The unilateral exercise programmes provide the greatest gains when the right limb is active limb (Farthing et al. 2005). Although, the greater effect of dominant limb on force irradiation has been reported for the upper limbs, not for the lower limbs. The results of the study may be associated with the leg muscles which are used bilaterally in reciprocal movements (Chiou et al. 2013).

Cross-effect is affected by the changes in the neuronal drive to the muscle. Thus, the researchers have been investigated the effect of sex on cross-over. A higher cross-effect have determined in men compared to women (Martin and Rattey 2007).

Older adults have greater contralateral activity compared to younger (Bodwell et al. 2003). The greater unintended contralateral activity also related with reduction of interhemispheric inhibition ability. The aging changes neuroanatomical structures and functions and causes to a decreased ability to depress contralateral activation during unilateral tasks (Shinohara et al.

2003; Reissig et al. 2015; Addamo et al. 2009). Furthermore, children produce greater contralateral activity compare to adults (Addamo et al. 2009).

One of the factors affecting the amount of force irradiation is the direction of the target movement. If the resting and active limbs are in the same position, the unintended muscle activity is observed in homologous muscle, but if the directions of active and resting limbs are asymmetrical, the muscle activity is mainly determined by another muscle in resting limb (Post et al. 2009). During three-dimensional movements, the contralateral activity is also produced by different muscles in the active limb (Abreu et al. 2015).

For the diseases with pain, the cross-education may be a treatment option. The pain in the resting limb does not alter the level of the contralateral muscle activity (Røe et al. 2000).

Cross-effect may be observed without an active muscle contraction in one limb. For example, electrical stimulation of a limb improves the contralateral activity of muscles (Toca-Herrera et al. 2008; Song et al. 2012; Cattagni et al. 2018). Additionally, unilateral somatosensory electrical stimulation also produces a cross-effect (Veldman et al. 2015). Visual feedback of active limb promotes the contralateral muscle activity/strength compared to the unilateral exercise training without visual feedback (Zult et al. 2015). Unilateral vibration training improves contralateral performance (Marín et al. 2014). Enhancement of cross-effect after these kinds of techniques are attributed to the changes in neural modifications.

1.1.3. Cross-effect in rehabilitation

The rationale behind the unilateral exercise training or cross-education is based on the cross-effect. It is generally applied in conditions characterized by unilateral neuronal and musculoskeletal deficits such as fracture, stroke, and ligament injuries. Cross-education is a pain- and range-free unload method and suitable for both lower and upper extremities which make this technique applicable for different rehabilitation processes.

1.1.3.1.Cross-effect on upper extremity injuries

Millions of people experience different types of upper extremity traumas and wholly or partially loss hand usage. Immobilization is required for many of these patients for a certain period. Immobilization causes deficits in muscle and neuro-motor pathways, and the therapy does not start until the end of the immobilization period. Under these conditions, cross-education is a useful method to maintain muscle strength and promote healing. Magnus et al. showed that unilateral exercise of non-fractured extremity improved strength and range of motion (ROM) in the fractured extremity after 12 weeks at the post-fracture period (Magnus et al. 2013). The healing process was faster in subjects who performed the unilateral exercises. Another study presented that unilateral hand training with uninjured hand influenced the functional performance of injured limb after an immobilization period (Troianello et al. 2017). An experimental study suggested that strength programs in the contralateral extremity improved the muscle size and strength of the immobilized extremity in healthy subjects after a period of immobilization (Magnus et al. 2010).

1.1.3.2.Cross-effect on lower extremity injuries

The basis of lower extremity diseases may be either trauma or musculoskeletal and degenerative problems. One of the most common traumatic lower extremity injury is the anterior cruciate ligament (ACL) injuries (Murphy et al. 2003). Early rehabilitation of ACL surgery includes protecting the graft and resting period (Majima et al. 2002). Furthermore, loss of the quadriceps strength is an important problem in this condition. Papandreou et al. focused on the quadriceps strength after ACL surgery (Papandreou et al. 2007; Papandreou et al. 2013). They revealed that unilateral eccentric training promoted the healing of the quadriceps strength weakness in the early rehabilitation period (Papandreou et al. 2013). Unilateral eccentric exercise training at different angles provided similar effects after early ACL rehabilitation (Papandreou et al. 2007). Furthermore, the impact of the concentric and eccentric unilateral exercise training on the quadriceps strength is not different in the early period of ACL rehabilitation (Harput et al. 2018). Even though, there is no superiority between only standard rehabilitation and standard rehabilitation with cross-exercise at long-term rehabilitation outcomes (Zult et al. 2018).

Knee osteoarthritis (OA), which is characterized by progressive joint degeneration, caused knee extensor muscles weakness. Reducing the loading on the osteoarthritic knee is a part of the treatment. Resting and weakness are creating a vicious circle in the rehabilitation interventions for the patients with OA. Studies showed that cross-training improved quadriceps strength and lower extremity functions among OA patients without the aggravation of knee degeneration (Onigbinde et al. 2017; Bowen et al. 2014).

Stretching or releasing the muscle affect the contralateral muscle performance in the lower extremity. The jump height and impulse decreased after unilateral static stretching to calf muscle on the non-stretched limb (da Silva et al. 2015). Additionally, unilateral dynamic and static hamstring stretching augment ROM of the contralateral hip (Chaouachi et al. 2017). Foam roller technique, a muscle release method, also shows ipsilateral and contralateral effects on the ROM of the ankle joint (Kelly and Beardsley 2016; Garcia-Gutierrez et al. 2018).

1.1.3.3.Cross-effect on Pain

Pain restricts movements reduces muscle activation and chronically causes strength loss. Unilateral exercise training can be a treatment option to promote healing. The pain and muscle activity have a controversy relation, but studies showed that pain does not change the amount of contralateral activity (Røe et al. 2000). Although a few studies is investigating the influences of unilateral training on pain, cross-education can have a significant impact on ipsilateral muscle activation, strength and ROM in the limb with pain (Fermin et al. 2018).

1.1.3.4.Cross-effect on rehabilitation of stroke

Hemiparesis following stroke causes disabilities related to locomotion and arm functions, which negatively affect the ability to perform daily activities (Adamson et al. 2004). Limited rehabilitation strategies are available to accelerate the healing of motor functions following stroke. Cross-education is one of the treatment options for hemiparesis. One-side limbs are called affected side, and the other side is less affected side. The studies focused on either upper extremity (Sun et al. 2018; Urbin et al. 2015) or lower extremity motor functions (Dragert and Zehr 2013).

Unilateral strength exercise increased force-generation capability and muscle activation of affected wrist extensor muscles after stroke (Urbin et al. 2015). Cross-training is clinically useful to reduce the impairments and improve the motor functions of the upper extremity in severe stroke (Sun et al. 2018). The ankle dorsiflexion torque may augment by 31%, and the muscle activation may increase by 20% in the chronic stroke patients after cross-education treatment (Dragert and Zehr 2013). Additionally, clinicians interpret that cross education is beneficial for stroke patients with severe impairments in arm strength, while it is not the main rehabilitation method but a complementary approach (Russell et al. 2017). A recent review also presented that unilateral exercise training had an effect on muscle strength but more randomized controlled studies are needed (Ehrensberger et al. 2016).

1.1.4. Instruments to Analyzing Cross-Effect

1.1.4.1.Electromyography

The muscle produces the myoelectric potentials during a contraction. EMG is an assessment method to determine the magnitude of this electrical activity of muscle. The surface EMG signal is obtained via surface electrodes which are put on the muscle belly. The EMG signals with high magnitude show that the high number of motor units are firing (Lippold 1952). The level of EMG signals is usually correlated with the level of muscle forces (Edwards and Lippold 1956). The contralateral EMG activity is first described by Cernacek (Cernacek, 1961). The contralateral muscle activation is considered the alterations between the baseline and the muscle activation of contralateral agonist muscle during unilateral contractions (Panzer et al. 2011). In some studies, normalized EMG signals by maximum isometric voluntary contraction (MIVC) is considered as the level of contralateral muscle activation (Røe et al. 2000; Abreu et al. 2015). In the literature, time domain EMG analysis is mostly performed for illustrating the contralateral muscle activity (Shinohara et al. 2003; Abreu et al. 2015).

1.1.4.2.Transcranial magnetic stimulation

Activity in the motor cortex may assess by using a noninvasive technique via stimulating neurons in the brain (Ridding and Rothwell 2007). It is named as transcranial magnetic stimulation (TMS). A special coil is placed over the scalp and generates short magnetic pulses. The coil transmits the magnetic pulses to the scalp, and electromagnetic induction creates a current flow in the tissue. Then, the flows cause a depolarization on the membrane of the cortical neurons and facilitate the excitations of the neurons. The short-latency responses related with TMS stimulation over the motor cortex produce muscular electrical activity (Tokimura et al. 2000). This is named motor evoked potential (MEP). The MEP represents the excitability of the cortico-motor neurons, and the alterations in motor cortex excitability can be examined during various motor activities (McNeil et al. 2009). It is also used for evaluation of the inhibition. The silent period is referred the duration of EMG silence which appear just after a voluntary contraction (Taylor and Gandevia 2001). The first 100 ms of silence is likely about the decreased excitability of spinal motor neurons in the refractory period and the later silent period presents intracortical inhibition. Additionally, intracortical or interhemispheric interactions are investigated by using paired pulse TMS. In this technique, TMS induces a condition stimulus to the motor cortex, and a test pulse is given to the contralateral or ipsilateral motor cortex after a few ms later. MEP decrease or facilitate according to the interstimulus intervals the between pulses, it means that inhibition or excitation respectively (Chen 2004; Taylor and Gandevia 2001).

1.1.4.3.Electrical stimulation

Several motor functions can be assessed by using electrical stimulation in central and peripheral nervous systems. Electrical stimulation of the nerve shows composite muscle action potentials (M-Waves). The area and amplitude of the M-Wave reveal the efficiency of neuromuscular transmission and impulse facilitation in muscular fibers and can represent alterations in the muscles during fatigue (Hicks et al. 1989). Electrical stimulation of the muscle or nerve may present the efficiency of the voluntary drive from the central nervous system to the muscle via twitch interpolation technique (Allen et al. 1995). The nerve or muscle can be stimulated during MVC in this technique. When the stimulation produces an augmentation in force, a real maximal contraction is not created via the neural drive. It is generally used to investigate the origin of contralateral activity changes in the voluntary drive during electrical stimulation.

1.1.4.4.Functional Magnetic Resonance Imaging

The oxygenated blood increment is assumed an increase in neural activity in a brain area. Enhancement of oxyhemoglobin in the blood related to activity results in a relative decrease in deoxyhemoglobin which changes magnetic resonance imaging (MRI) signals because of paramagnetic property. Functional magnetic resonance imaging (fMRI) detects these changes and shows a map which refers to brain activity during a targeted task. The alteration in MRI is attributed to as the blood-oxygenated-level dependent (BOLD) reaction. The BOLD response does not give information about the firing patterns of the active neurons; it is related to the potential of a specific area (Logothetis et al. 2002). A promotion in BOLD response is interpreted as an increment in the input relate with this area. The fMRI findings showed that unilateral task is not just related with the contralateral motor area activity, also with co-activity of the ipsilateral motor area. (Kim et al. 1993; Stippich et al. 2007).

1.1.4.5.Mechanomyography

The mechanical properties of muscular function during contraction can be assessed by using Mechanomyography (MMG) (McKay et al. 2006). It supposes as the intrinsic mechanical equivalent to the electrical activity signal of the motor unit which obtained over the skin, such as EMG method but the advantage of MMG is that the changes in the sensor-skin interface do not affect MMG signals (Jaskolska et al. 2004). Additionally, alterations of muscle stiffness, temperature, intramuscular pressure, mass, the viscous characteristics of the extracellular and intracellular fluid, or the firing ratio of the motor units may affect the MMG signal (Orizio and Gobbo 2006). Additionally, the frequency component of the MMG signal represents about the motor unit firing rates, but not about the motor unit recruitment/decruitment (Akataki et al. 2001; Beck et al. 2007). In the literature, there is a few studies have focused on contralateral muscle activity using MMG (McKay et al. 2006; Toca-Herrera et al. 2008; Ebersole et al. 2002; Wages et al. 2016). The contralateral effect of one-session unilateral electrical stimulation has been investigated, and no change was observed on the MMG signals. However, EMG signals and torques increased compared to those recorded in the pre-intervention session (Toca-Herrera et al. 2008).

1.2.KINESIOTAPING

1.2.1. Definition of Kinesiotaping

Kinesiotaping (KT) is a relatively new form of therapeutic taping, using a novel kind of elastic therapeutic tape. Dr. Kenzo Kase developed tape and taping method in 1973, and the technique and tape are still evolving (Kase et al. 2003). It has become popular at the Beijing 2008 Olympics. KT differs from classic, non-elastic tape. Kinesiotape has a wider treatment approach than just the stabilizing and immobilizing of joints (Kumbrink 2012). The non-elastic taping has some disadvantages such as limited joint movements and functions. Some non-elastic taping techniques cause to delay healing because of their compressive effect (Celiker et al. 2011). The adhesive side of the tape has a sinusoidal waveform which allows the tape to be stretched longitudinally by 40-60% from resting length. The forces are distributed horizontally and vertically, allowing for the lifting of the skin or underlying tissue. The thickness and weight of the tape are similar to the epidermis of the skin. The elastic characteristics of the tape may affect skin, fascia, muscle, and joint lymphatic and circulatory systems, depending on the type of the application.

1.2.2. Indications and contraindications

Indications of KT technique are wide-range. The main indications about the musculoskeletal and neural system are as below;

- Biomechanical problems of the spine
- Soft tissue problems
- Myofascial pain syndrome
- Muscle spasms
- Soft tissue traumas in the musculoskeletal system
- Sports injuries
- Sprains
- Posture problems
- Joint instability
- Scoliosis
- Post-operative rehabilitation of orthopedic surgery
- Degenerative arthritis
- Tendinitis and bursitis
- Plantar fasciitis
- Muscle weakness related with immobilization
- Foot deformities

- To support the muscle and joints
- Thoracic outlet syndrome
- Neuralgia
- Peripheric nerve injuries
- Brachial plexus lesions
- Cerebrovascular accident
- Multiple sclerosis
- Central nerve injuries
- Cerebral palsy
- Spina bifida etc. (Yoshida and Kahanov 2007; Kaya et al. 2011; Jaraczewska and Long 2006; Karabay et al. 2016; Walsh 2010; Cortesi et al. 2011; Anandkumar et al. 2014; Tamburella et al. 2014)

There are currently no known side effects of KT. Though, the following contraindications should be considered (Kumbrink 2012)

- Open wounds
- Scars which have not healed
- Skin diseases, for example, neurodermatitis or psoriasis
- Pregnancy (relative contraindication)
- Known allergies to acrylic material
- Active infections
- Malignity
- Serious cardiac problems

- Radiotherapy site

1.2.3. Underlying Mechanism

Kinesiotape is applied directly to the skin to get the therapeutic effects. The tape is stretched or unstretched and cut into "I", "Y", "X", "web", "donut" or fan shapes depending on the desired effect or the size of the affected muscle (Kase et al. 2003) (Figure 1.2). The basic principles of selection of strip types are as below;

Figure 1.2: The some of the strip types of kinesiotape: "I", "Y", "X" and the fan shape tapes.

- "I" shape: It can be used for an injured muscle at acute phase in place of "Y" strip to limit edema and pain.

-"Y" shape: It is used for surrounding a muscle to either facilitate or inhibit muscle stimuli. The tape is wrapped around the weakened muscle. The "Y" strip should be approximately five centimeters longer than the muscle measured from origin to insertion.

- "X" shape: When origin and insertion of a muscle may differ according to the motion of the joint, "X" strip is used.

- The fan shape: It is used for lymphatic drainage.

- The web shape: It is a modified fan cut.

- The donut shape: It is used for edema in a focal or sport-specific area.

The base strip is placed without any stretch 2 cm below the area to be treated. The corners of the tape should be rounded to prevent premature loosening of the tape. The rounded corners allow the longitudinal forces to be redistributed around the corners.

The application method of the tape determines according to the problem to be treated. Corrective application techniques are as below (Kase et al. 2003)

- Mechanical correction: The technique creates a recoil under the skin which provides a positional stimulus. 25-75% of the available tension of the tape was generally used.

- Fascia correction: Fascia correction technique has a holding effect to influence the alignment of the fascia and is applied with a light to moderate 15-50% of the available tension of the tape.

- Space correction: The technique provides a lifting effect of increasing the space above the pain area and inflammation, swelling or edema. Space correction generally uses light to moderate 25-50% of available tension.

- Ligament and tendon correction: This technique stimulates mechanoreceptors over the area via the pressure effect. Kinesiotape usually is stretched 50-75+% or 25-75+% available tension.

- Functional correction or spring: It is used to limit or assist a movement of joints via sensory stimulation. The tension rate of kinesiotape is approximately 50-75+%.

- Lymphatic correction or channeling: A space like a channel under the tape area is occurred to direct the exudate to the closest lymph duct. The kinesiotape tension is approximately 10-25% of available tension.

There are two main mechanisms of action for KT;

1. The application method lifting the skin decreases the pressure over the area of interest. Reduction of pressure in the treatment area inhibits the stimulation of chemical receptors, decreases inflammation and thus reduces pain. The taping methods also increase peripheral circulation and activation of the mechanoreceptors and the gate control theory so that pain perception is reduced (Kase et al. 2003). Furthermore, the lifting effect, which provides a larger space between the skin and the muscle and interstitial space, induces blood and lymphatic fluid circulation (Halseth et al. 2004; Yoshida and Kahanov 2007; Akbas et al. 2011)

2. Kinesiotape is applied directly to the skin. The functions of the skin are sensory perception, immunity, thermoregulation, and homeostasis of water balance (Amirlak et al. 2013). The sensory system of the skin provides information from the internal and external environment as a part of homeostatic feedback control of the body (Kibble and Halsey 2009). Taping could affect the muscle tone as well as muscle control. The application of the tape activates skin receptors and proprioceptors. Tone regulation is reinforced, and information with regards to the position in space and muscle effort is relayed (Kumbrink 2012) (Figure 1.3).

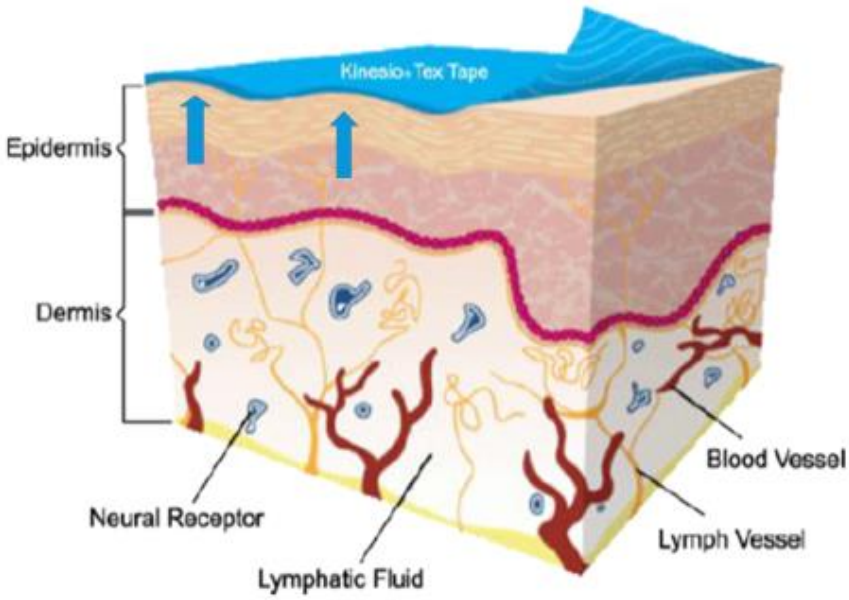

Figure 1.3: Mechanism of action of KT (Kase et al. 2003).

1.2.4. Kinesiotaping in rehabilitation

The studies about KT focused on especially sports injuries and pain at the beginning (Kase et al. 2003). Nowadays, KT is frequently used in rehabilitation centers.

1.2.4.1. Effect of Kinesiotaping on Muscle Strength

KT frequently is applied to promote muscle force, but the studies are insufficient. Slupik et al. presented that KT increases the electrical activation of the vastus medialis muscle, the most efficient application time is 24 hours after KT (Slupik et al. 2007). Adversely, the KT applied to the trapezius muscle decreased the H-reflex (Alexander et al. 2003). The researchers also showed the inhibition effect in the gastrocnemius and soleus muscles (Halseth et al. 2004) but, it is not certain that the level of muscle electrical activity shows muscle strength.

Fu et al. reported that the eccentric and concentric strengths of the quadriceps and hamstring did not change 24 hours after the KT application among healthy adults (Fu et al. 2008). However, Aktas et al. presented that the isokinetic quadriceps strength increased following KT (Akbas et al. 2011). Chang et al. revealed that KT did not influence hand grip strength immediately after KT application (Chang et al. 2010).

1.2.4.2. Effect of Kinesiotaping on Proprioception

The researchers claim that KT promotes proprioception via cutaneous receptors (Kase et al. 2006; Chang et al. 2010; Lin et al. 2011). Halseth et al. presented that KT did not have an impact on the ankle joint position sense in healthy volunteers (Halseth et al. 2004). However, KT was successfully applied in sensing the knee joint position compared to the non-elastic taping (Chen and Lou 2008). It was revealed that KT influenced the proprioception of hand and shoulder (Lin et al. 2011; Chang et al. 2010).

1.2.4.3. Effect of Kinesiotaping on Lower Extremity

KT, placebo taping, or stretching treatments have been applied to individuals with plantar heel pain. KT was found superior compared to the other treatment options on pain relieving (Hyland et al. 2006). KT did not affect the performance of lower extremity after six weeks in patients with patellofemoral pain syndrome, which is a very common knee complaint (Akbas et al. 2011; Tunay et al. 2008).

After stroke, the weakness of lower extremity muscles impairs the gait and mobility functions. KT is a complementary alternative to the conservative treatment. Kilbreath et al. determined that KT promote the strength of the gluteus maximus muscle and improved gait patterns (Kilbreath et al. 2006). Furthermore, KT applying on the ankle was found to be useful to improve balance parameters in multiple sclerosis (Cortesi et al. 2011).

1.2.4.4. Effect of Kinesiotaping on Upper Extremity

Subacromial impingement syndrome especially causes pain during overhead activities. KT is applied to decrease edema and pain, to increase ROM and myoelectrical activity (Kase et al.

2003; Hsu et al. 2009; Kaya et al. 2011). Kaya et al. compared two approaches: KT and physical therapy modalities in subacromial impingement syndrome. KT decreased pain more than physical therapy modalities after the first week of treatment. At the end of the second week, they did not find differences between the two interventions. They claimed that KT stimulated neuromuscular pathways via afferent feedback, thus the gate-control theory is validated (Kaya et al. 2011). Another study revealed that there were not any differences at shoulder pain and disability score after placebo taping or KT among subjects with subacromial impingement syndrome or rotator cuff tendinitis. Only abduction movement restriction was decreased with KT application compared to the placebo taping (Thelen et al. 2008). However, Hsu et al. presented that KT influenced the scapulohumeral rhythm via proprioceptive feedback in subacromial impingement syndrome (Hsu et al. 2009). There is no scientific evidence about the effectiveness of KT in other shoulder diseases such as instability, bursitis, bicipital tendinitis, etc.

Epicondylitis is a frequently diagnosed upper extremity disease, especially women at the age of 40-60 years (Shiri and Viikari-Juntura 2011). KT is applied to reduce edema and pain in lateral and medial epicondylitis. Liu et al. presented that muscle technique of KT decreased the motion of extensor carpi radialis after 24 hours (Liu et al. 2007).

Upper extremity activity after stroke decreases due to the weakness and spasticity of muscles. Different KT applications were developed for upper extremity functions in stroke patients (Jaraczewska and Long 2006). KT taping was also used in patients with brachial plexus injuries, but the scientific evidence is insufficient (Walsh 2010).

1.3.PURPOSES

Force irradiation and kinesiotaping are different treatment approaches which are generally used for similar purposes such as weakness of a muscle. The studies showed that the effect of force irradiation is modest (Munn et al. 2004; Abreu et al. 2015), but the contralateral exercises are extensively used in clinics to prevent muscle weakness in injured extremity, to treat the neurological disease such as stroke, increase mobility and strength in early rehabilitation of sport and orthopedic injuries (Papandreou et al., 2013, Urbin et al., 2015). Therefore, enhancing the effect of force irradiation on the contralateral muscle activity may enable important clinical outcomes. In this respect, the first aim of the thesis is to detect the effects of KT on the contralateral agonist and antagonist muscle activation. The second aim of the thesis is to determine the differences among isometric, concentric and eccentric contractions on the contralateral agonist and antagonist muscle activation.

It is well known that contralateral targeted muscle has greater muscular activity during maximum voluntary contraction than submaximal voluntary contraction (Abreu et al. 2015). The joint torques level of exercising limb are also evaluated and revealed the effect of joint torques on contralateral muscle activity.

As a summary, there are two main purposes of this thesis;

1) to investigate the force irradiation effect of the KT on the contralateral agonist and antagonist muscle activity.

2) to reveal the differences in contralateral agonist and antagonist muscle activity during isometric, concentric and eccentric contractions under KT and non-KT conditions.

2. MATERIALS AND METHODS

2.1.PARTICIPANTS

Forty healthy volunteers (mean±standard deviation 22.22±1.84 year) with any history of neurological diseases or recent musculoskeletal injury participated to the study. Only right-handed-dominant individuals were selected by asking them what hand they use to write. All subjects had a normal or corrected vision and any history of strength training. Subjects were asked to avoid from exercise, alcohol, or any form of central nervous system depressant or stimulant for at least 6 hours before testing. Written informed consent was provided before the experiment. The study procedures were approved by the Bezmialem University Human Research Ethics Committee and experiments were done in accordance with the Declaration of Helsinki. The study was registered to ClinicalTrial.Gov website with the registration number of NCT03470714.

2.2.PROCEDURE

Prior to experimental testing, the subjects were randomly divided into two groups as the control (12 females, 8 males) and KT (14 females, 6 males) groups.

KT was applied to non-dominant biceps brachii muscle from origin to insertion by “X” taping method according to Kenzo Kase for only KT group (Kase et al. 2006). The length of the applied kinesiotape was determined from the supraglenoid tubercle and coracoid process to the proximal third of supinated forearm with the elbow positioned in 30°-45° flexion. First, the medial tail of the tape was anchored on the coracoid process and was applied paper-off tension encircling the biceps toward the antecubital crease with the forearm in a supinated position. The lateral tail of the tape was anchored on the supraglenoid tubercle and was applied paper-off tension surrounding the biceps toward the antecubital crease. The middle portion of the tape was applied paper-off tension over the antecubital area during the elbow in 30°-45° flexion position. The lateral and medial tails of the distal “X” were applied at the proximal third of the forearm on radius and ulna with the forearm supinated and elbow in flexion (Figure 2.1). After 24 hours the taping, the subjects attended to the experimental protocol, which was also followed by the control group.

Figure 2.1: KT application.

The experiments began with MIVC of the left triceps brachii and biceps brachii muscles for normalizing the contralateral muscle's EMG signals (Figure 2.2). The contralateral muscle's EMG signals were collected from left biceps brachii and triceps brachii muscles by using Nihon Kohden EMG machine model 9400 (Japan) (Figure 2.3) during right elbow flexion contractions. These values were presented as the percentage of the MIVC multiplied by 100 (referred to as $\%EMG_{max}$). The outcomes of the study were defined as the $\%EMG_{max}$ for each muscle. All muscle contractions were practiced by using Cybex isokinetic dynamometer (Humac Norm, Cybex CSMI, Stoughton, MA, USA.) (Figure 2.4). After a warm-up, subjects performed elbow flexion at an angular velocity of 60°/s for concentric contractions, 30°/s for eccentric contractions, at 90° elbow flexion position for isometric contractions with a maximal voluntary contraction level in supine position. The sequence of contractions types was determined randomly for each subject.

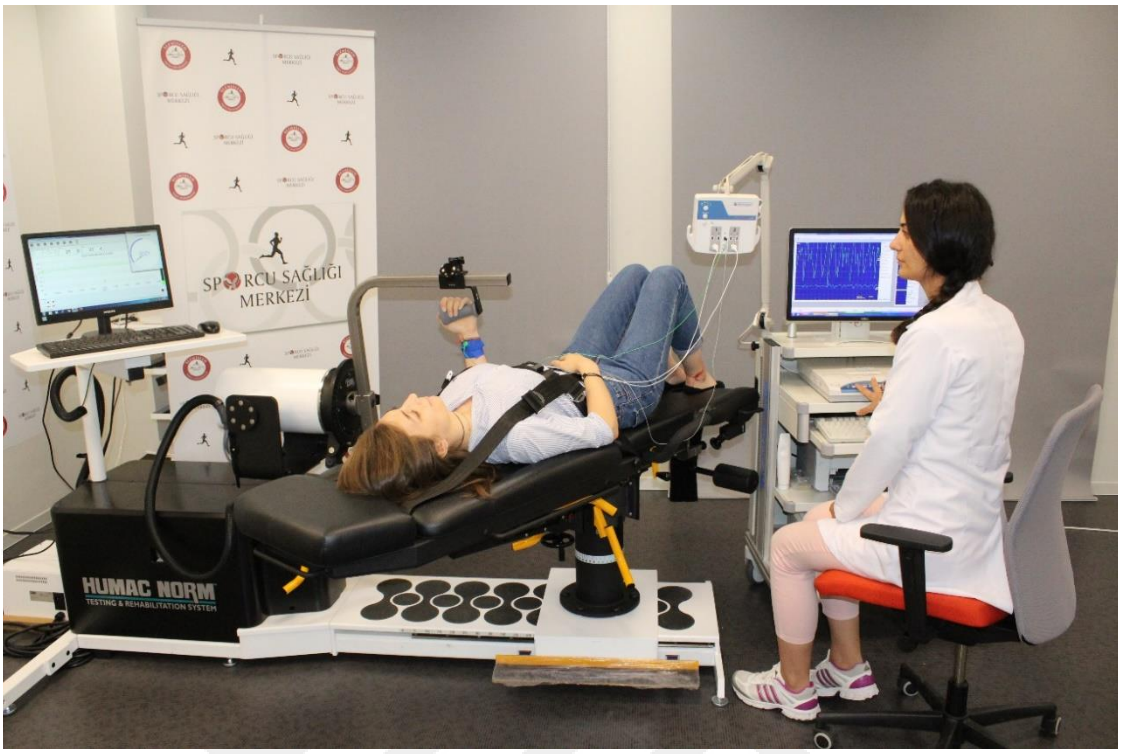

Figure 2.2: The gathering of maximum isometric voluntary contraction EMG of the left arm biceps and triceps brachii muscles.

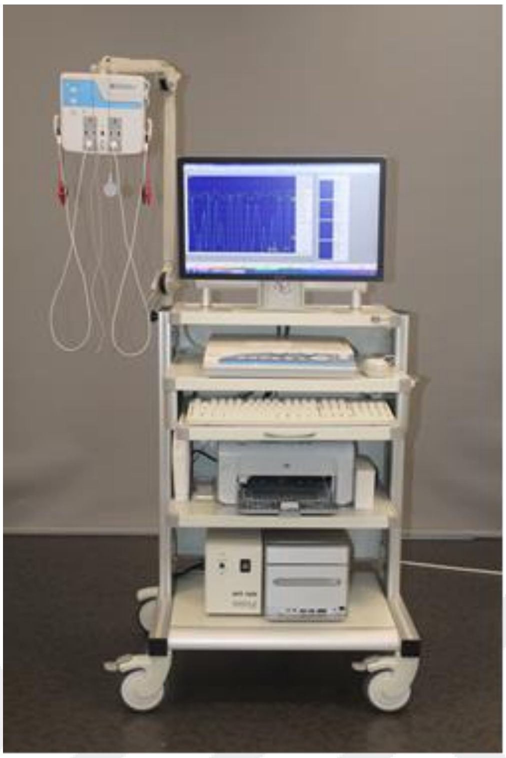

Figure 2.3: Nihon Kohden 9400 EMG Machine.

Figure 2.4: Humac Norm, Cybex CSMI Machine.

After each contraction, subjects had a one-minute resting period to prevent the occurrence of fatigue. During these contractions, the resting arm (left arm) position was near the body, with the forearm was supinated and the wrist was in neutral position (Figure 2.5). The EMG electrodes were placed on the middle of the left arm biceps brachii, and triceps brachii muscle belly (the resting arm), parallel to the direction of muscle fibers, and electrodes were fixed with adhesive tape (Hermens et al. 1999). Before the placement, the cell debris was removed, and the skin was cleaned with 70% of ethyl alcohol. Then a special conducting gel was applied. Ag/AgCl disk electrodes with 10 mm diameter were used for EMG recordings. The sampling frequency of the signals was 2000 Hz. A bandpass filter with 20 Hz lower and 450 Hz upper cut-off frequencies was performed. Bipolar configuration with 20 mm of inter-electrode distance was adopted. The reference electrode was put on the wrist.

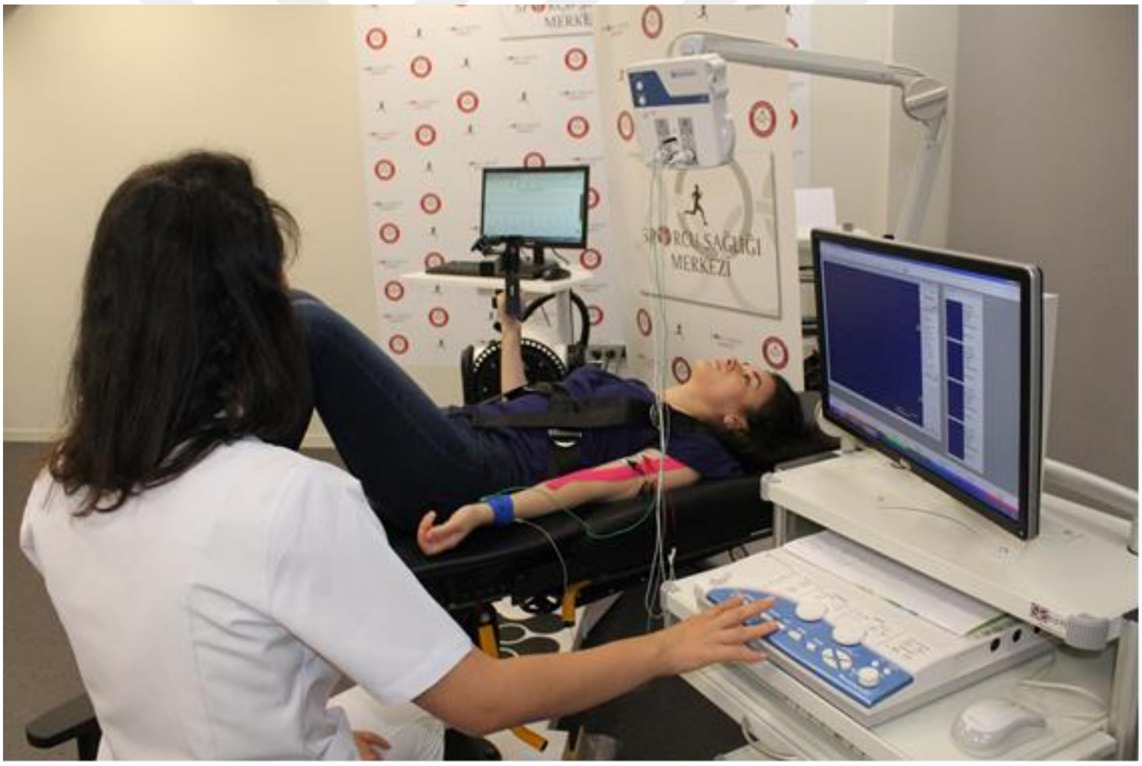

Figure 2.5: The experimental design.

2.3.DATA PROCESSING

The central 3 s, 2 s, and 2 s signals were extracted from each trial of the isometric, concentric, and eccentric contractions, respectively, for analyses. First, raw EMG signals were filtered (6th Butterworth bandpass filter ranged between 50-450 Hz) and full-wave rectified. Then, the signals were segmented via sliding windows having 200 ms time interval. The time interval between the successive windows was defined as 25 ms (Chen et al. 2013). Root mean square (RMS) value was calculated for each segmented window, and the average of the RMS values was calculated for the entire signal. Average RMS values obtained from each subject were normalized to the maximum value found in the processed EMG of the MIVC tests. By doing so, muscle activations of the biceps brachii were expressed as a percentage of the MIVC, which was referred to as $\%EMG_{max}$ (Figure 2.6-2.14).

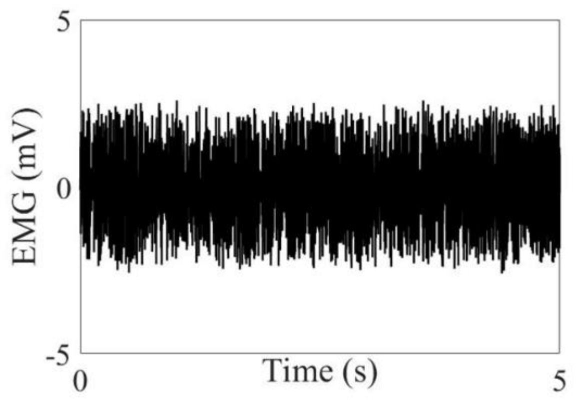

Figure 2.6: Raw EMG signal of non-dominant biceps brachii muscle during MIVC.

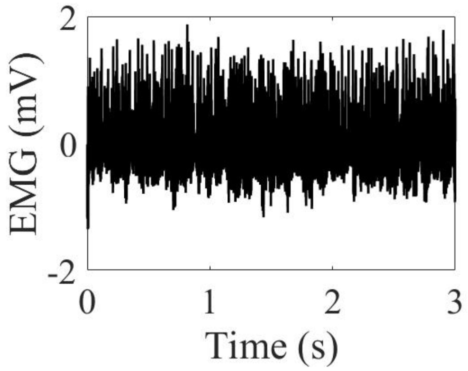

Figure 2.7: Detrended EMG signal of non-dominant biceps brachii muscle during MIVC.

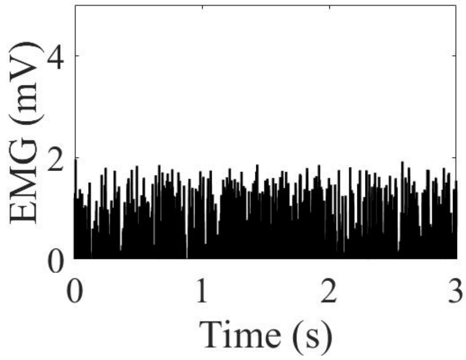

Figure 2.8: EMG signal of non-dominant biceps brachii muscle during MIVC that full-wave rectified and filtered with Butterworth band pass filter.

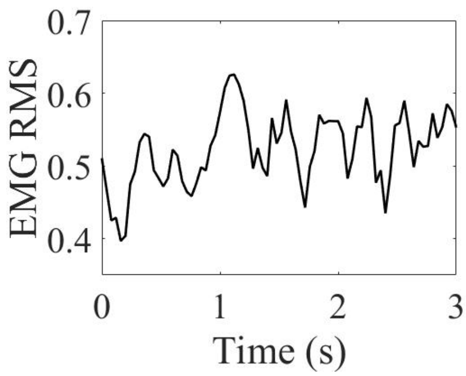

Figure 2.9: EMG signal of non-dominant biceps brachii muscle during MIVC after calculation of RMS.

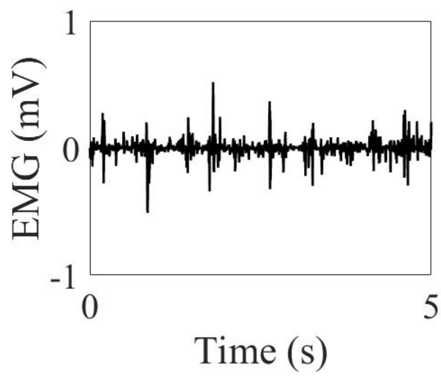

Figure 2.10: Contralateral raw EMG signal of non-dominant biceps brachii muscle during isometric muscle contractions of the dominant biceps brachii muscle

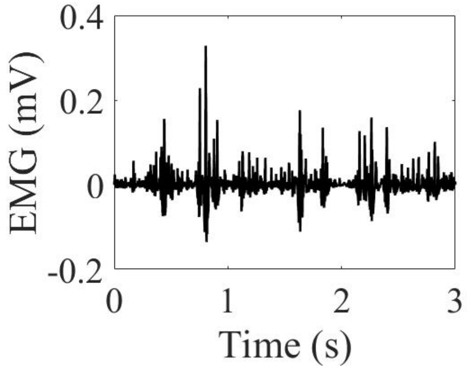

Figure 2.11: Detrended EMG signal of non-dominant biceps brachii muscle during isometric muscle contractions of dominant biceps brachii muscle.

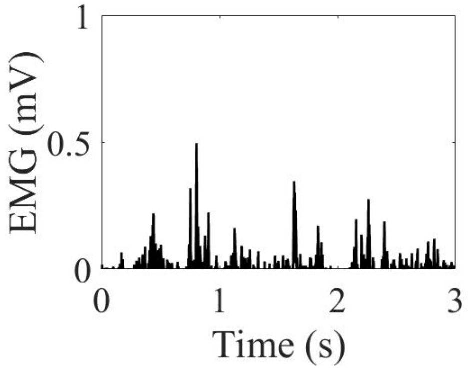

Figure 2.12: EMG signal of non-dominant biceps brachii muscle during isometric muscle contractions of dominant biceps brachii muscle that full-wave rectified and filtered with Butterworth band pass filter.

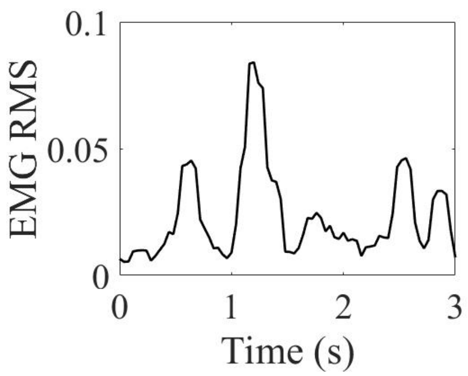

Figure 2.13: EMG signal of non-dominant biceps brachii muscle during isometric muscle contractions of dominant biceps brachii muscle after calculation of RMS.

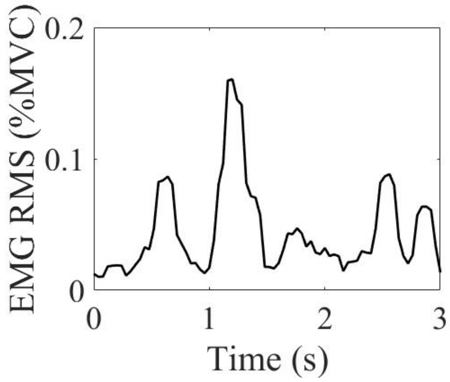

Figure 2.14: The normalization curve of the sample EMG signal.

2.4.STATISTICAL ANALYSIS

A pilot study was designed to define sample size by using G-Power analysis. The pilot study included data from 10 individuals (five from each group). We assumed a medium to the large effect size of .30, consistent with other studies in the field. As a result, setting alpha at .05, power at .80 with two groups the power calculation yielded a sample size of 36 participants (18 in each group) at least.

Statistical procedures were completed using SPSS (Version 16.0; SPSS; Chicago, IL, USA). Normality of all variables was verified using the Kolmogorov-Smirnov test (Fig. 2.15-17). The Mann-Whitney U tests were performed on variables between groups (KT versus control group). Differences in EMG among the three contraction types were assessed by Kruskal–Wallis one-way analysis of variance for both groups. A p-value of less than 0.05 was considered statistically significant.

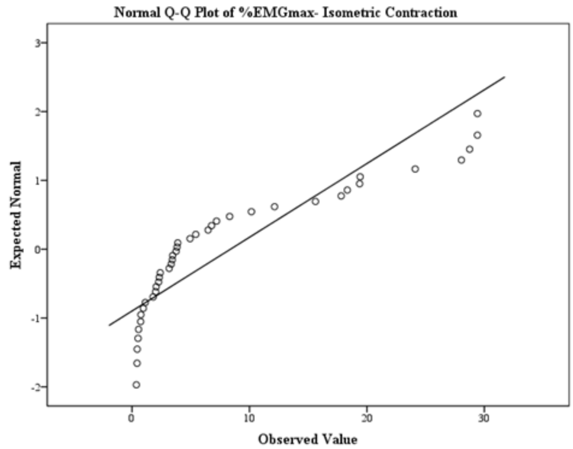

Figure 2.15: Kolmogorov-Smirnov test normality graph of $\%EMG_{max}$ values for isometric contraction.

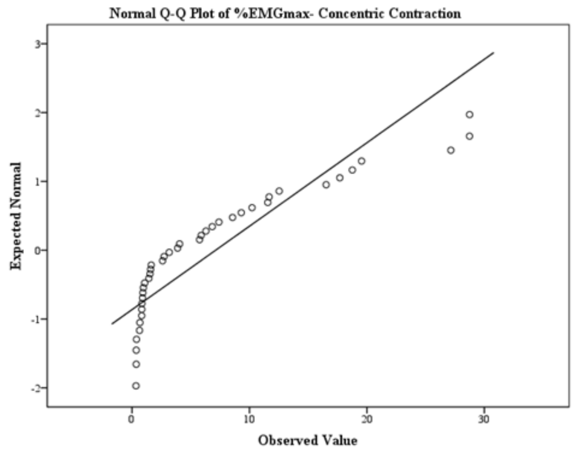

Figure 2.16: Kolmogorov-Smirnov test normality graph of $\%EMG_{max}$ values for concentric contraction.

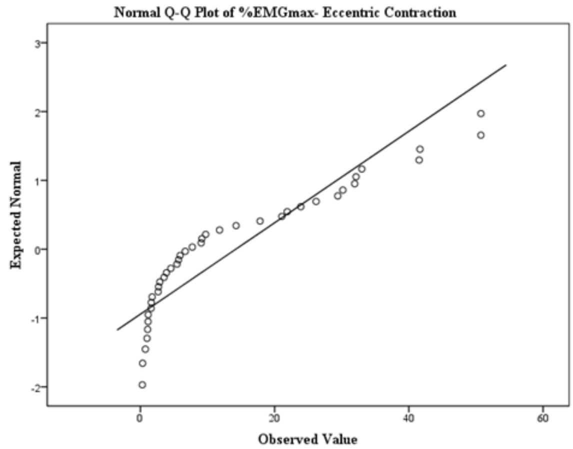

Figure 2.17: Kolmogorov-Smirnov test normality graph of $\%EMG_{max}$ values for eccentric contraction.

3. RESULTS

The demographic characteristics of the subjects are presented in Table 3.1. There were no statistical differences between the demographic characteristics of groups (*p*>0.05).

Table 3.1: The demographic characteristics of groups.

	Control Group **n=20**	**KT Group** **n=20**	***p***
Sex	60% female 40% male	70% female 30% male	0.507
Age (year)	22.45±1.98	22.00±1.72	0.398
Height (cm)	168.50±10.01	169.50±9.92	0.698
Mass (kg)	63.8±9.89	62.60±10.42	0.698
BMI	22.40±2.13	21.69±2.59	0.341

3.1.ELECTRICAL ACTIVITY OF CONTRALATERAL BICEPS BRACHII

KT group had statistically higher %EMG_{max} of the biceps brachii than the control group in the non-dominant limb during the isometric, concentric, and eccentric contractions of dominant limb (*p*=0.035, *p*=0.046, and *p*=0.002, respectively) (Table 3.2).

In the KT group, %EMG_{max} of the biceps brachii muscle recorded during the eccentric contraction was statistically higher than those recorded during the isometric and concentric contractions (*p*=0.044), but post hoc test did not reveal a significant difference among them (Figure 3.1). In the control group, all contraction types in the dominant limb had a similar effect on the electrical activity of the biceps brachii muscle in the non-dominant limb (*p*=0.372) (Figure 3.2).

Table 3.2: The mean %EMG_{max} values of biceps brachii muscle in both groups.

	Control Group n=20	**KT Group** n=20	***p***
Isometric-%EMG_{max}	5.41±6.88	11.35±10.63	**0.035***
Concentric-%EMG_{max}	3.41±3.38	10.82±9.96	**0.045***
Eccentric-%EMG_{max}	6.51±7.25	21.91±16.95	**0.003***

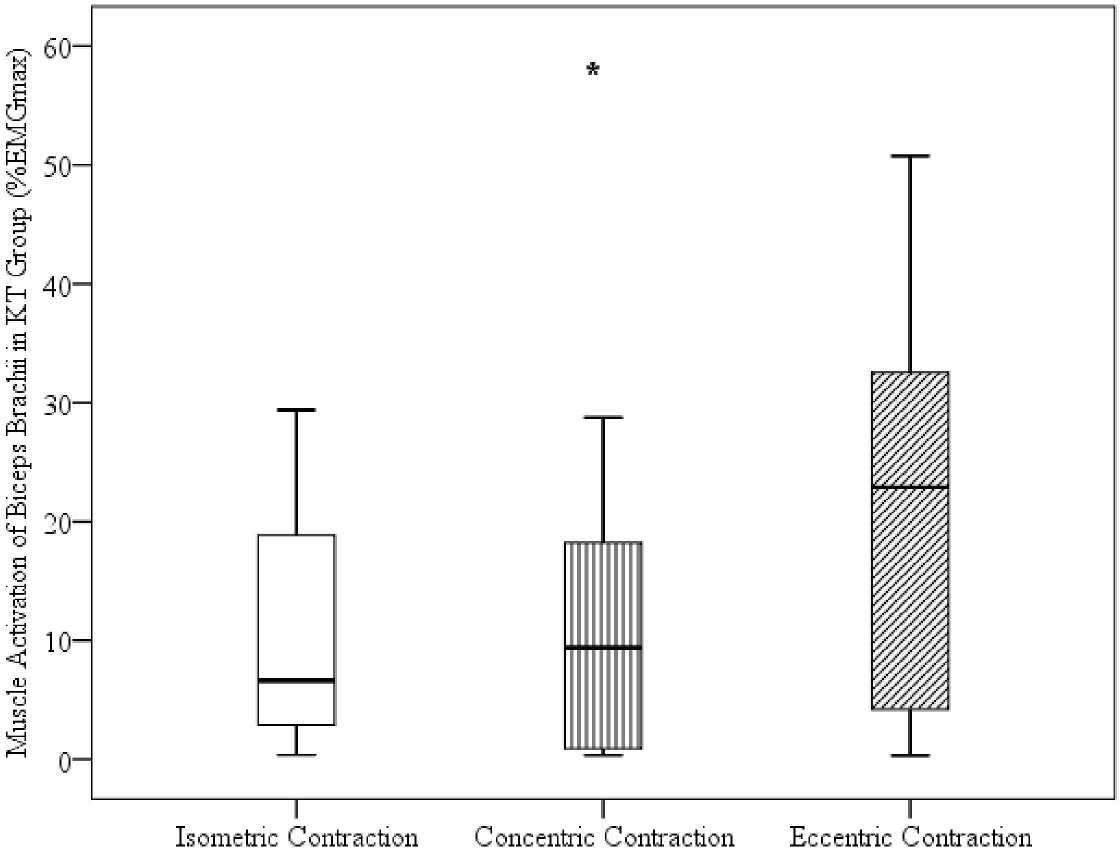

Figure 3.1: The differences between $\%EMG_{max}$ of the biceps brachii muscle during isometric, concentric, and eccentric contractions in KT group. *There is a statistically significant difference between three contraction types in KT group (p<0.05).

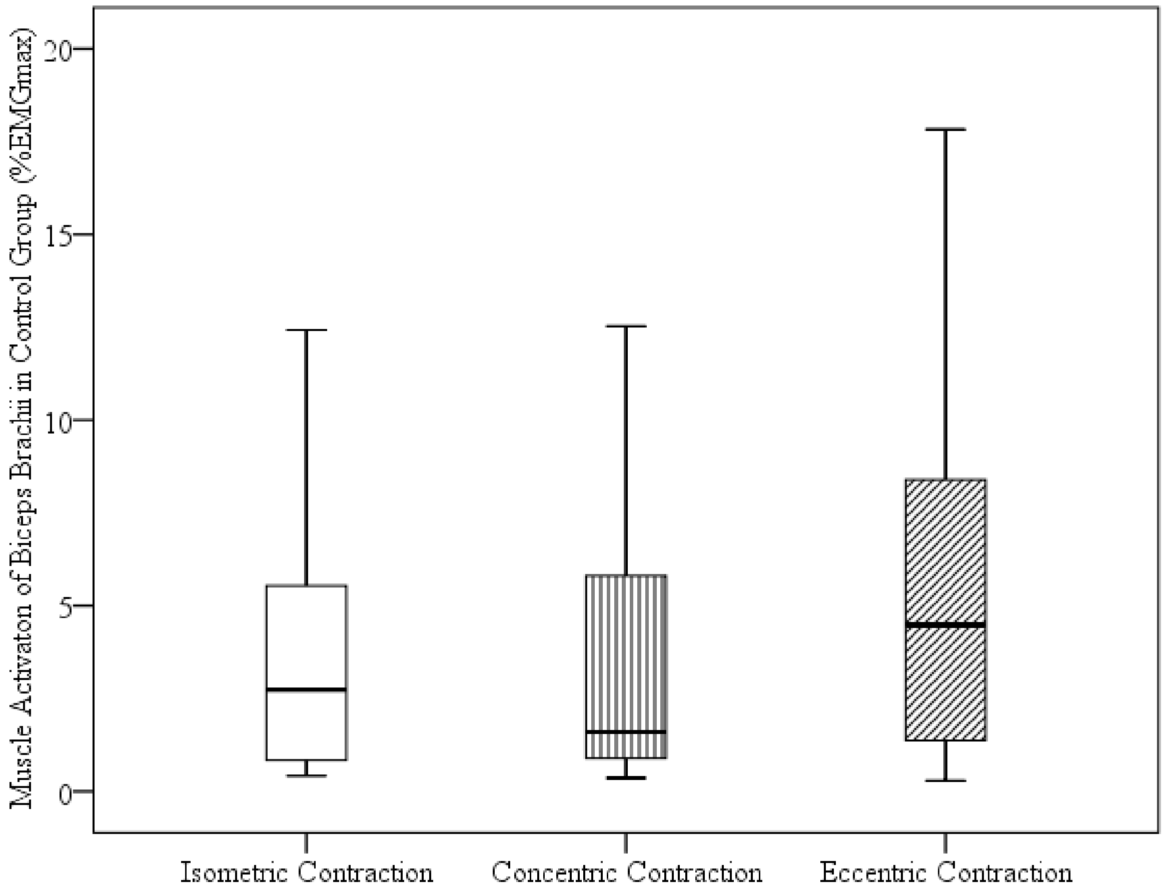

Figure 3.2: The differences between $\%EMG_{max}$ of the biceps brachii muscle during isometric, concentric and eccentric contractions in the control group.

3.2.ELECTRICAL ACTIVITY OF CONTRALATERAL ANTAGONIST MUSCLE

$\%EMG_{max}$ of the triceps brachii muscle during isometric and concentric contractions were higher in the KT group than in the control group, although these differences were not statistically different (p=0.091, p=0.231; respectively). $\%EMG_{max}$ of the triceps brachii was statistically higher in the KT group than in the control group for the eccentric contraction (p=0.046) (Table 3.3). In the control and KT groups, all contraction types in the dominant limb had the similar effect on the electrical activation of the triceps brachii muscle in the non-dominant limb (p=0.427, p=0.352; respectively) (Figure 3.3 and 3.4).

Table 3.3: The mean %EMG_{max} values of the triceps brachii muscle in both groups.

	Control Group n=20	**KT Group** n=20	***p***
Isometric-%EMG_{max}	5.89±6.08	13.48±14.91	0.091
Concentric-%EMG_{max}	3.71±2.31	8.82±10.06	0.231
Eccentric-%EMG_{max}	6.66±7.27	12.98±13.72	**0.046***

*$p<0.05$ is statistically significant.

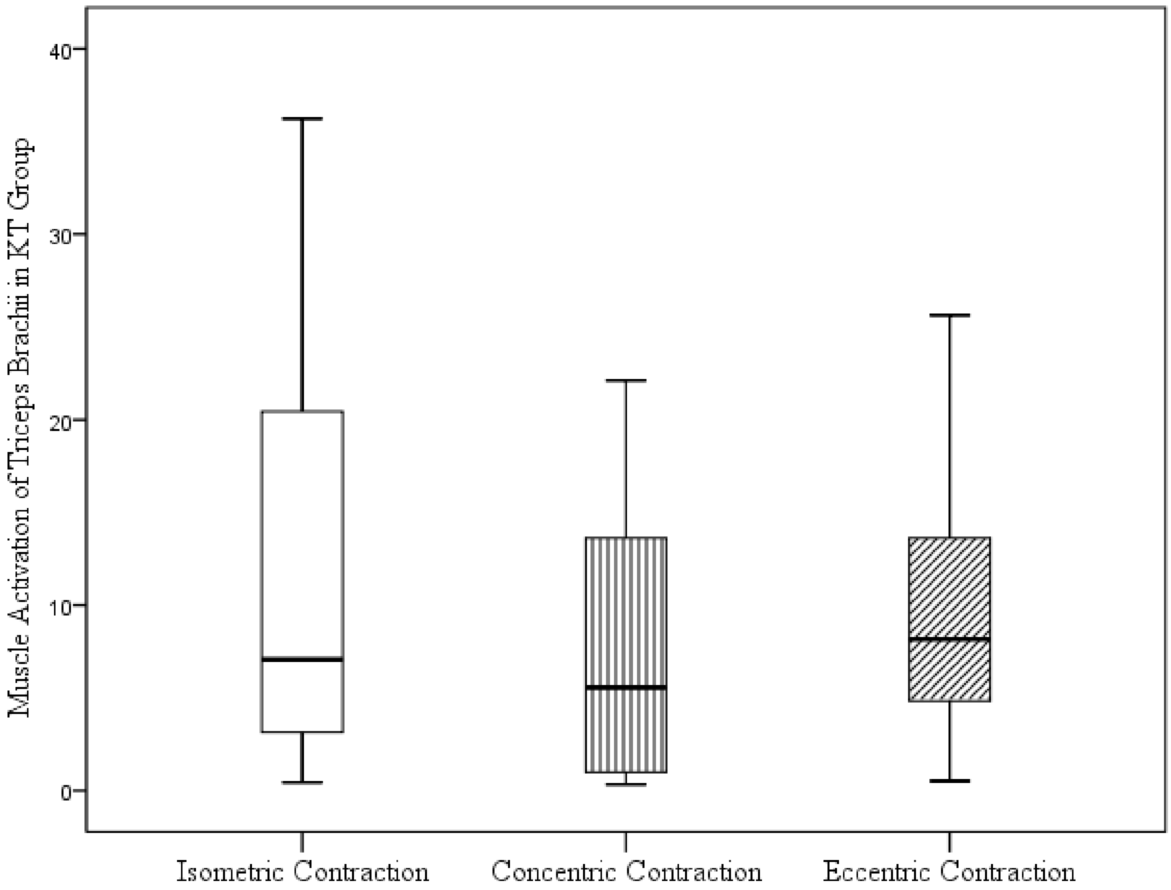

Figure 3.3: The differences between $\%EMG_{max}$ of triceps brachii muscle during isometric, concentric and eccentric contractions in KT group.

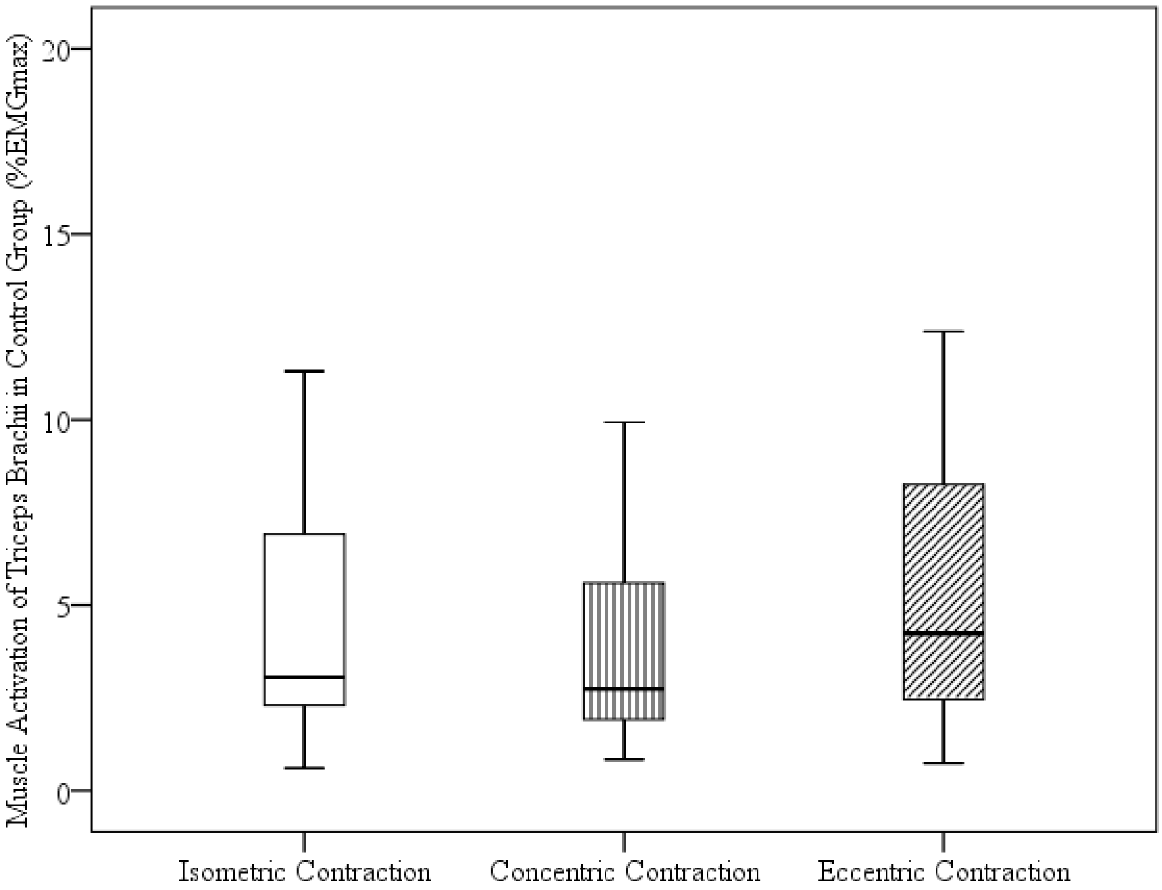

Figure 3.4: The differences between $\%EMG_{max}$ of triceps brachii muscle during isometric, concentric and eccentric contractions in the control group.

3.3.MAXIMUM JOINT TORQUES DURING ELBOW FLEXION AND EXTENSION

The dominant maximum elbow joint torques during isometric, concentric, and, eccentric contractions of the biceps brachii were not different between the control and KT groups (p=0.414, p=0.904, p=0.968; respectively) (Table 3.4). Torques of the non-dominant limb were also not different between the KT and control groups. The non-dominant elbow joint torques at MIVC of the biceps brachii were 40.0±17.4 and 38.9±19.6 Nm in the control and KT groups, respectively (p=0.715) (Figure 3.5). The non-dominant elbow joint torques at MIVC of the triceps brachii were 29.1±12.5 and 25.5±12.7 Nm in the control and KT groups, respectively (p=0.284) (Figure 3.6).

Table 3.4: The dominant maximum elbow joint torques at isometric, concentric, and, eccentric contractions of the biceps brachii in the control and KT group.

	Control Group n=20	**KT Group** n=20	***p***
Isometric (Nm)	43.0±17.2	40.2±18.4	0.414
Concentric (Nm)	30.1±12.3	29.5±14.2	0.904
Eccentric (Nm)	44.6±15.8	44.6±20.0	0.968

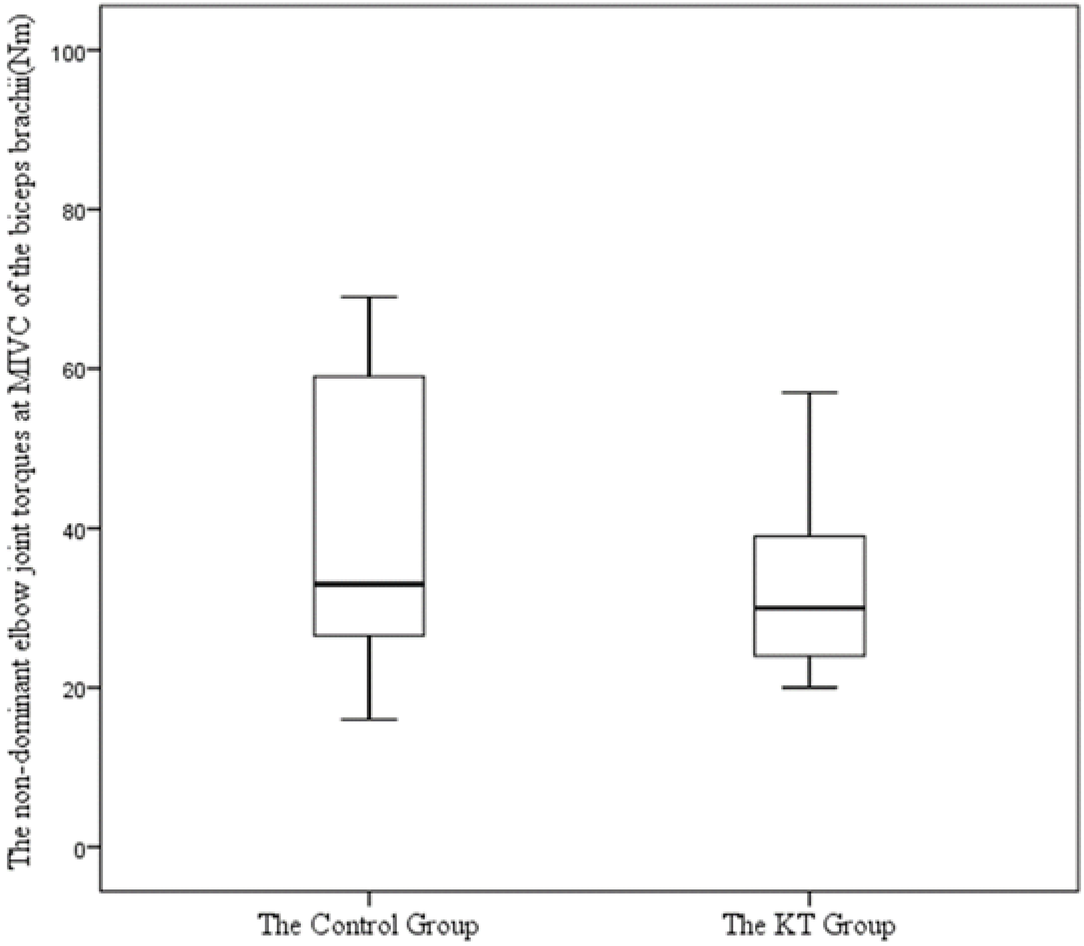

Figure 3.5: The non-dominant elbow joint torques at MIVC of the biceps brachii muscle.

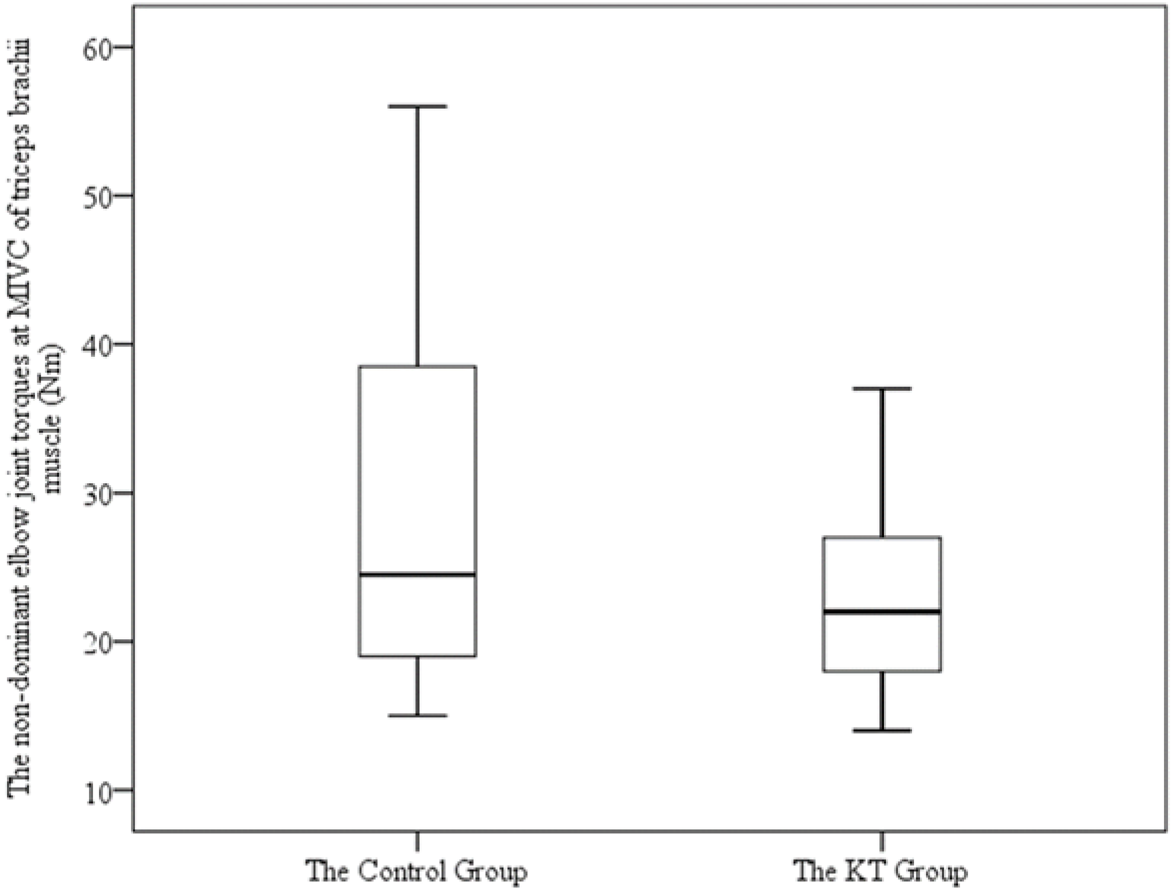

Figure 3.6: The non-dominant elbow joint torques at MIVC of the triceps brachii muscle.

4. DISCUSSION

In this thesis, the force irradiation effect of KT on contralateral muscle activity was investigated by using electromyography signals. Our objective was to determine whether or not there is a synergistic effect of KT which is used for muscle facilitation such as force irradiation. Additionally, we aimed to assess the effects of isometric, concentric, and eccentric contractions on the contralateral agonist and antagonist muscle activation under KT and non-KT conditions. Our study showed that the KT promoted the contralateral agonist and antagonist muscle activity. Eccentric contraction more influenced the amount of contralateral agonist muscle activity than isometric and concentric contractions in the KT group. We suggest that the KT on the resting limb may promote the force irradiation.

We observed that contralateral muscle activation in the biceps brachii muscle obtained from the KT group was higher than those obtained from the control group for all contraction types, indicating that the combination of force irradiation and KT induced synergistic effects on the contralateral muscle activation in the biceps brachii muscle during all contraction types. When intragroup evaluations were performed, we deduced that eccentric contraction created higher contralateral force irradiation in the biceps brachii than isometric and concentric contractions in the KT group, although post hoc test failed to show the significant difference in the $\%EMG_{max}$ between contraction types. Intragroup comparison of the muscle activation results of the biceps brachii muscle obtained in the control group indicated that contralateral muscle electrical activities were not affected by the muscle contraction types. The contralateral muscle activations of the triceps brachii muscle were higher in the KT group compared to the control group for all contraction types, but only the eccentric contraction created statistically higher contralateral triceps activation in the KT group than the control group among three contraction types. Intragroup analyses showed that contralateral muscle activities of the triceps brachii muscle were not different among isometric, concentric, and eccentric contractions in the control and KT groups.

KT is a taping method commonly used to increase muscle performance and facilitate or inhibit muscle activity in rehabilitation. One of the mechanisms of action of KT is the skin-lifting effect which is considered to increase the blood and lymphatic fluid circulation (Halseth et al. 2004). Another theory is that KT creates pressure and stretching effects on the skin surface that stimulate cutaneous mechanoreceptors, which enhances somatosensory inputs (Kase et al.

2003). The activation of modulatory mechanisms within the central nervous system through proprioception feedback revealed an increase in the muscle excitability (Lin et al. 2011).

Force irradiation is that the stimulation of strong muscles to cause an activity in the contralateral homologous muscles (contralateral muscle activation) or any another body segment via proprioceptive inputs (Pink 1981; Adamson et al. 2008). The mechanism underlying the contralateral muscle activation is unclear. Some theories attribute the origin of the contralateral activation to the muscular, neural, spinal cord, cortical, and subcortical structures (Devine et al. 1981; Dragert and Zehr 2013). The amount of the force irradiation associated with the abundance of the stimulus from the central motor pathways to the active muscles and also the afferent feedback to contralateral motor neurons (Zijdewind et al. 2006a). Recent studies have reported that sensory feedback using a mirror, which reflects the active limb vision instead of the resting limb, augmented crossed effect (Carson and Ruddy 2012; Zult et al. 2016). Additionally, electrically stimulated muscle contraction and added cutaneous afferents or inputs from muscle spindles in the active limb also produce crossed effects (Hortobágyi et al. 2003; Veldman et al. 2015; Veldman et al. 2018; Cattagni et al. 2018). Unilateral body vibration that induces short and rapid changes in muscle fiber length, which stimulates reflexive muscle contractions via monosynaptic reflexes or skin and joint receptors, augments crossed effect (Marín et al. 2014). Contraction types such as lengthening and shortening or the level of muscle contraction also change the level of the crossed effect (Shinohara et al. 2003; Abreu et al. 2015).

In the thesis, KT was applied on the basis of its augmentation effect on the somatosensory inputs in the taped area (Tamburella et al. 2014). Tamburella et al. investigated the effect of KT and non-elastic tape to incomplete spinal cord injury patients on ROM, spasticity, clonus, pain, balance, and gait which evaluate by using stabilometric platform assessment of center of pressure (COP) movements and recording of EMG activity of the soleus and gastrocnemius, tibialis anterior and extensor hallucis longus muscles. They found that only KT treatment had a significant effect on these parameters among incomplete spinal cord injury (Tamburella et al. 2014). Additionally, Lin et al. assessed the effect of scapular taping on shoulder proprioception which was assessed by using the FASTRAK electromagnetic motion tracking system. In the study, electromyographic activation of the upper and lower trapezius, serratus anterior, anterior part of deltoid muscle was recorded during proprioception assessment. The researchers revealed that KT alters the muscle activation of shoulder muscle and these effects are associated with proprioceptive feedback (Lin et al. 2011).

It is known that the modulation of the corticospinal output by visual input or proprioceptive feedback from resting limb may affect contralateral muscle activation (Post et al. 2009; Zult et al. 2015). Post et al. assessed the contralateral muscle activity during a maximum voluntary contraction of the right index finger abduction in both experiments. Both hands were placed in the vertical position in one of the experiments. The contralateral hand position was changed in the second experiment such that the right hand was held in vertical position and the left hand was positioned pronated. They reported that when the hands were in asymmetric position, the contralateral activity was determined in the extension direction, not in the abduction direction. These results supported that motor commands are also organized by extrinsic inputs, not only by internal inputs (Post et al. 2009). In our study, the contralateral limb was positioned in the same direction as the target movement to prevent asymmetrical orientation. Furthermore, we used KT as an external input to promote the contralateral muscle activity.

Previous studies focused on the visual feedback and altered sensory input of active limb and found greater crossed effects in the literature (Hortobágyi et al. 2003; Zult et al. 2015; Zult et al. 2016). Zult et al. evaluated the short-interval intracortical inhibition and corticospinal excitability of right-ipsilateral primary motor cortex, and electromyographic activity of contralateral hand under mirror and non-mirror condition during 60% MVC of right wrist flexors. They showed that mirror image of moving hand reduced motor cortical inhibition in the primary motor cortex which is related with the contralateral agonist muscle (Zult et al. 2015). Zult et al. found similar results on primary motor cortex after one session exercise training which included 640 concentric contractions of the right wrist flexor at 80% MVC under mirror and non-mirror conditions (Zult et al. 2016). In both studies, they demonstrated that reduced inhibition related to mirror viewing increased cross-effect. Hortobagyi et al. investigated the effect of different sensory inputs which were contralateral mixed nerve stimulation, cervicomedullary stimulation, cutaneous nerve stimulation, tendon vibration, and percutaneous muscle stimulation during unilateral exercise. They demonstrated that unilateral motor and sensory activity affect the neural pathways in different levels and cause cross-effect (Hortobágyi et al. 2003). To our best knowledge, there is no study to focus on the effects of external (additional) inputs on the resting limb during unilateral contractions. Only Giovannelli et al. evaluated the effect of real or imagined movement of the contralateral limb during unilateral movements. The subjects were assessed under three conditions: minimal contraction, maximal contraction and, relaxed position of the left finger during isometric contraction of the right finger. This study presented that movement of the contralateral limb during unilateral exercise causes an increment of interhemispheric motor inhibition in the contralateral primary motor cortex (Giovannelli et al. 2009). Hübers et al. stimulated opposite primary motor cortex during unilateral exercise in their study. They found that transcranial stimulation of contralateral primary motor cortex during unilateral exercise induce the interhemispheric motor inhibition which is a critical factor for cross-effect (Hübers et al. 2008). In our study, the KT was applied on the contralateral limb, and the contralateral limb was in relax position. When we take our results into consideration, we assumed that the occurrence of the change in the somatosensory inputs triggered by the KT was due to the somatosensory re-afferent feedback modulated the motor output of the resting muscle.

Both dynamic and static muscle contractions induce a contralateral muscle activation. Panzer et al. analyzed contralateral limb EMG signals during two different contraction types, concentric and isometric elbow extension. The subjects performed maximal muscle contractions. They found that the level of contralateral muscle activation was similar during unilateral concentric and isometric contractions (Panzer et al. 2011). Additionally, in a study about cross-education, one group of subject exercised concentric training, another group of subjects performed eccentric training and the last group was the non-exercising group. The groups performed the training for 36 sessions over 12 weeks. The study revealed that the unilateral eccentric exercise increased the contralateral muscle strength more than the unilateral concentric exercise (Hortobagyi et al. 1997). Furthermore, Shinohara et al. analyzed the contralateral activity of hand during different kinds of unilateral contractions among young and elderly adults. They presented that the contralateral EMG amplitude was found greater during isometric contractions than that during isotonic contractions. Shinohara et al. revealed that older adults produce more contralateral activity than younger, because of a decreased ability to suppress involutional contralateral activation during unilateral movements (Shinohara et al. 2003). However, Uematsu et al. analyzed the probability that the contraction type associated with modulation of the corticospinal excitability in the ipsilateral primary motor cortex to the contracting muscle. They assessed MEPs in the resting finger during unilateral concentric, eccentric and isometric contractions of the right wrist flexors at 10, 20, and 30% of MIVC force. Uematsu et al. presented that there were differences between contraction types on H-reflex which shows excitability changes at the spinal level, but they could not reveal significant differences among the sequence of isometric, concentric, and eccentric contractions (Uematsu et al. 2010). Our study revealed that eccentric contraction produced higher contralateral muscle activity than isometric and concentric contractions in the KT group, while it was not statistically significant. Furthermore, in the control group, contralateral muscle activity was not affected by the type of the contraction. It is considered that contralateral muscle activity is related to the supracortical level, and KT effect is related to supracortical and subcortical level (Alexander et al. 2003), which may explain why we found a difference between the effects of the contraction types on the contralateral muscle activity only in the KT group, but not in the control group.

KT causes mechanical changes in muscle and other deep and superficial connective tissues (Pamuk and Yucesoy 2015). Pamuk and Yucesoy examined the high-resolution three-dimensional MRI images of lower extremity before and immediately after the KT on tibialis anterior muscle. They observed that local alterations were happening under the taped such as skin, fascia, and muscular structures (Pamuk and Yucesoy 2015). The skin and muscle are elaborately innervated with specific receptors which ensure sensorial information to the central nervous system. KT creates pressure and stretching stimulation to the receptors of skin and muscle under the taped area that produces an enhancement afferents (Lin et al. 2011; Kase et al. 2003). The information, which is gathered from mechanoreceptors, promotes the blood flow within the cerebellar, subcortical and cortical regions via the dorsal column. Furthermore, the studies revealed that the effect of somatosensory inputs does not limit the sensorimotor cortex, it produces widespread cortical projections (Veldman et al. 2018; Tamburella et al. 2014; Wardman et al. 2014). Consequently, the effects of muscle and cutaneous afferent stimulus, which created by KT, may create a summation effect on the motor activity of the resting limb, which we observed in the thesis.

The contralateral muscle activity occurs in both contralateral agonist and antagonist muscles during unilateral exercise (Abreu et al. 2015; Devine et al. 1981). Devine et al. asked the subjects to perform maximal isometric contractions in the knee at flexion and extension position while the contralateral antagonist and agonist muscle activations were recorded by using EMG. The results of the study revealed that contralateral antagonist muscle activation was not greater than contralateral agonist muscle activation (Devine et al. 1981). However, Panin et al. determined that the contralateral antagonist muscle activity was higher than the agonist at the knee (Panin 1961). Pink et al. reported that contralateral pectoralis major muscle activity was not greater when the role of pectoralis major was an agonist muscle and a stabilizer during unilateral shoulder movement (Pink 1981). Abreu et al. also found that the role of the contralateral muscle is deterministic for the amount of contralateral muscle activity during unilateral contractions (Abreu et al. 2015). Pamuk and Yucesoy showed that application of KT changes the antagonist muscle mechanics, actually it changes the whole limb (Pamuk and Yucesoy 2015). We determined that KT group had greater contralateral antagonist muscle activation during all contraction types, although only the contralateral antagonist muscle activation during eccentric contraction was statistically significant.

The increase of the amount of unilateral contraction is related with the increase of contralateral muscular activity. Abreu et al. compared the contralateral muscle activity during MVC and 25% of MVC. They showed that contralateral muscle activity was greater during MVC than 25% of MVC (Abreu et al. 2015). Uematsu et al. tested the MEPs size during unilateral exercise which performed at 10%, 20%, and 30% of MVC. They presented that the MEPs size was hierarchically enhanced with the contraction intensity during concentric, eccentric and isometric contractions (Uematsu et al. 2010). In our study, maximum joint torques of both limbs were found to be similar between the KT and the control groups, indicating the alterations in the magnitudes of the contralateral muscle activity cannot be referred to the changes in the torques of the groups.

In the thesis, only one group was formed as a control group whose members performed the unilateral movement without KT. Further studies may investigate the probable effect of placebo taping and KT on the contralateral muscle activation, especially in patients with neurologic and orthopedic impairments.

5. CONCLUSION AND RECOMMENDATIONS

Our study showed that the KT promoted the contralateral agonist (the biceps brachii) and antagonist (the triceps brachii) muscle activity. Eccentric contraction more influenced the amount of contralateral muscle activation in the biceps brachii than isometric and concentric contractions in the KT group. For the triceps brachii muscle, we observed the effect of contraction type on the contralateral muscle activity neither in the KT nor in the control group. We concluded that the KT on resting limb promotes the contralateral muscle activity, especially the activity of the agonist muscle.

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APPENDICES

APPENDIX 1: The assessment form

Tarih:

DEĞERLENDİRME FORMU

ADI SOYADI: DOĞUM TARİHİ:

DOMİNANT TARAF: Sağ: ( ) Sol ( )

BOY: KİLO: BKİ: CİNSİYET:

İlaç Kullanımı: Var ( ) Yok ( )

Hastalıklar:

Kontraksiyon Tipi Sırası:
(....) İzometrik
(....) Konsantrik
(....) Eksantrik

EMG Kas-Kanal Seçimi:
Kanal1:
Kanal2:

APPENDIX 2: Bezmialem University Human Research Ethics Committee Approval Form

Evrak Tarih ve Sayısı: 20/04/2017-7120

T.C.
BEZMİALEM VAKIF ÜNİVERSİTESİ REKTÖRLÜĞÜ
Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu

BEZMİÂLEM
VAKIF ÜNİVERSİTESİ

Sayı : 54022451-050.05.04-
Konu : Etik Kurul Kararı

Sayın Doç.Dr. Tolga SAKA

27.12.2016 tarihinde yapılan Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu toplantısında "Kinezyolojik Bantlama İle Kontralateral Ekstremitedeki Kuvvet Yayılımı Arasındaki İlişkinin Belirlenmesi " başlıklı başvurunuz değerlendirilmiş olup karar yazısı ektedir.
Bilgilerinize.

e-imzalıdır
Prof.Dr. İsmail MERAL
Başkan

Ek: Karar Yazısı (3 sayfa)

19/04/2017 Sek. Elif Gamze ASLAN

Mevcut Elektronik İmzalar
İSMAİL MERAL (Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu - Başkan) 20/04/2017 07:38

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Unvanı: Sekreter

Bu belge 5070 sayılı Elektronik İmza Kanununun 5. Maddesi gereğince güvenli elektronik imza ile imzalanmıştır.

BEZMİALEM VAKIF ÜNİVERSİTESİ GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR ETİK KURULU (2011-KAEK-42)
KARAR FORMU

ARAŞTIRMANIN AÇIK ADI	Kinezyolojik Bantlama İle Kontralateral Ekstremitedeki Kuvvet Yayılımı Arasındaki İlişkinin Belirlenmesi

27.12.2016

ETİK KURUL BİLGİLERİ	ETİK KURULUN ADI	Bezmialem Vakıf Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu
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BAŞVURU BİLGİLERİ	KOORDİNATÖR/SORUMLU ARAŞTIRMACI UNVANI/ADI/SOYADI	Doç.Dr. Tolga SAKA			
	KOORDİNATÖR/SORUMLU ARAŞTIRMACININ UZMANLIK ALANI	Spor Hekimliği			
	ARAŞTIRMAYA KATILAN MERKEZLER	TEK MERKEZ ☒	ÇOK MERKEZLİ ☐	ULUSAL ☐	ULUSLARARASI ☐

DEĞERLENDİRİLEN BELGELER	Belge Adı	Tarihi	Versiyon Numarası	
	ARAŞTIRMA PROTOKOLÜ	-	-	Gerekli Değil ☐ Var ☒
	BİLGİLENDİRİLMİŞ GÖNÜLLÜ OLUR FORMU	-	-	Gerekli Değil ☐ Var ☒
KARAR BİLGİLERİ	Karar No:10/112	Tarih: 27.12.2016		
	Yürütücülüğünü Doç.Dr. Tolga SAKA ' nin yaptığı "Kinezyolojik Bantlama İle Kontralateral Ekstremitedeki Kuvvet Yayılımı Arasındaki İlişkinin Belirlenmesi " başlıklı çalışmanın Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu tarafından değerlendirilmiş ve etik açıdan uygun bulunmuştur.			

Etik Kurul Başkanı
Prof. Dr. İsmail MERAL

BEZMİALEM VAKIF ÜNİVERSİTESİ GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR ETİK KURULU (2011-KAEK-42)
KARAR FORMU

ARAŞTIRMANIN AÇIK ADI	Kinezyolojik Bantlama İle Kontralateral Ekstremitedeki Kuvvet Yayılımı Arasındaki İlişkinin Belirlenmesi

BEZMİALEM VAKIF ÜNİVERSİTESİ GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR ETİK KURULU	
ETİK KURULUN ÇALIŞMA ESASI	İlaç ve Biyolojik Ürünlerin Klinik Araştırmaları Hakkında Yönetmelik, İyi Klinik Uygulamaları Kılavuzu
BAŞKANIN UNVANI / ADI / SOYADI:	Prof. Dr. İsmail MERAL

Unvanı/Adı/Soyadı	Uzmanlık Alanı	Kurumu	Araştırma ile ilişki		Katılım *		İmza
Prof. Dr. İsmail MERAL	Fizyoloji	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☒	H ☐	
Prof. Dr. Ömer SOYSAL	Göğüs Cerrahisi	Bezmialem Vakıf Üniversitesi Sağlık Bilimleri Fakültesi	E ☐	H ☒	E ☒	H ☐	
Prof. Dr. Şeyda HERGÜNER SİSO	Restoratif Diş Tedavisi	Bezmialem Vakıf Üniversitesi Diş Hekimliği Fakültesi	E ☐	H ☒	E ☒	H ☐	
Prof. Dr. Türkinaz AŞTI	Hemşirelik Bölümü	Bezmialem Vakıf Üniversitesi Sağlık Bilimleri Fakültesi	E ☐	H ☒	E ☒	H ☐	
Doç. Dr. Fahri AKBAŞ	Tıbbi Biyoloji	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☒	H ☐	
Doç. Dr. Binnur AYDOĞAN TEMEL	Eczacılık	Bezmialem Vakıf Üniversitesi Eczacılık Fakültesi	E ☐	H ☒	E ☒	H ☐	
Doç. Dr. Tolga SAKA	Spor Hekimliği	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☒	H ☐	E ☐	H ☒	KATILMADI
Doç. Dr. Aclan ÖZDER	Aile Hekimliği	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☒	H ☐	
Yrd. Doç. Dr. Nur BÜYÜKPINARBAŞILI	Tıbbi Pataloji	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☒	H ☐	
Yrd. Doç. Dr. Serdar UYSAL	Temel Bilimler Biyofizik	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☐	H ☒	KATILMADI

Etik Kurul Başkanı
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BEZMİALEM VAKIF ÜNİVERSİTESİ GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR ETİK KURULU (2011-KAEK-42)
KARAR FORMU

ARAŞTIRMANIN AÇIK ADI	Kinezyolojik Bantlama İle Kontralateral Ekstremitedeki Kuvvet Yayılımı Arasındaki İlişkinin Belirlenmesi

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Av. Mustafa Fırat ALKAYA	Hukuk	Bezmialem Vakıf Üniversitesi	E☐	H☒	E☒	H☐	[signature]
Eda BAYRAKTAR	Sivil Üye	Bezmialem Vakıf Üniversitesi	E☐	H☒	E☒	H☐	[signature]

* :Toplantıda Bulunma **Karar:** ☒ Onaylandı ☐ Reddedildi

Etik Kurul Başkanı
Prof. Dr. İsmail MERAL
[signature]

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Publications

1. Narin, A., Alpozgen, A., Denizoglu Kulli, H., 2016, Effects of matrix rhythm therapy on primary lymphedema: a case report, *Journal of Physical Therapy Science*, 28: 2418-21.
2. Gurses, H.N., Zeren, M., Denizoğlu Kulli, H., Durgut, E., 2018, The relationship of sit-to-stand tests with six-minute walk test in healthy young adults, *Medicine*, 1:9489,9489.
3. Denizoglu Kulli, H., Durgut, E., Alpay, K., Gurses H.N., 2017, Effects of whole-body vibration on fall risk and functional mobility in a case of unilateral chronic stroke patient. *Neurosurgery*, 2:1.

4. Denizoğlu Külli, H., Afşin, F., Gürses, H.N., 2018, İnmeli hastalarda dominant ve dominant olmayan el paralizisinin etkilenmemiş el kuvveti, fonksiyonları ve yaşam kalitesi üzerine etkisi. Türk Fizyoterapi Ve Rehabilitasyon Dergisi; 29(2):10-10.
5. Uçgun, H., Denizoğlu Külli, H., Gürses, H.N., 2018, "Pontoserebellar köşe tümörü cerrahisi sonrası denge rehabilitasyonu sonuçları: vaka serisi" Türk Fizyoterapi vee Rehabilitasyon Dergisi; 29(2):S12.
6. Denizoğlu Külli, H., Afşin, F., Zengin Alpözgen, A. , Gürses, H.N., 2018, "İnmeli hastalarda kuvvet yayılımı ile birlikte kullanılan farklı uyaranların el fonksiyonları ve kuvvet üzerine etkisi: pilot çalışma" Türk Fizyoterapi ve Rehabilitasyon Dergisi; 29(2):S26.
7. Denizoğlu Külli, H., Durgut, E., Alpay, K., Gürses, H.N., 2018, "Kronik İnmede Tüm Vücut Vibrasyonu Tedavisinin Spastisite Üzerine Etkisi: Olgu sunumu" Türk Fizyoterapi ve Rehabilitasyon Dergisi; 28(3):S40.