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EFFECTS OF NEURODYNAMIC TECHNIQUES (ULTT1) FOR MEDIAN NERVE ON THE CARPAL TUNNEL SYNDROME SYMPTOMS

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ONAY
Bu tez Yeditepe Üniversitesi Lisansüstü Eğitim-Öğretim ve Sınav Yönetmeliğinin ilgili maddeleri uyarınca yukarıdaki jüri tarafından uygun görülmüş ve Enstitü Yönetim Kurulu'nun 31/07/2020 tarih ve 2019/13-68 sayılı kararı ile onaylanmıştır.

Prof. Dr. Bayram YILMAZ
Sağlık Bilimleri Enstitüsü Müdürü

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.

Hande YOLCU

DEDICATION

I would like to dedicate my dissertation work to my family and many friends. A have special feeling of gratitude to my loving parents Mehmet Ali YOLCU, Nevin YOLCU, my sister Hilal YOLCU and my nephew Miraç Arda EVSEN.

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LIST OF SYMBOLS AND ABBREVIATIONS

BCTQ: Boston Carpal Tunnel Questionnaire

BCTQ-fss: Boston Carpal Tunnel Questionnaire Functional Status Scale

BCTQ-sss: Boston Carpal Tunnel Questionnaire Symptom Severity Scale

CTS: Carpal Tunnel Syndrome

JPS: Joint Position Sense

PCS: Pain Catastrophizing Scale

SWM: Semmes Weinstein Monofilament

ULTT: Upper Limb Tension Test

ULTT1: Upper Limb Tension Test for Median Nerve

VAS: Visual Analogue Scale

ABSTRACT

Yolcu, H. (2020). Effects of Neurodynamic Techniques (ULTT1) for Median Nerve on the Carpal Tunnel Syndrome Symptoms, Yeditepe University, Institute of Health Sciences, Department of Physiotherapy and Rehabilitation, Master Thesis. Istanbul.

The aim of our study was to investigate sensory evaluation; light touch sensation on median nerve innervated areas of the hand and joint position sense (JPS) of wrist after by using Upper Limb Tension Test for median nerve (ULTT1) in healthy subjects who have CTS symptoms. The 32 healthy subjects aged between 21-63 years were participated to study according to higher than 11 points and lesser than 46 points from Boston Carpal Tunnel Questionnaire (BCTQ) included. The demographic features of subjects (age, gender, height, body weight, health problems) and Pain Catastrophizing Scale (PCS) scores were recorded. Participants were treated with ULTT1 which consisted of 12 repetitions and 15-20 seconds for each repetition after by baseline measurements which are Semmes –Weinstein Monofilament (SWM), JPS and Visual Analogue Scale (VAS) are taken. Immediately after therapy and 1-week after therapy SWM, JPS and VAS evaluations were taken and values were recorded. According to the results of the study, there was a meaningful decrease in pain status both immediately and 1-week after therapy ($p<0.05$). In accordance with sensory evaluations; SWM was improved both thumb and index finger also JPS was improved in 45^{o} and 20^{o} flexion degrees and 20^{o} extension degrees ($p<0.05$).

Key Words: carpal tunnel syndrome, neurodynamic technique, sensory evaluation, pain

ÖZET

Yolcu, H. Karpal Tünel Sendromu Bulgularına Median Sinir Nörodinamik Tekniğinin (ÜETT1) Etkisi, Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Fizyoterapi ve Rehabilitasyon Anabilim Dalı, Yüksek Lisans Tezi.İstanbul.

Bu çalışmanın amacı, karpal tünel sendromu semptomu bulunan sağlıklı kişilerde, median sinir için uygulanan Üst Ekstremite Tension Testinin (ÜETT1) duyu değerlendirmelerinde elde median sinirin inerve ettiği alanlarda dokunma hissinin ve el bileğinde eklem pozisyon hissinin (EPH) üzerindeki etkisinin değerlendirilmesidir. Çalışmaya yaşları 21 ile 63 arasında bulunan ve Boston Karpal Tünel Anketine (BKTA) gore 11 puandan fazla ve 46 puandan az alan kişiler çalışmaya dahil edilmiştir. Katılımcıların demografik özellikleri (yaş, cinsiyet, boy, kilo, sağlık problemleri) ve Ağrıyı Felaketleştirme Anketi (AFA) değerleri kaydedilmiştir. Katılımcıların ilk değerlendirme sonuçları Semmes-Weinstein Monofilamet testi (SWM), EPH ve ağrı değerlendirmesi Görsel Analog Skalası ile ÜETT1 tedavisinden önce kaydedilmiştir. ÜETT1, 15 tekrardan ve her tekrar 15 ile 20 saniyeden oluşmaktadir. Tedaviden hemen sonra ve 1 hafta sonrasında SWM, EPH ve ağrı değerlendirmeleri tekrar değerlendirilmiştir. Çalışmamızın sonuçlarına göre; tedavinin hemen sonrasında ve 1 hafta sonrasındaki değerlere gore ağrı değerlendirmesinde anlamlı düşüş bulunmuştur ($p<0.05$). Duyu değerlendirmelerinde: SWM testine göre baş ve işaret parmağında, EPH değerlendirmesinin 45^o ve 20^o flexion ve 20^o ekstansiyon açılarında anlamlı gelişme kaydedilmiştir ($p<0.05$).

Anahtar kelimeler: karpal tünel sendromu, nörodinamik teknik, duyu değerlendirmesi, ağrı

1. INTRODUCTION AND PURPOSE

Median nerve consists of lateral cord (C6-C7 fibers) and medial cord (C8-T1 fibers) of the brachial plexus. These fibers enters to the wrist together with 9 finger flexor tendons which are 4 flexor digitorum profundus, 4 flexor digitorum superficialis and flexor pollicis longus through carpal tunnel (1,2).

Carpal tunnel is composed of osteofibrous structure and located under fibrous carpal ligaments and over carpal bones. There are 9 flexor tendons and median nerve passing through carpal canal (3).

Carpal tunnel syndrome (CTS) is a common neuropathy occurs with traction and compression of the median nerve at tunnel level and brings out increased pressure with disrupted median nerve functioning. This median nerve neuropathy is the most well known and most common neuropathy among individuals (3).

In case of median nerve neuropathy, it is characterized with sensory loss and motor weakness on the narrowed carpal canal (4). On the affected side, intermittent numbness, tingling, burning, pain or awakening night pain may be seen. The most common sensory symptoms present in all digits (2).

Depending on the position of upper extremity and its movement pattern, median nerve has tension changes and gliding movements to meet new states. With the median nerve adaptation to changed conditions of the surrounding structures which shows decreased gliding of the nerve, it results in increased symptoms and limitations of the movement (4).

During extremity movement, peripheral nerves are pulled longitudinally and laterally (5). Median nerve's maximal length during longitudinal movement is 10-15 mm in the carpal tunnel which is reduced during carpal tunnel pathophysiologic reconditioning and this brings the irritated median nerve, increased pressure on the nerve trunk with edema formation and obstructed venous flow (3, 5).

Neurodynamic techniques which are termed neural provocation tests are used to assess the mechanical and physiological aspects of the nervous system. Its mechanical subsets contain the capability of nerve to have movement and to strain interrelated to surrounding tissues (4). And also these tests are used in peripheral nerve evaluation and treatment with positioning and mobilization of different anatomical structures (4).

Neurodynamic tension technique for median nerve which is called Upper Limb Tension Test 1 (ULTT1) gives tension on the main truck of the median nerve, its rootlets and surrounding soft tissues (6). ULTT1 moves one or more joints so glides the nerve and elongates the nerve bedding. ULTT1 can enclose issues with extensibility, gliding or irritability of the nerve throughout its pathway (7, 8).

In the literature, researchers used ULTT1 on people who have CTS symptoms to compare effects of ULTT1 and ultrasound and laser therapy according to sensory assessment (9). Researchers studied with ULTT1 with people who has the CTS diagnosis and they observed range of motion of the upper extremity joint (4). On the other hand, studies that worked on sensory evaluation compared with range of motion of the joints but studies that are involves only sensory evaluation found inadequate. Additionally, neurodynamic techniques were used to improve sensory loss on stroke patients (10) and ULTT1 were used to investigate effects on sensory and proprioceptive evaluation on patients with brain injury (11).

Regarding these reasons, we aimed to investigate sensory evaluation in the healthy subjects who show CTS symptoms according to Boston Carpal Tunnel Questionnaire (BCTQ) after by using neurodynamic tension technique for median nerve (ULTT1).

Hypothesis H0: There is no effects of ULTT1 on subjects who have CTS symptoms.

Hypothesis H1: There is effects of ULTT1 on subjects who have CTS symptoms.

2. GENERAL INFORMATION

2.1. Anatomy of Brachial Plexus

The most of the upper extremity nerves arise from the brachial plexus (plexus brachialis) to provide motor, sensory, and sympathetic fibers to the upper extremity (12, 13). It is a complex network of nerves, arising from the neck to the axilla which is typically formed by the unity of the ventral primary rami of the spinal nerves, C5–C8 & T1, the so-called “roots” of the brachial plexus (14). Brachial plexus gives the all its branches in the axillar region after it crosses the 1st rib. The last 4 cervical and 1st thoracic spinal nerves’ ventral branches usually lay between subclavial artery, anterior and medial scalene muscles (Figure 2.1) (12, 14).

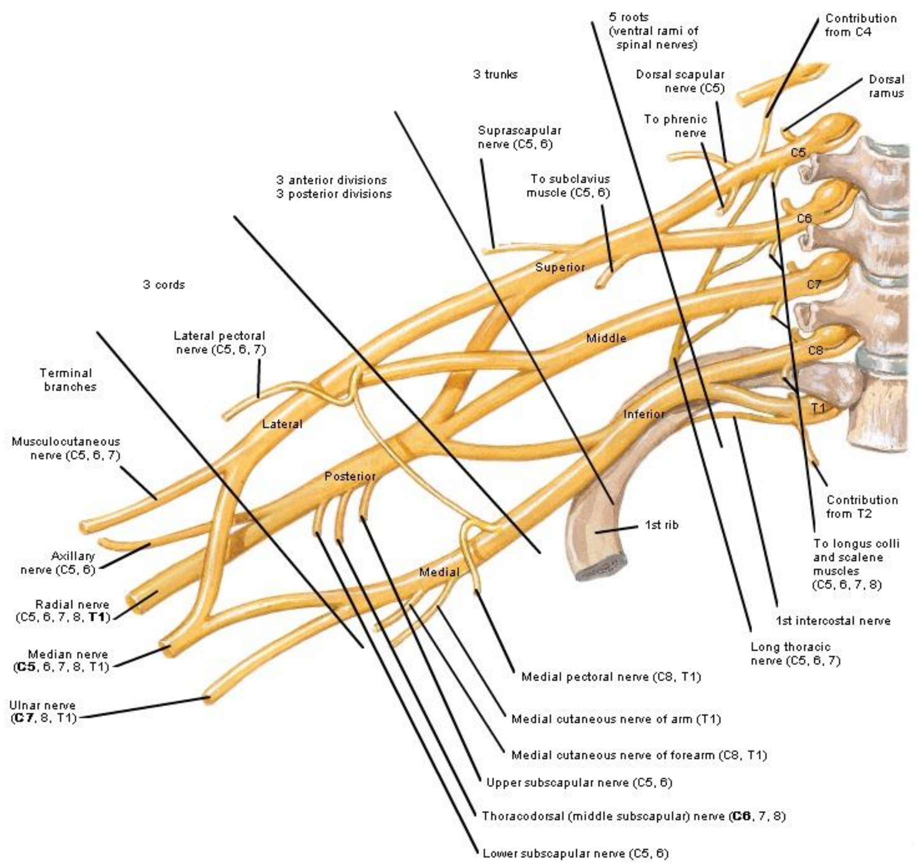

Figure 2.1. Brachial plexus (15)

The direction of the plexus is downwards and outwards with some versatility of the members that participate to the network. At the intervertebral foramen region, C5 and C6 droop caudally where C7 lies in the equal axis as the brachial plexus and C8 and T1 have a cranial course (14, 15).

Ventral spinal nerves give rise to 3 truncus which are:

- Truncus superior: C5 and C6 merge at the lateral border of the medial scalene muscle to create the superior or upper truncus
- Truncus medius: C7 composes by itself to form the middle truncus
- Truncus inferior: to effectuate the inferior or lower truncus C8 and T1 merge behind the anterior scalene muscle and subclavian artery at the neck of the first rib (12, 14, 17).

These 3 truncus that are resulting in union at the posterior edge of the clavicle have an oblique path caudally and laterally. In the infraclavicular section, the truncus operate a parallel course, surrounding the axillary artery. During adduction, the truncus are vertically declined and during 90° abduction they horizontally lied (18).

While each truncus discharge downward and laterally just above or behind the clavicle, give rise anterior and posterior divisions. These functionally significant divisions have a role that anterior parts supply anterior region of the upper limb or flexor parts while posterior parts supply posterior region or extensor parts of the upper limb (12, 14).

The anterior and posterior divisions of the truncus give constitute fasciculus lateralis, medialis and posterior. The anterior branch of the posterior and medial truncus form fasciculus lateralis. The anterior branch of the inferior truncus continues as fasciculus medialis. The posterior branches of all truncus are band together to find out fasciculus posterior (12).

In order to simplify the anatomical definition, the network is separated into topographically into 2 parts by the clavicula: (1) the supraclavicular part that based in the posterior cervical triangle and (2) the infraclavicular part situated in the axilla (3). The supraclavicular branches of the plexus exit from rami ventrales and truncus (nervus dorsalis scapula, nervus torasic longus, nervus subclavius and nervus suprascapularis) and then approach through the neck region. The infraclavicular divisions of the brachial plexus emerge from fasciculus from axilla and then near through the axilla (12).

The anterior division of the lower truncus proceeds as the medial cord and it crosses down behind and then on the medial side of the axillary artery. The medial fasciculus of the brachial plexus takes fibers from C8-T1 and gives 5 branches:

- 3 lateral branches: Medial pectoral nerve, medial cutaneous nerve of arm and medial cutaneous nerve of forearm.
- 2 branches: ulnar nerve and radix medialis nervi median (medial root of the median nerve) (3).

Above the axillary artery and then behind this artery, the posterior divisions of all three truncus incorporate to form the posterior cord that is smaller than the other cords (19).The posterior fasciculus (cord) of the brachial plexus takes fibers from C5-T1 and gives 5 branches:

- The three nerves where they emerge from the lateral side of the fasciculus are superior and inferior subscapular nerve and thoracodorsal nerve or middle subscapular nerve.
- 2 nerves are axillary nerve and radial nerve (12).

On the lateral side of the axillar artery, the anterior divisions of the superior and middle truncus fuse together to form the lateral cord. The lateral fasciculus (cord) of the brachial plexus takes fibers from C5-C7 and gives 3 branches which are lateral pectoral nerve, musculocutaneous nerve and radix lateralis branch of the medianus nerve (lateral root of the median nerve) (Figure 2.2) (14).

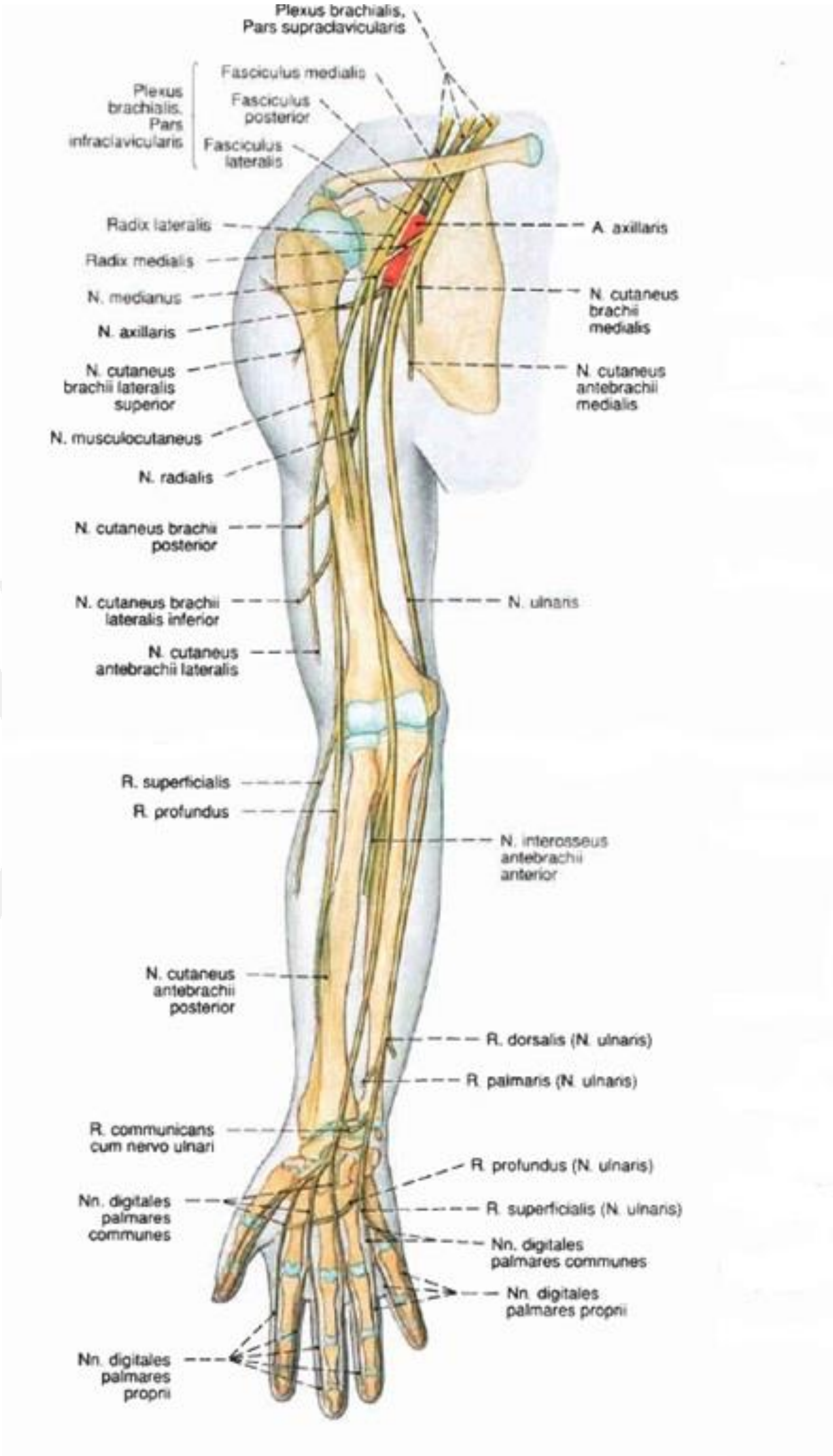

Figure 2.2. Brachial plexus distribution on upper extremity (20)

2.1.1. Variations of brachial plexus

In the literature, there is a classical definition of the network which contains the C5 to T1 nerve roots that are associated with three truncus, six divisions, three fascicules and five main motor and sensory divisions or branches to the upper extremity. In reality, numerous variation forms of the brachial plexus exist between patients (14). According to Uysal at al. (2003) 46.5% of subjects showed the normal plexus network while 53.5% of the subjects indicated considerable variations (21).

The one typical way for the variations of the plexus is may be the more caudal elongation than normal. Otherwise the most widespread variation involves the union of the ventral rami of the lower 4 cervical nerves and the greater part of the ventral ramus of T1 where C4 usually gives branch to C5 and T2 usually gives branch to T1. These contributions are leaded to frequent variations on the brachial plexus (14).

In some cases, absent of the bilateral or unilateral divisions of the truncus or cords may be seen but in these conditions the terminal branch formation may not be collapsed. In addition that lateral and medial cord may have fibers from above or below the normal level.

On the other hand, in some situations, median nerve may have 2 branches instead of 1 branch. It may be explained by the never fibers combinations that form peripheral nerve are hold on together. This condition is resulted in 3 subdivisions of the medial cord. 2 of these branches form the median nerve and all of these branches form the ulnar nerve. In some situations, there may come up different variations if medial cords are totally separated. Although there are 2 different branches that form the median nerve, the components of the median nerve are constant. For example impulses received from the same region, it will reach the same target area even if it goes from 1 or 2 roots (12).

2.2. Median Nerve

Median nerve is rising from anteromedial and anterolateral cords of brachial plexus. Therefore it is innervated by C5-T1 which makes up from lateral and medial cord of the brachial plexus (Figure 2.3) (2, 22).

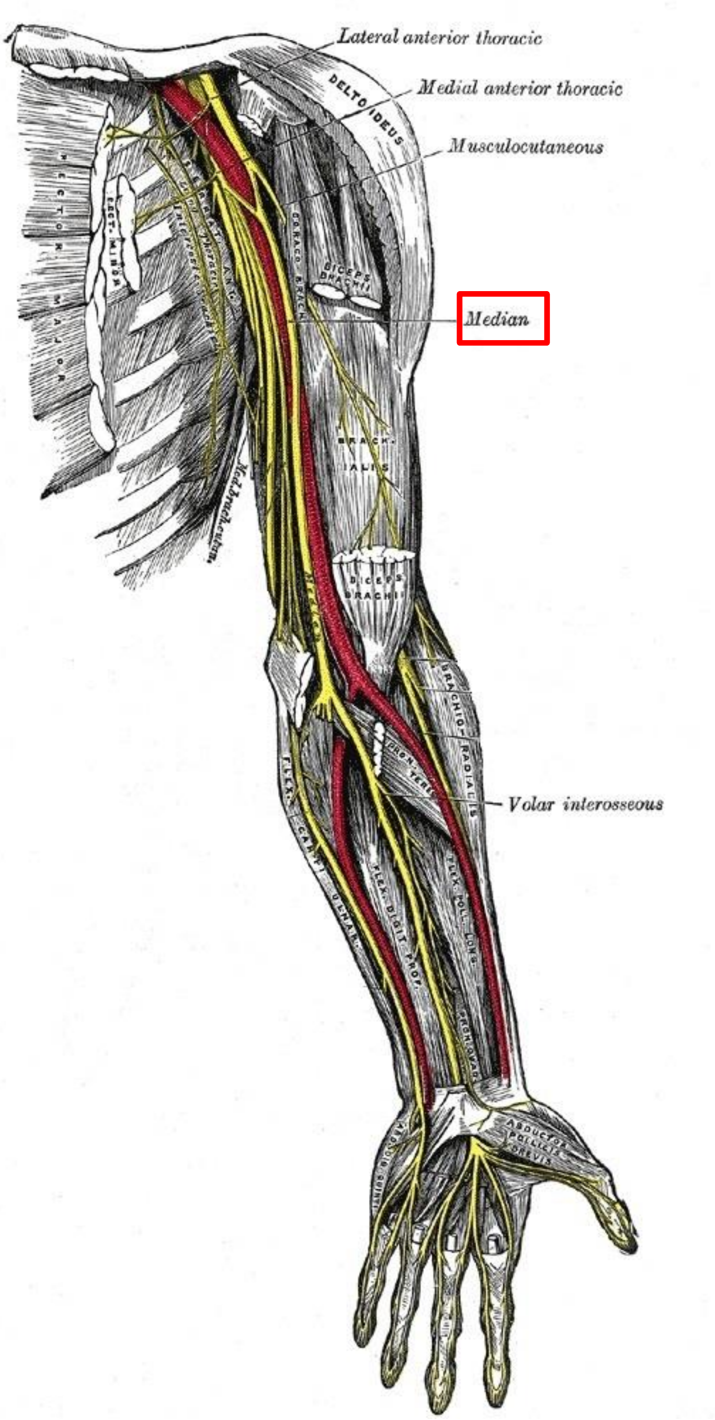

Figure 2.3. Median nerve distribution on upper extremity (23)

Median nerve which is called as one of the large nerve lay on the arm is formed by the lateral cord of the radix lateralis nervi median that is branched from lateral fasciculus or lateral cord and medial cord of the radix medialis nervi median which is branched from medial cord of the brachial plexus (12).

Median nerve constructs ‘S-Shape’ after moving down from axillar region and approach brachial artery laterally until middle part of the arm. While following this pathway it intercrosses brachial artery anteriorly and medially so neighbors to the brachialis muscle. Median nerve does not give branches on axilla and arm but it has divisions which go through the elbow (12, 22).

Median nerve is the most important nerve on anterior compartment of the arm. Median nerve exceeds under bicipital aponeurosis over the brachialis muscle and then between 2 heads of the pronator teres after going in cubital fossa and it gives branches to pronator teres. Median nerve follows inferior part of the aponeurotic arch of the flexor digitorum superficialis prior to cruising between the flexor digitorum superficialis and profundus muscles. During this path, it deeply presents the tendon of palmaris longus muscle (12, 22).

Median nerve has any branch on the arm except for little branches which are served to brachialis muscle. Its branches leave it at forearm and hand area. These branches are:

- Rami articularis: it is derived from the median nerve near the elbow joint during its pathway
- Rami musculares: it is derived from the median nerve. It supplies all the superficial muscles on front of the forearm which are flexor muscles except for the flexor carpi ulnaris and medial half of the flexor digitorum profundus muscle. This branch usually goes to elbow joint and goes in the lateral part of the pronator teres muscle. A bundle of nerve ream the superficial flexor muscle group and supply the flexor carpi radialis, palmaris longus and flexor digitorum superficialis muscles.

Nervus interosseus antebrachii anterior leaves the median nerve at distal part of the cubital fossa and it distally follows with anterior interosseous ramus of radial artery over interosseous membrane of forearm. This nerve cruises between flexor digitorum profundus and flexor pollisis longus muscle and reach to the pronator quadratus muscle so innervates these muscles. In addition that, it supplies ulnar nerve: medial part of the flexor digitorum profundus muscle (13).

Nervus interosseus antebrachii anterior ends while innervating flexor digitorum profundus muscle and running deeply pronator quadratus muscle after giving articular ramifications which reach to the wrist (Figure 2.4) (13).

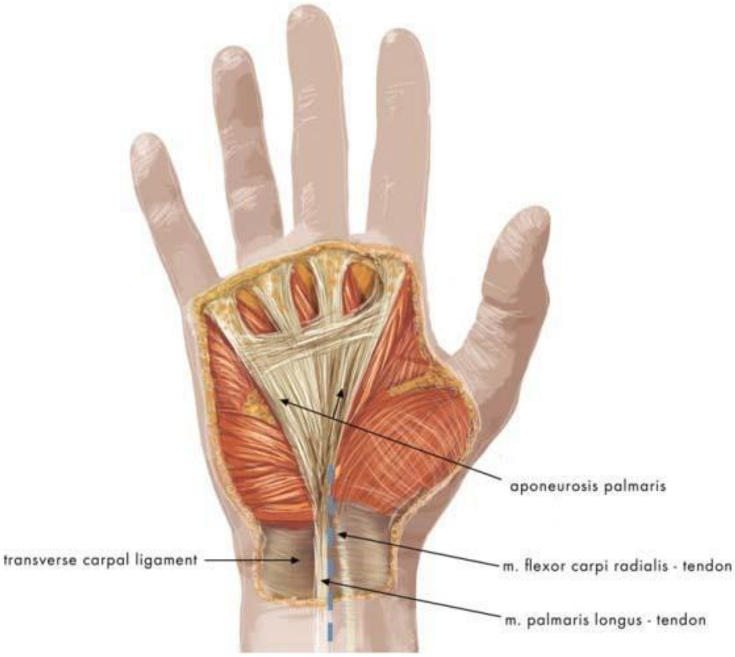

Figure 2.4. Median nerve at wrist (The route of the median nerve is signed with a dashed blue line) (25)

After the ramus recurrence of the median nerve (C8-T1) crosses the distal part of the retinaculum musculorum flexorum of the median nerve, it leaves from the nerve and supplies the thenar muscles (Figure 2.5) (12).

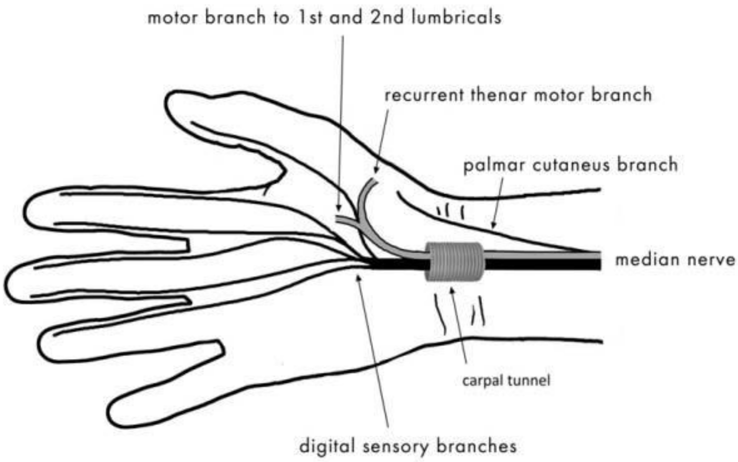

Figure 2.5. Median nerve distribution on hand (25)

Ramus cutaneous of the median nerve leaves the nerve at the proximal side of the retinaculum musculorum flexorum and travel superficially between tendons of the palmaris longus and flexor carpi radialis muscles. It supplies the cutaneous innervation of the palmar and lateral side of the hand (12).

Prior to the median nerve reaching to wrist, approximately 5-6 cm, it gives palmar cutaneous branch and reaches the palmar area through flexor retinaculum. It serves to the thenar area motor branch so innervates the radial sensation of the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} index (12, 13).

2.2.1. Median nerve innervation areas of hand

Median nerve has both motor and sensory nerve function. It involves branches from C5 to T1 spinal cord nerve roots. Median nerve entails to palmar cutaneous branch at the distal forearm level (5 cm proximal to distal transverse flexion curve of the wrist) and it gives sensory supply to the skin on the proximal side of the palm (14, 22). The sensory innervation is on palmar surface of radial 3 digits, half of fourth digit, part of thenar eminence; dorsal surface of last 2 phalanxes of radial 3 digits and radial half of the fourth digit. The motor distribution is on radial 2 lumbricals and thenar muscle compartment. It supplies innervation to opposition muscles which are short abductor of the thumb, oppenens polllicis, superficial bundle of the short flexor of the thumb and also first 2 lumbrical muscles (Figure 2.6) (1, 3, 22, 24).

Figure 2.6. Median nerve sensory innervation areas on hand (26)

2.3. Physiological Movement of Peripheral Nerve

The body motion has an essential role in nervous system apart from its existing function in our daily living lives. When the nervous system is examined, it keeps normal impulse conduction and it goes obvious that many of features relate to body motion.

Each part of the nervous system from axonal cylinder of peripheral nerve to the dural theca own specific features which preserve it during normal physiological movement. That’s why; it is not separated from mechanical components such as joint or muscle structures which provide to us to create a specific motion. In the case of impaired movement or decreased elasticity of the nervous system, symptoms or restricted motion can appear at its own tissues or different parts of the body.

The difficulty of nervous system structures underlines that it must be considered with mechanics and physiology of the nervous system. Because of the complex pieces of the system and close connections through the body and multi-tissue pieces, it shows reactions in a different way towards injury. It affects total neural and may non-neural structures (27, 28).

In a simple way, nervous system has adaptations to a simple or complex mechanical movement or to lengthening as a whole in 2 fundamental ways. These ways are:

1- As a result of the elongation of the nervous system branches, the progression of tension or increased pressure can be seen in these paths. And then it arises in all tissues and fluids that contain epineurium or dura mater. These tissues or fluids are generally closed with structure which is specialized its own anatomical components for example carpal tunnel.

2- The second adaptation is the movement. It can be separated in 2 topics: (a) gross movement and (b) movement which occur in interneural spaces between connective and neural tissues.

(a) Gross movements are determined as holistic movements and the nerve moves according to surrounding tissue. For example median nerve slides through the carpal tunnel in a longitudinal aspect but pathological conditions obstruct this movement adaptation (27, 28).

(b) Intraneural movement prepares actions of the neural tissues by the side of connective tissue interfaces. For example nerve fibers act in relation to endoneurium, in peripheral nerves and nerve roots a fascicle slips in relation to other fascicle. However, edema formation or fibrosis is expected to obstruct these mechanisms (27, 28).

2.3.1. Nervous system injury

In some cases, the nervous system physiologically or mechanically responds in a different way. If it encounters with a trauma that exceeds its own movement or stretch range, it may not adapt. The trauma is a term encompasses a wide scale so any part of the nervous system can not be excluded because there are patterns for the injury of the nervous system which are based on vulnerable anatomical areas. These sites are the most likely to have an injury or put forward itself after an injury. These vulnerable areas are:

1- Tunnels with osseous or fibro-osseous structure: Carpal tunnel with median nerve is one of the examples of the nervous system structure with tunnel that have specialized contents and the walls. In this tunnel, the tough structure of the wall has the more risk for the injury because the contents of tunnel buildings has the capability to create friction forces.

2- Branching areas of the nervous system: There is a potential risk when the main truncus is divided to branches with a rough or sharp angle where it loses its own sliding capacity and it becomes susceptible for the injury.

3- Comparatively fixed regions of the nervous system: The adherence of the radial nerve to the head of the radius and suprascapular nerve in the scapular notch are the examples of fixed areas.

4- The branches of the nervous system travel closely to the inflexible interfaces especially the divisions of the brachial plexus follow the way above the first rib. From this point, fascia is regarded as an inflexible interface that creates a potential friction force for the nervous system injury.

5- Previous traumas: The parts of peripheral nerve that is exposed trauma or irritation previously are susceptible to further injury. Even an injury which was not included with the nervous system before, it may predispose the system to a new damage for example an old fracture. It seems that, a subject can be possessed of a subclinical injury for months or for years and the indications from the previous injury may be taken action with a new damage to this site which is sensitized.

As a result, after a trauma or an injury in the nervous system where it can not adapt, there is an abnormal reaction from this system. This injury may be on vulnerable areas or may be on the non-vulnerable ones but the nervous system should be considered like an organ of the body. The physiological or mechanical reactions in the nervous system occur as a whole because of the continuity of the peripheral, central and autonomic nervous system (27, 28).

2.3.2. Peripheral nerve injury

The most common nerve traumas are observed due to friction, stretching and pressure on nerve and occupational disease which are mechanical and physiological issues. Also there are some lending factors to these topics such as posture disturbances and recurrent contraction of the muscle. To streamline the nervous system to an injury there may be formed a secondary factors. These are not included in direct injury for example lack of blood supply, alterations of axoplasmic flow, edema formation. Also abnormalities of the nerve anatomy may prepare the nervous system to have damage (27, 28, 29).

2.4. Pathological Process of Peripheral Nerve

The nervous system is considered as a continuous tunnel with structural walls. The contents of this tunnel are repeatedly changing with vascular and mechanical factors.

According to vascular factors of the peripheral nerve, the quantity of tunnel contents are changing with pressure level which is important to avoid entrapment neuropathy and to keep blood supply which is essential for the nerve to realize intrafascicular circulation and nerves normal mechanism (30). If the pressure level falls or tunnel pressure exceeds the vein pressure, the impairment of venous drainage may be seen. For example in CTS, the pressure is increased may due to flexor tendon thickening, edema formation or hyperplasia of synovial tissue With CTS condition, hypoxia and fibrosis may accompany to entrapment (30, 31, 32, 33).

In the following sequences of the vascular factors; elevation of the protein rich edema volume, fibroblastic reproduction, intraneural fibrosis, intraneural pressure and connective tissue stiffness are all bring along fibrous nerve cord in one fascicle (30).

In the peripheral nerve system, tunnels may have the friction forces on the nerve due to vascular abnormalities. Sunderland et al. has advocated that this condition can create the friction fibrosis and it may produce more pain and damaging effects. Millesi et al. suggested that if the nerve fibers lose its own longitudinal motion and distribution of created forces due to friction fibrosis, the nerve becomes more under risk of injury and creates more symptoms than intraneural course (30, 34).

The nervous system gets injured by mechanical or physical enforcements and may have impact on neural and connective tissue where it needs large forces to be damaged. Mechanical factors of the peripheral nerve may cause detriment with intraneural and extraneural blood vessel tears. In addition, the epineurium have more risk for the injury for example a minor trauma, mild compression pressure may lead to edema formation and its consequences. Because of this sensitivity, epineural tears are very common (30, 35).

There is a confliction about nerve injury factors. According to Fowler et al. and Ochoa et al. there is a great effect of mechanical forces on nerve compressions rather than vascular factors (36).

2.5. Carpal Tunnel

Carpal tunnel is a narrow fibro-osseous canal of 6 cm length under fibrous carpal ligaments which is a part of flexor retinaculum (transverse carpal ligament) and over carpal bones (1, 22, 24) and tunnel is taken form by U-shaped by these structures (37). Carpal canal has the function which brings about field to structures to pass from distal forearm to hand (38). The carpal bones form the floor and lateral walls of the tunnel and fibrous but rigid transverse carpal ligament forms canal's anterior roof (2, 24). Intercalarily, on the dorsal side of the wrist there is an annular group of ligaments to shape extensor retinaculum: on the volar side of the wrist there is volar carpal ligament. These dorsal and volar ligaments are able to revive like a set of annular bands which are allocated by longitudinal elastic components (Figure 2.7) (37).

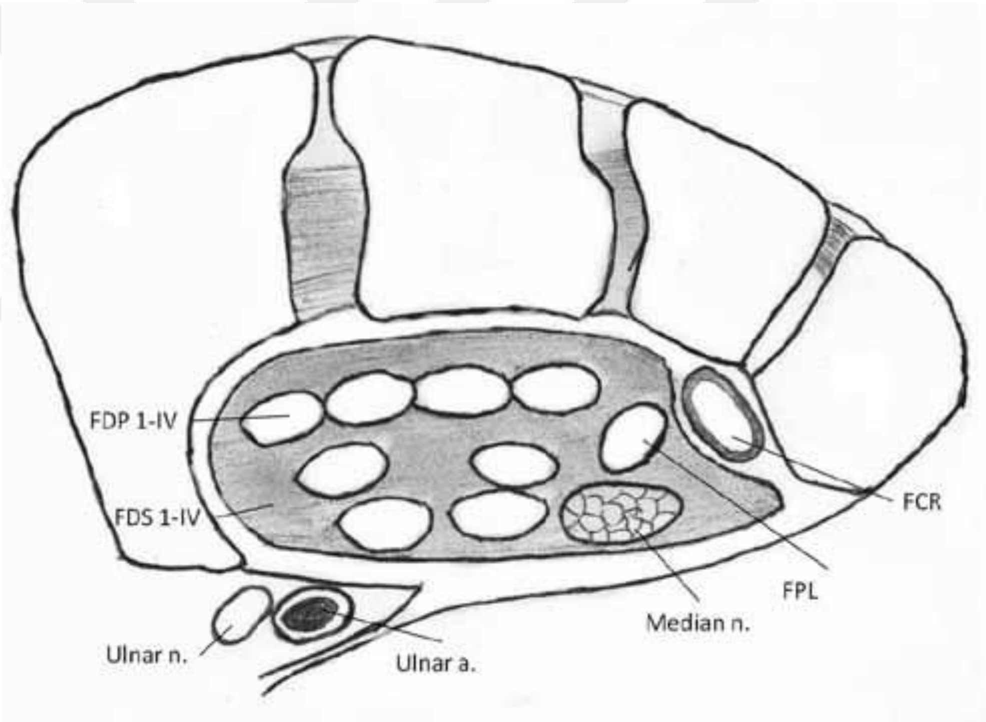

Figure 2.7. Axial section of carpal tunnel (24)

(FDS I-IV: flexor digitorum superficialis I to IV, FDP: flexor digitorum profundus I to IV, FPL: flexor pollicis longus tendon, FCR: flexor carpiradialis tendon a: artery, n: nerve.)

Carpal tunnel has the structure from surface to more deep part of the wrist:

- Cutaneous part
- Palmaris longus tendon
- Flexor retinaculum

Flexor retinaculum has the function to act like a strong flexor pulley for the flexors of the wrist and it attaches these carpal bones which are os scaphoideum and os trapezoideum laterally, os psiforme and hook of os hamatum medially and they are transforming the palmar arch into carpal tunnel (Figure 2.8) (24).

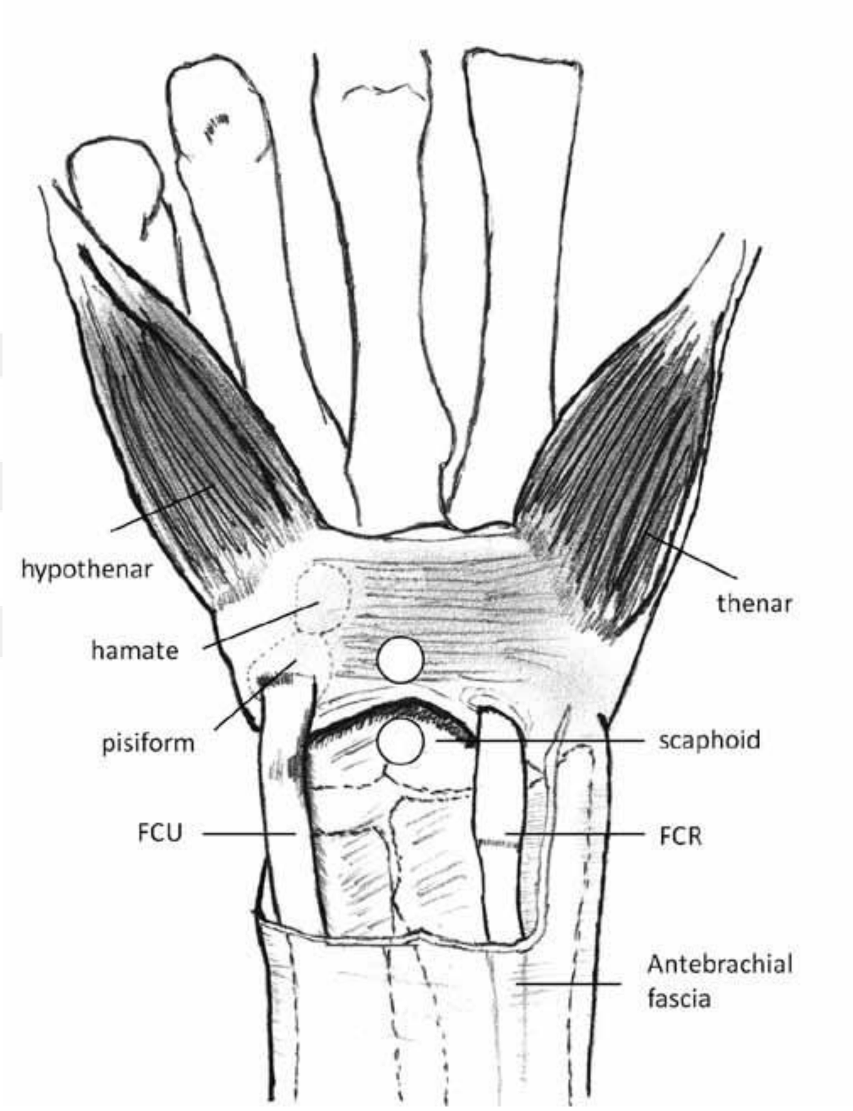

Figure 2.8. Flexor retinaculum and carpal tunnel (24)

(FCU: flexor carpi ulnaris, FCR: flexor carpi radialis)

The structure that passes the carpal tunnel:

- Tendon of flexor pollicis longus: It is the most radial element of the tunnel (38,39),
- 4 flexor digitorum superficialis tendons,
- 4 flexor digitorum profundus tendons ,

- Median nerve: Median nerve enters tunnel generally medial or slightly radial to center of tunnel (1, 38). It travels in the canal in a superficial position below the flexor retinaculum and goes across the flexor tendons of index and middle finger (2, 22).

Flexor retinaculum which is also named as transverse carpal ligament has 2 layers: one of them is superficial part and made up of palmaris brevis tendon, the second layer is the deepest one and constructed by transversal fibers (22).

Normal pressure level of the carpal tunnel is ranged between 2-10 mm Hg (1) and this pressure is increased by movement specifically wrist extension and flexion. In the case of decreased flexibility of the surrounding connective tissue and variations formed on the ligaments around the nerve, the pathological differences at the carpal tunnel result in increased tunnel pressure (37).

2.5.1. Wrist motion with carpal tunnel

During extension of the wrist: Longitudinal components are stretched and separated from annular bands on the volar side then squeezes dorsal elements. Wrist extension results in volar carpal ligament are pushed down on the carpal contents and during this movement flexor retinaculum preserves carpal elements from the stress. This motion also procures the proximal edge of the carpal bones to slide through concave surface of the radial head to opposite side through the concave surface of the radial head. Therefore carpal elements are tightened between volar carpal ligament and volar side of the carpal bones by the extension of the wrist (37, 39).

At the same time, volume of the carpal canal elements are increased and normal anatomical space is reduced by the wrist extension which includes flow of the proximal finger flexor tendons through space of the volar carpal ligament and the carpal canal (Figure 2.9, Figure 2.10) (37, 39).

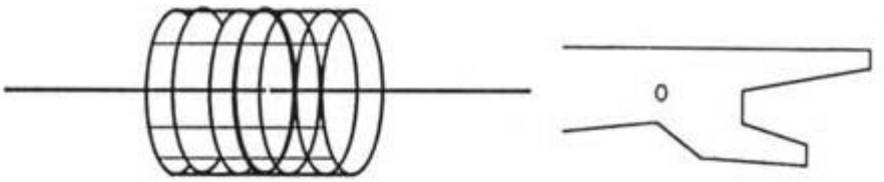

Figure 2.9. Wrist position in neutral (37)

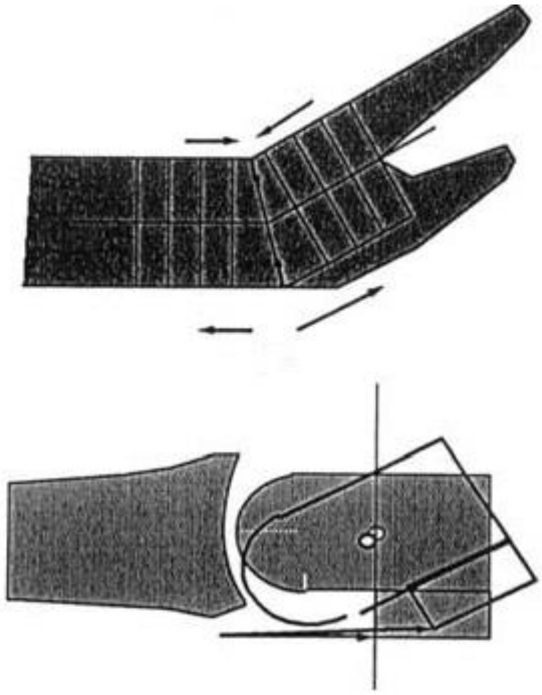

Figure 2.10. Wrist position in extension (37)

During flexion of the wrist: The fluid pressure is elevated within the canal. Proximal edge of the flexor retinaculum forces the flexor tendons across distal head of the radius. This flexion effect may lend to have larger diameter of the median nerve and it is usually monitored proximal portion of carpal canal. Also tendons and nerves are exposed to pressing force against surrounding anatomical structures. This results with a stretching force which is transformed from finger flexor muscles and is liable to friction because tendons slip forward and backward within the carpal canal (Figure 2.10) (37).

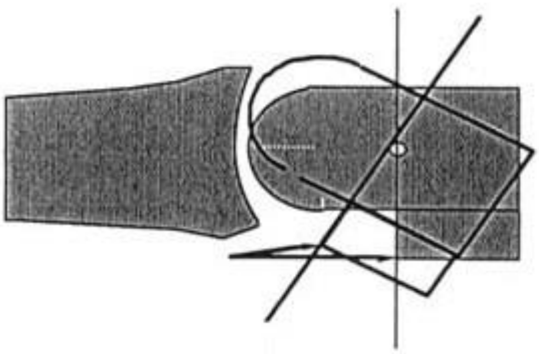

Figure 2.11. Wrist position in flexion (37)

The same pressure impact may be seen on the volar, radial and ulnar deviation motion of the wrist. Lateral dimensions of the section on the wrist are organized by radius and carpal bones. However these movements may not have same effect because of the smaller range of motion than extension or flexion.

A large number of studies have been demonstrated that ischemic compression of the median nerve may be seen because of the raised carpal canal pressure and external compressions (40). The nocturnal elevation of the carpal tunnel stress would result from reallocation of the upper limb fluids in supine position, decreased muscle pump mechanism which subscribes to the drainage of interstitial fluid in the canal, propensity to keep the wrist in the flexed position that increases intracanalicular pressure (3, 41).

2.6. Carpal Tunnel Syndrome

CTS is the most common peripheral neuropathy of the upper extremity among individuals and it contains 90% of all neuropathies. It is the disease spectrum which is related with the hand or wrist with median nerve (42). It occurs at the level of carpal tunnel traction and compression of the median nerve which has motor and sensory ramifications and brings out increased pressure with disrupted median nerve functioning in canal (1, 22).

The incidence rate is higher among females (9.2%) than among males (6%) aged between 45-60 years (1). The most CTS cases are idiopathic but some of them are due to fibrous hypertrophy of the synovial flexor sheath and some of them are caused by repetitive movements of wrist joint (12, 14, 37).

According to investigations, Sir James Paget mentioned firstly to the CTS in 1854. In following years, in 1912, Marie and Foix at all defined pathological modifications after prolonged median nerve compression. The first ‘Carpal Tunnel Syndrome’ diagnosis is mentioned by Pierre Marie. In 1933, the description of the first surgical decompression of the median nerve is made by Learmonth who was worked on a case that post-traumatic with osteoarthritic osteophytes (12, 43).

Phalen GS who has the many publications about the carpal tunnel syndrome put forward that thickening of the synovium or fibrosis that leads to increasing volume of the synovial sheath through canal is the most common cause of the CTS in 1966. All factors are necessarily influenced by age, gender, genetic, anthropometric condition that may contains length or width of carpal canal. These variables especially concern the idiopathic CTS (44, 45).

2.7. Pathophsiology of Carpal Tunnel

The pathophysiology compasses a compound of recurrent micro-traumatic stretching and mechanical compression. And also CTS pathophysiology covers combination of compression and traction phenomena. A normal nerve submits independent movement during flexion and extension of the wrist joint and fingers. It moves through the carpal canal without any limitation or mechanical stress. In the case of these limitations, scantiness of intraneural microcirculation of the median nerve, synovial tissue hypertrophy, lesions at the level of myelin sheath of the nerve and its axon, and also changes in the surrounding median nerve connective tissue may be seen (3, 22). The increased pressure at the carpal tunnel results from tightening of the normal anatomical field of canal. It evokes changed functioning of the nerve and results with malfunction or damaged nerve at the level of compression and on the further side of the nerve (3, 46). The median nerve malfunctioning in the carpal tunnel is secondary to stresses median nerve through canal which is resulted in mechanical stress and regional ischemia (32, 37).

There are wide variety causes of the CTS in the literature which are;

- diabetes mellitus,
- pregnancy (after birth, symptoms are frequently lost),
- menopause,

- repetitive strains,
- the fracture of the wrist or the distal radius,
- obesity and hypothyroidism,
- the heredity of the small carpal tunnel size,
- rheumatoid arthritis,
- chronic gout,
- renal failure,
- the usage of the oral contraceptives
- congestive heart failure can increase the hazard of the CTS (3, 22). Especially diabetic patients are more under risk of CTS with the prevalence of clinical CTS rate of 14% without and 30% with diabetic polyneuropathy (22).

The remainder and other possible causes of the CTS have extrinsic factors which cause compression with various anatomical conditions. These are due to;

- muscles and tendons: palmaris longus, palmaris profundus, flexor digitorum muscle or lumbricales,
- synovitis at the wrist or tenosynovitis at the flexor tendons,
- tumors which are ganglion cyst on the wrist, lipoma, hamartoma, hemangioma and different lesions arising from circumambient tissues.

At the same time, there may be intrinsic factors that cause CTS which is neurogenic neoplasm involves neurinoma and neurofibroma. (22).

There are gradual problems that caused by compression and traction combination of the nerve or may causes compression and traction of the nerve and these problems are increased tunnel pressure, intraneural blood microcirculation and connective tissue alterations. These topics are related with each other and in some cases they may gradually follow each other about nerve entrapment.

2.7.1. Tunnel pressure alterations

There are 2 sites for the median nerve compression:

1. During wrist flexion, median nerve may be squeezed at the level of proximal carpal tunnel due to alterations of the thickness, stiffness or rigidity of the fascia of the forearm and proximal edge of the flexor retinaculum.

2. Compression can be observed at the narrowest level that near to the hook of hamate bone (39).

Normal pressure at the carpal tunnel is changed by the wrist joint motion and has changes in fluid stress. Bauman et al. recorded with their study that the canal pressure is higher in idiopathic CTS patients than normal participants (47).

The main reason for the raising pressure in the tunnel, pathological alterations present in the ligaments ambient nerves that have environmental connective tissue with decreased flexibility is explained. These structures have the pathological alterations and follow this continuous pathway (3, 48).

There are studies have investigated that there is a relation between the median nerve malfunctioning, the sum of the duration and the quantity of the pressure stress in the tunnel. The increased pressure that is caused by externally implemented stress produces ischemic compression (3, 48).

2.7.2. Microcirculation alterations

Vascular topic of the nerve is a significant component of the CTS. The internal cells of the perineurium and endothelial cells of the endoneurial capillaries which are attended the median nerve from inside the carpal canal compose the blood-nerve-barrier (3). An elevated stress on the canal may produce faulty on the vasculature in the barrier. The lack of blood supply which is termed as venous stasis turns to hypoxia. This leads to deficiency of nutrient through the nerve fibers which may termed as neuroischemia. It may be the origin of the pain formation and may continue as the parasthesia (27). This condition triggers the mass of inflammatory cells, formation of proteins, endoneurial fluid and intrafascicular edema (49, 50). The pressure in the endoneurial and intrafascicular fluid are increased because lymphatich structures can not diffused in perineurium and edema is trapped along the nerve trunk. In these spaces mechanical pressure add more damage on capillaries and blood-nerve-barrier is not as effective as before. Then nerve may swell proximal area to the area where there is no compressive elements. Subjects who have the prolonged stress or vascular problems are susceptible to have failure on the blood-nerve-barrier (Figure 2.11) (27, 51, 52).

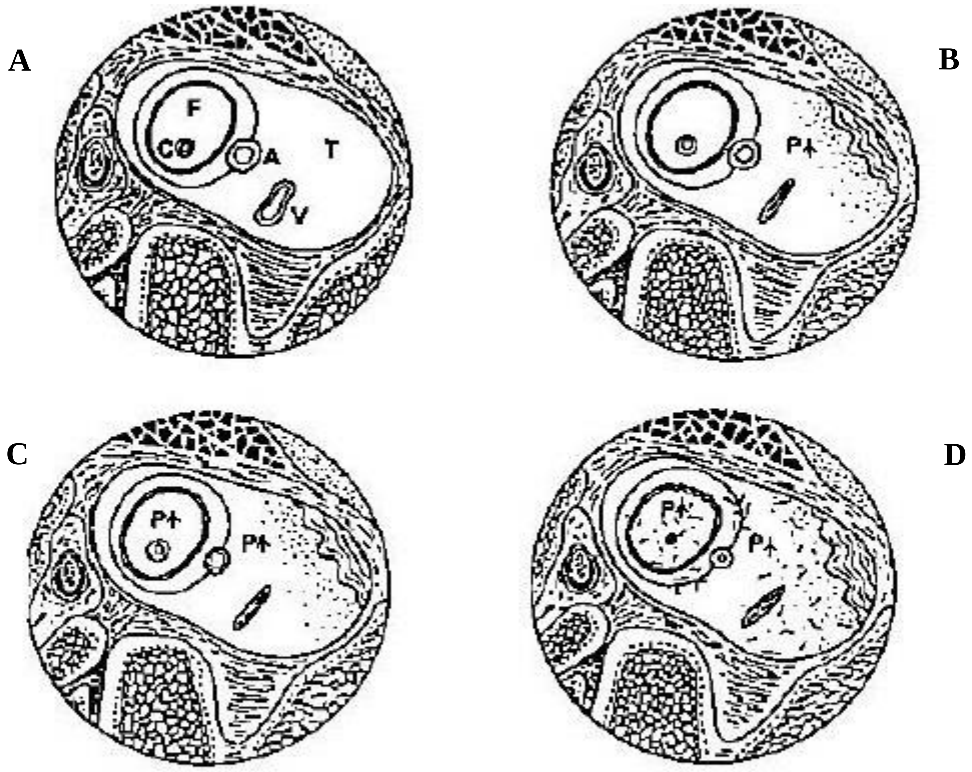

Figure 2.12. Pressure gradients in carpal tunnel (27).

Normal carpal tunnel, A.

Hypoxia in carpal tunnel, B.

Edema in carpal tunnel, C.

Fibrosis in carpal tunnel, D.

The other cause for the potential of the nerve compression is microvascular structure alterations of the nerve, irritated due the biochemical changings which causes to decrease in endoneurial blood flow and oxygen pressure (53). Regional compression causes to alterations in the intraneural circulation and causes raising the permeability of endoneurial vessels. This concept leads to edema formation in the endoneurial field. Because of the edema formation, diffusion space between capillaries where oxygen is diffused is increased and hypoxia may be provoked (3, 53).

2.7.3. Connective tissue alterations

Nerve fibers have sheets that surround them and these layers are mesoneurium, epineurium, perineurium and endoneurium. The nerve gliding which is related to only epineurium is associated with nerve layers' extensibility and this motion is essential for the joint movement (54). The normal median nerve length is approximately 9.6mm from full flexion to extension or visa versa. However in the loss of rigid surrounding connective tissue, this motion distance is limited and subjects the nerve to shearing forces and may leads to nerve injury (55).

Researchers have investigated that during extremity movement, median nerve is pulled longitudinally and it has transverse movement which is observed in wrist positioning or during finger flexion towards to resistance. Median nerve's length during flexion is 9.6 mm as mentioned before and 0.7-1.4 mm during wrist extension in the carpal tunnel which is reduced in carpal tunnel pathophysiologic reconditioning and this brings the irritated median nerve, increased pressure on the nerve trunk with edema and obstructed venous flow (1, 3, 5). Depending on the position of upper extremity and its movement, the position of upper extremity joints, median nerve uses tension changes and gliding movements to meet new states (4). The length of the median nerve is attached to shoulder, elbow, wrist and finger location. Median nerve strain differs from 8% subjecting to position of shoulder, and 19% depending on the position of the fingers (3).With the median nerve adaptation to changed conditions of the surrounding structures which shows decreased gliding of the nerve, it results in increased symptoms and limitations of the movement (4). In the compressive status and epineural adhesions, the movement is reduced and making lesions because of the repetitive traction on the nerve path during motion (3).

Lundborg and Dahlin et al. underlined with their studies the continuous mechanism of the nerve compression and traction that leads to nerve damage. A gradual elevation of the pressure on the nerve trunk propagates the pressure slope that redelivers structures of compressed tissue to the field that not compressed. Epineurial and vascular components start to stretch. The formation of the edema, especially in the epineurium, causing to nerve swelling and limits the motion of the nerve through the already narrowed carpal canal. This violent continual situation of the structures decreases the amount of the nerve gliding during limbs movement, elevates the stress on the nerve trunk and formation of the edema (3, 53).

2.7.4. Synovial tissue alterations

One of the reasons of increased pressure in carpal canal is the hypertrophy of synovial tissue. It usually occurs between the flexor tendons of the tunnel and causes the development of the syndrome (45).

There are several studies searched the tenosynovitis which is related factor for CTS. They find out that rising fibroblast density, size of collagen fiber and type III collagen result in synovial tissue increase in the synovial connective tissue (3).

There is tissue which surrounds the median nerve and constricts the nerve; it may cause the nerve compression. Within the carpal tunnel, the increment of inflammatory and thickened synovial tissue increase body of the tissue and then fluid pressure. The most thickening of the tissue have seen at the entry of the canal. The entrance and exit areas of the canal contain tendons which slide on flexor retinaculum (3, 37).

2.7.5. Associated pathological conditions

With the all forms of the polyneuropathy that encompasses diabetes mellitus, it encourages the CTS with constructional and functional changes of the median nerve. It provides the nerve more sensitive to all forms of compression.

Nerve compression syndrome or double constriction syndrome presents on the proximal portion of the nerve and this squeezing makes the nerve more suspicious. If the compression is located more distal portions, it will have less cumulative effect on the nerve. (39, 57).

2.8. Epidemiology of Carpal Tunnel

A thumping majority of the cases are defined as idiopathic CTS and secondary CTS may be interested with abnormalities of the canal or the structures. In addition of all these factors and causes, researchers have given point to dynamic factors that include environmental and occupational conditions. People may have repetitive task, repetitive force, posture misalignment and prolonged vibration on their wrist (3, 22).

2.8.1. Idiopathic CTS

The idiopathic CTS is more frequent in women with the ratio of 65-80% between ages of 40 and 60. The most cases are bilateral with the ratio of 50-60% (58). Degeneration of the surrounding connective tissue, sclerosis, edema and collagen disruption bring about hypertrophy of synovial membrane of the flexor tendons. The most significant streamline factors which are sex, age and anthropometric factors affect the impression ratio. In addition to these elements, obesity, smoking, repetitive movements, vibration, cold temperatures are involved affecting factors (39, 59).

2.8.2. Secondary CTS

2.8.2.1. Abnormalities of carpal tunnel

- Anomaly of the form or location of the carpal bones that may be dislocation, subluxation or fracture.

- Conditions about distal extremity of the radius affect the container which may be fracture, inclined bone position, osteosynthesis material.
- Joint anomalies that can be wrist arthrosis, inflammatory or infectious arthritis may be involved (39).

2.8.2.2. Abnormalities of structure

- Hyperthrophy of the tenosynovium,
- Inflammatory tenosynovitis which can be inflammatory rheumatism, lupus or infection,
- Metabolic tenosynovitis that involves diabete mellitus, amyloidosis and gout,
- Differences in fluid dispersion on pregnancy particularly third trimester and chronic kidney failure,
- Abnormity of the muscles,
- Stable arterial hypertrophy of the median nerve,
- Intra-cannal tumors that contains lipoma, synovial cyst, sarcoma or neural tumor,
- Hematoma,
- Obesity has affects on the secondary CTS (39).

2.8.3. Dynamic CTS

The compression of the carpal canal is elevated during wrist movement especially in repetitive wrist flexion and extension positions along with flexed finger and supinated forearm which are used repetitively in daily living life (39). Researchers have been reported that with the wrist extension, the pressure is elevated by 10-fold and also with the wrist flexion, the pressure is deepened by 8-fold (37).

2.8.4. Acute CTS

The acute CTS may be caused various topics:

- Trauma that may involves distal radius fracture, wrist dislocation,
- Infection,
- Hemorrhage because of the anticoagulant usage for hemophilia,
- High-pressure injection,
- Median nerves acute thrombosis,
- Burns (39).

2.9. Symptoms

In case of neuropathy of the median nerve, it is characterized with sensory loss and motor weakness on the narrowed carpal canal side (4). In addition that, there are studies indicate that large myelinated sensory fibers (Aβ) are more under risk of mechanical compression where CTS affects primarily large fibers. Small fibers may be affected end stages of mild cases of CTS (60). Therefore peripheral nerve fibers are affected before more central parts and myelinated fibers are responds prior to smaller fibers. In addition, sensory fibers are imposed before motor fibers (39).

On the affected side; intermittent or persistent numbness (especially during full wrist extension or full wrist flexion), tingling, burning, pain in daily living (diurnal pain) or awakening night pain (nocturnal pain) may be seen. Subjects may relief symptoms by shaking their hand due to increased pressure in the canal. The most common sensory symptoms present in all digits and after median digits. There may be present a glove hand distribution. At the same time dominant hand is usually involved first and may have these symptoms in first place. (2).

Although the symptoms are thought to be at the median nerve innervation areas, Stevens et al. committed that CTS symptoms are usually in both median and ulnar nerve innervated digits despite median nerve innervated digits alone. They noticed the position of the symptoms from patients; 21% of them have forearm pain and paraesthesias, 13.8% of them have elbow pain, 7.5% of the subjects report arm pain, 6.3% of the patients has shoulder pain and 0.6% of the patients have neck pain according the study (37, 61).

There are also secondary symptoms which might be pain, numbness or clumsiness. These symptoms may not be correlated with the nerve compression according to You et al. They indicated that these secondary symptoms can be related to other factors especially tenosynovitis which is determined as inflammation of the synovium of the flexor tendon. The other causative factors of the tenosynovitis are fibrosis and edema rather than inflammation (37, 62).

2.10. Neurodynamic Techniques

Neurodynamic techniques are the developing concepts of the tests and also treatment techniques of the movement restriction. They are based on movement and treatment of the different nerves on anatomical pathways and member of the total treatment concept. They should be combined different treatment of the nerve and other anatomical structures. In this manner, they have significant and intentional aims in activity of the body (28).

Neurodynamic tension tests are used in peripheral nerve evaluation and treatment with mechanical loading concept. Within the peripheral nerve, heightened sensitivity according to mechanical load has been based on local inflammation, ischemia, or changed local circulation and its specific surrounding connective tissue (63). During technique, the nerve is tested or treated based on mechanical and physiological adaptation process with position and mobility of different anatomical structures (4).

In the upper extremity, to assess altered nerve trunk mechanosensitivity of the cervical roots and physical capabilities, neurodynamic tension techniques are widely used (6, 64, 65). Neurodynamic tension techniques have 5 Upper Limb Tension Test (ULTT) for the upper extremity which are:

- ULTT1: In this test median nerve heavily takes the tension with shoulder abduction.

- Modified ULTT1: Median nerve takes the tension without contralateral cervical flexion.

- ULTT2a: Median nerve is dominant nerve with the usage of shoulder girdle depression and shoulder external rotation.

- ULTT2b: Radial nerve is predominant nerve in this test. It is practiced by shoulder girdle depression and shoulder internal rotation.

- ULTT3: Ulnar nerve is the dominant nerve because this test is applied by using shoulder abduction with elbow flexion (27, 28).

Kleinrensink et al. researched that despite other ULTT tests for ulnar and radial nerve ULTT1 is more sensitive and specific test (66). Combinations of the movements of the different upper limb joints provide tension to the median nerve, dermatomes of C5, C6 and C7 nerve roots (67) and central connections of the brachial plexus. In this manner, different parts of the nerve and its surrounding soft tissue are stressed and they glide according to position relative to its joint axes and nerve bed is elongated (4, 7, 27, 64).

Abnormal neural responses which may be deep stretch, ache sensation or tingling during ULTT1 can enclose issues with extensibility, gliding or irritability of the nerve throughout its pathway. These responses or symptoms are experienced by the subjects and reported subjectively. Thus, sensitized neural tissue may become non-compliant to an increase in relative length and dimension of the nerve bedding and length of neural structures that surround the nerve is changed (4, 63, 64, 68, 69).

According to studies, it is commended for pathological conditions of median nerve evaluation (4). During ULTT1, intraneural swelling or edema and circulatory leakage is reduced with fluctuating effect on intraneural pressure, altered intraneural blood flow, impulse traffic and axonal transport. Pumping action or milking effect has beneficial effects on nerve hydration during dynamic intraneural pressure alterations (70, 71)

2.10.1. ULTT1 and CTS

Neurodynamic techniques are becoming a common therapy option for the CTS patients because this technique repairs dynamic balance between the nerve and its tissues that its neighborhoods. This technique improves anatomical aspects and physiological conditions of the nerve. Therefore application for the median nerve, decreases its negative consequences and symptoms that experienced by the subjects such as adhesion of the surrounding tissues, impaired blood supply, decreased nerve nutritioning, axonal transport and pain. Repaired nerve conduction by the neurodynamic technique, improves pain sensation that felt by the patient who suffer from median nerve compression or traction at the wrist and improves nerve conduction (72). For the purpose of increasing the density of innervation of the skin (touch receptors) and for the innervation of the somatosensory cortical representation of the hand and median nerve innervated skin neurodynamic techniques can be used (9).

3. MATERIALS AND METHODS

3.1. Participants

This study was managed with 32 people who are willing to participate from the society to the research and they were concluded Boston Carpal Tunnel Questionnaire (BCTQ). Participants concluded ULTT1 technique at Özel Sempati Özel Eğitim ve Rehabilitasyon Merkezi (Appendix 1). To search effects of ULTT1 on CTS symptoms, participants who have score that bigger than 11 points and less than 45 points according to BCTQ are involved to study. The observations were made between March 2020 and May 2020. This study was approved by Marmara Üniversitesi Sağlik Bilimleri Fakültesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu (Marmara University Non-interventional Clinical Research Ethics Committee) (Appendix 2).

3.1.1. Inclusion criteria for the subjects:

- Participants who have score >11 points on the BCTQ,

3.1.2. Exclusion criteria for the subjects:

- Participants who have score ≥45 points on BCTQ,
- The positive Spurling test (64),
- History with symptoms from cervical region or the upper limbs or fracture,
- Range of motion limitation in any of the movements required to perform the ULTT1,
- Muscular atrophy of the thenar eminence,
- Neurological signs,
- Rheumatoid disease, diabetes, pregnancy,
- Trauma history to the wrist,
- History of surgical or conservative treatment for CTS.

3.1.3. Flow chart: Study protocol

All participants were informed about the research before assessments; signatures were taken (Appendix 3). Participants answered some questions about physical activity, demographic characteristics features such as age, gender, height, body weight, dominant hand and other information. The form that includes information about their general health status and demographic features is filled by their own in Turkish language (Appendix 4).

The assessments started with BCTQ (Appendix 5), Visual Analogue Scale (VAS) (Appendix 6), Pain Catastrophizing Scale (PCS) (Appendix 7) and Semmes-Weinstein Monofilament (SWM), Joint Position Sense (JPS) were evaluated (Table 3.1).

Table 3.1. Flow chart of study

Assessment for eligibilitiy
(n=32)
Boston Carpal Tunnel Questionnaire (BCTQ)

Before Therapy Assessments
Demographic Characteristics
Semmes-Weinstein Monofilament (SWM)
Joint Position Sense (JPS)
Visual Analogue Scale (VAS)
Pain Catastrophizing Scale (PCS)

ULTT1 therapy

Immediately After Therapy Assessments
Semmes-Weinstein Monofilament (SWM)
Joint Position Sense (JPS)
Visual Analogue Scale (VAS)

1-Week Follow-up Assessments
Semmes-Weinstein Monofilament (SWM)
Joint Position Sense (JPS)
Visual Analogue Scale (VAS)

3.2. Evaluations

3.2.1. Boston Carpal Tunnel Questionnaire (BCTQ)

The BCTQ is a self-administered questionnaire which is reproducible, internally consistent, valid, and responsive to clinical change for assessment severity of symptoms and functional status in CTS and who are susceptible for CTS. It contains symptom severity scale (BCTQ-sss) that have 6 critical domains: pain, parasthesia, numbness, weakness, nocturnal symptoms over-all functional status. Symptom Severity Scale includes these 6 important fields (71). This scale has 11 questions with multiple-choice responses. They were calculated as mean of the scores for 11 items which is scored 1 point (mildest) to 5 points (most severe). The score that 11 point is no symptom, between 12 and 22 point is mild, between 23 and 33 point is moderate, between 34 and 44 point is severe, between 45 and 55 point is very severe (63, 70).

The functional status scale (BCTQ-fss) was also included in this questionnaire affected by possible carpal tunnel syndrome symptoms and has 8 activities. Functional status evaluates how the symptoms that patients' experience affect daily living activities. The responses were scored from 1 point (no difficulty) to 5 point (can not perform) and over-all score is the mean value of all 8 items. The score that 8 point is no difficulty, between 9 and 16 point is mild difficulty, between 17 and 24 point is moderate difficulty, between 25 and 32 point is severe difficulty, between 33 and 40 point is very severe difficulty. The higher scores show subjects insufficient functional status capacity (Appendix 5) (63, 70, 71).

3.2.2. Visual Analogue Scale (VAS)

The VAS is used to assess the severity of pain subjectively of participants. Subjects indicated their pain severity on along a distance of 10 cm line, started with 0 point (no pain) and ended with 10 point (most severe pain) (Appendix 6) (74).

3.2.3. Pain Catastrophizing Scale (PCS)

The PCS has 13 items and is a self-reported questionnaire and contains 3 subscales. It measures different features of pain catastrophizing which are rumination, magnification and helplessness. The rumination measures ruminative thoughts and inability to obstruct pain related thoughts. The magnification scale measures condensation of the unpleasantness of pain and expectancy of negative outcomes. The helplessness reflects insufficiency to cope with pain. It uses 5-point Likert scale (0-4) and was developed by Sullivan et. al. This inventory measure the responses to pain in people who catastrophize the pain (Appendix 7) (60, 72).

3.2.4. Semmes-Weinstein Monofilament (SWM)

Sensory evaluation was performed by SWM. It contains 5 filaments which are ranged between 2, 83 level (0, 07 grams force) and 6, 65 level (300 grams force) and they were applied to skin. The procedure is explained to subjects and made sure that subject can not see the filament with their head turned away from the table and closed their eyes during application for the median nerve palmar surface of the thumb and index finger evaluation. While holding the handle of the filaments, it was pushed 90◦ vertically and kept 1.5 seconds. If they can feel the pressure on their hand they should respond verbally 'yes' or if they can't feel the pressure they should respond verbally 'no'. Firstly the lightest filament was used (2, 83 level or 0, 07 grams force). One filament was applied 3 times and if the subject felt 2 of 3 trials this filament number was recorded. If participant responded to test at all regions, normal cutaneous sensation is noted or if can not feel a thicker filament was applied in ordered levels with same way (Figure 3.1) (75, 76).

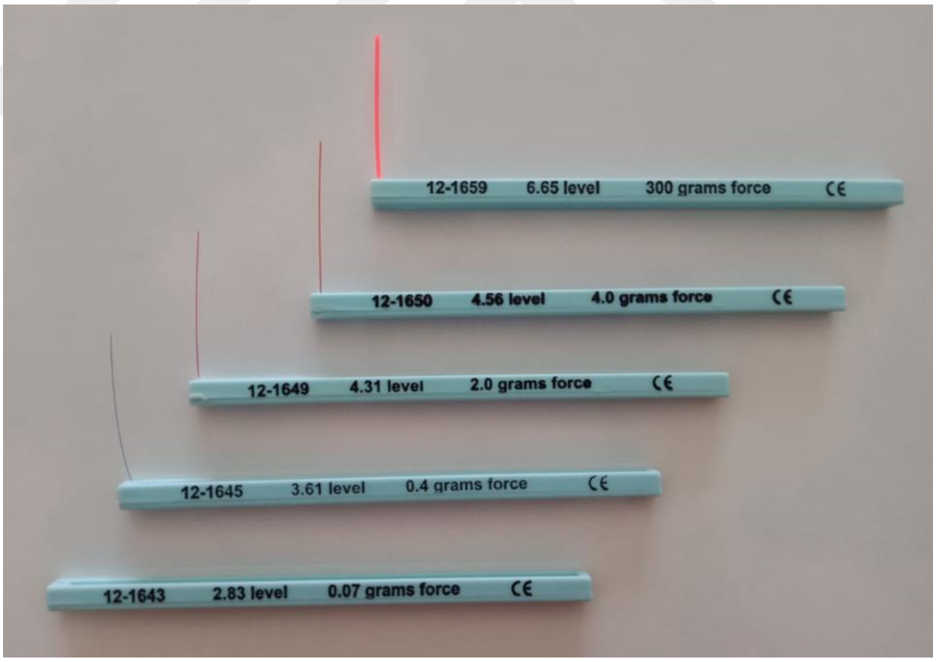

Figure 3.1. Semmes-Weinstein Monofilaments

3.2.5. Joint Position Sense (JPS)

Joint position Sense (JPS) is defined as conscious sense of the joint and it evaluates proprioception of the position of the joint. To put forth the affected proprioceptive pathways of the previously determined joint angle, it is used for the evaluation of the motion according to reference point from the same side joint is used (77).

Without visual information, after passive wrist motion administered by the therapist participants try to uncover the same movement actively on their wrist. During evaluation, the elbow of the participant should be positioned on the table and maintained stable with closed eyes. During affected side assessment, electronic goniometer is put on wrist reference point (ulnar styloid process) and wrist is flexed 20^{o} and 45^{o} and extended 20^{o} and 45^{o} by therapist separately. After each target angle and position, subject's wrist is turned back to the neutral position and asked to get the wrist actively to the angle that passively positioned. Each reference point is repeated 3 times and average value is noted (6).

JPS is repeated before, after and 1 week after neurodynamic technique ULTT1 for the subjects by Baseline Evaluation Instruments Digital Absolute + Axis Goniometer Electronic Goniometer (Figure 3.2).

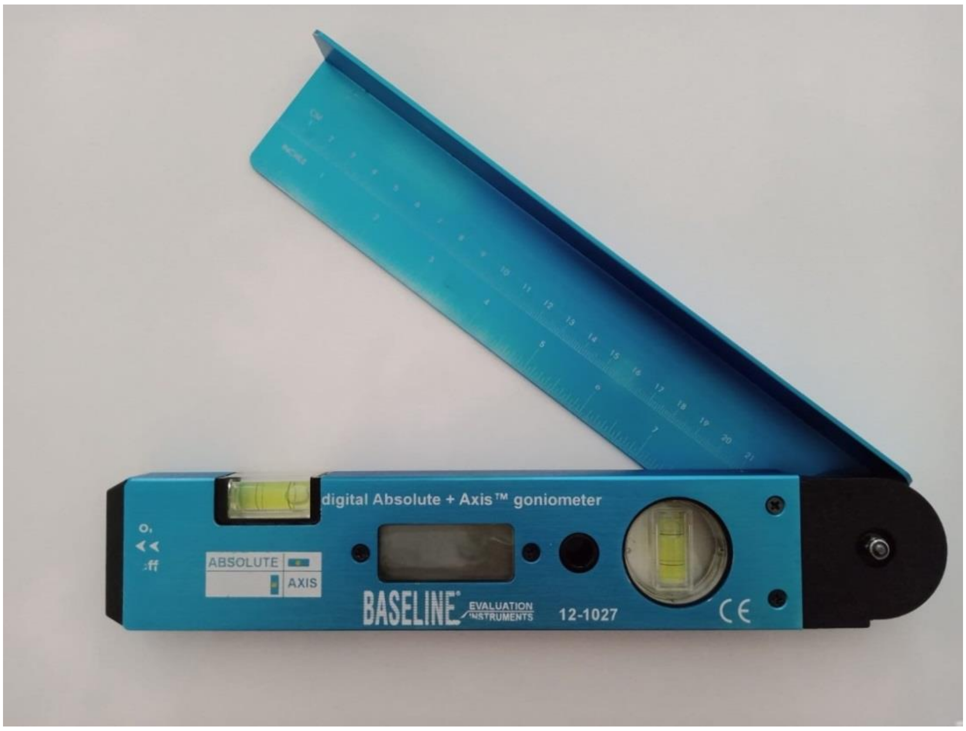

Figure 3.2. Electronic goniometer

3.3. Intervention

3.3.1. Upper Limb Tension Test 1 (ULTT1)

ULTT1 technique has 6 stages that have full range of finger, wrist, elbow, shoulder and neck motion. When starting the treatment of the ULTT1, participant is positioned supine without a pillow. Participants' side to be included treatment is near the edge of the bed which allows the shoulder girdle is controlled by examiner.

- *Stage 1. Shoulder girdle depression:* Shoulder girdle is depressed constantly during movement by therapist by using fist or hand. Therapist's one hand holds the subjects involved side of the hand to be sure for the check the fingers. During abduction on stage 2 shoulder girdle elevation must be prevented.
- *Stage 2. Glenohumeral abduction (behind the coronal plane):* Approximately 110◦ glenohumeral abduction is applied in the coronal plane. The abduction component can be done by using therapist's thigh to maintain control on abduction angle
- *Stage 3. Glenohumeral external rotation:* Following the glenohumeral external rotation, position is maintained by therapist who can put more control on the patient's arm if the patient's abduction stage is performed on physiotherapist's thigh.
- *Stage 4. Forearm supination*
- *Stage 5. Elbow extension*
- *Stage 6. Wrist and finger extension:* Final position of this test is depending on the participant's responses (Figure 3.3, Figure 3.4, Figure 3.5) (27, 67).

Figure 3.3. ULTT1 technique: Stage 1 and Stage 2

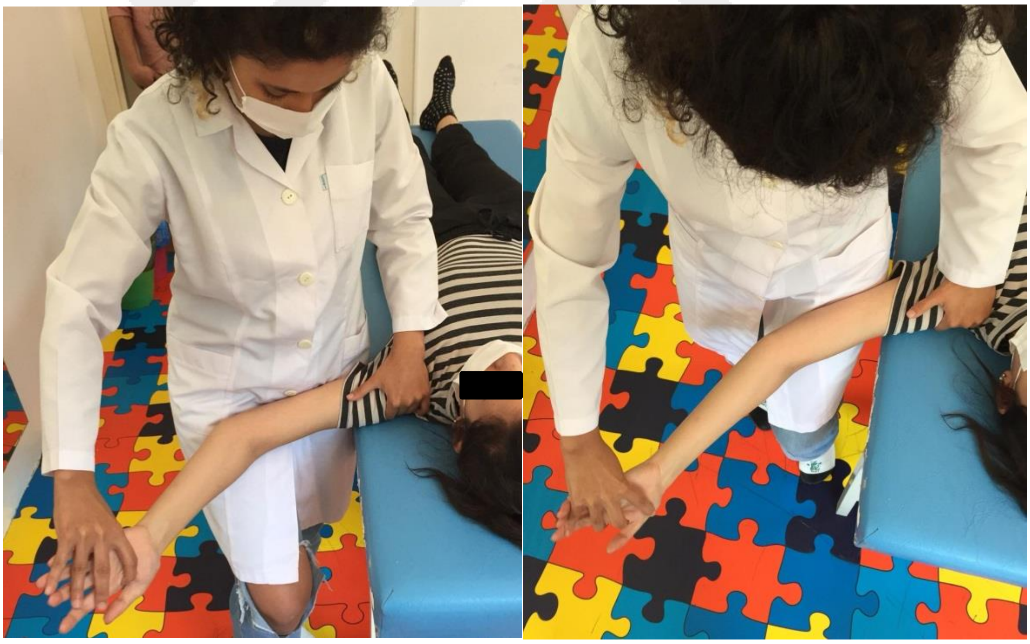

Figure 3.4. ULTT1 technique: Stage 3 and Stage 4

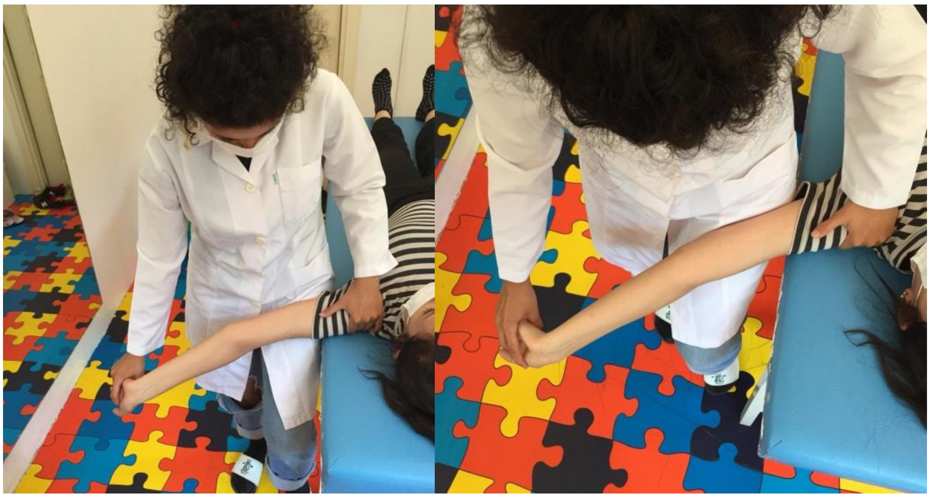

Figure 3.5. ULTT1 technique: Stage 5 and Stage 6

During application of these stages the most essential step is to maintaining each part before adding the next stage. The responses gained from the subjects must be observed and noted. If there is any discomfort from subjects, the ranges are decreased for example elbow extension or wrist and finger extension. In addition, participants are informed about maintaining the head at neutral position. To prevent cervical lateral flexion, during treatment procedure subjects are informed to keep their eyes closed or to keep on the ceiling (27, 67).

This process was repeated 12 times and the final test position during repetitions maintained for 15-20 seconds. This procedure performed approximately for 10 minutes within degree which is not cause a sense of discomfort in the subjects. Immediately after application SWM and JPS applied to the participants and their pain status is evaluated by the VAS. Their all values are recorded. The same test procedure was performed 1 week later the neurodynamic tension test. All results were compared after they concluded (78).

3.4. Data Analysis

Analysis of the collected data according to upper extremity evaluation parameters of the participants were calculated by Statistical Package Analyze for Social Sciences (SPSS) version 17.0 program. Quantitative variables were offered by mean, standard deviation, minimum and maximum valuation. Qualitative values were presented by frequency and in percentage. Kolmogorov-Smirnov test was used to search normal distribution of the variables. According to normal distribution test, although there are non-parametric values, measurements were analyzed by parametric test because sample size is more than 30. An analysis of variance (ANOVA) model for analysis of the variables with repeated measures, in which the repeated measures factor was VAS, SWM and JPS was used. ANOVA was supplemented by the post hoc Bonferroni test. The sample size was determined based on statistical power. The results presented as mean and 95% confidence interval. For all analyses, the level of significance was defined as $p<0, 05$.

4. RESULTS

Data were collected from 32 voluntary participants. Their mean age is 37,15±11,29, mean height is 164,34±6,08 and mean weight is 70,28±10,68. Participants' mean BMI (body mass index) which indicates nutritional status in adults is 26,07±4,12 that within the limits of pre-obesity or overweight. There are 4 (12, 5%) men and 28 (87, 5%) female subjects (Table 4.1).

Table 4.1. Demographic characteristics of the participants

	Participants n=32			
	mean	**SD**	**min**	**max**
Age (years)	37,15	11,29	21	63
Height (cm)	164,34	6,08	155	178
Weight (kg)	70,28	10,68	47	90
BMI (kg/m^2)	26,07	4,12	18,83	33,06
Male n (%)	4 (12, 5)			
Female n (%)	28 (87, 5)			

BMI: body mass index

Distribution of the participants according to existing chronic disease, operation history, exercise and exercise duration, history of sport branch and dominant wrist is reported. 22 of the participants do not have any chronic disease, however, 1 of the remaining participants have heart disease, 4 of them have high blood pressure, 1 of them have musculoskeletal problem which is osteoporosis, 1 of them have vitamin deficiency which is identified as D vitamin deficiency, 3 of them have other problems which are vertigo and asthma.

According to physical activity, 7 of the participants exercise within a week regularly and 11 of the participants exercise at least 30 minutes. 13 of the participants are interested a sport branch in their lives which are football, basketball, volleyball, swimming and others that include cycling and fitness.

According to dominant wrist, 30 of the participants are using right wrist and 2 of them are using left wrist dominantly in daily living.

Table 4.2. Demographic characteristics of the participants

		Participants n=32 % (n)
Chronic Disease	Absent	68,8 (22)
	Heart disease	3,1 (1)
	High blood pressure	12,5 (4)
	Respiratory system disease	-
	Musculoskeletal	3,1 (1)
	Vitamin deficiency	3,1 (1)
	Other	9,4 (3)
Exercise	Never	65,6 (21)
	1/month	3,1 (1)
	>2 /month	9,4 (3)
	1/week	3,1 (1)
	2-3/week	9,4 (3)
	4-5/week	6,3 (2)
	Everyday	3,1 (1)
Exercise Duration	Absent	65,6 (21)
	30 min	9,4 (3)
	30-50 min	18,8 (6)
	>60 min	6,3 (2)
Sport Branch	Absent	59,4 (19)
	Football	9,4 (3)
	Basketball	3,1 (1)
	Volleyball	18,8 (6)
	Swimming	3,1 (1)
	Folk Dance	-
	Other	6,3 (2)
	Right	93,8 (30)

Dominant Wrist	Left	6,3 (2)

BCTQ scores collected from participants to be included in our study. BCTQ-sss is analyzed for inclusion criteria that should be bigger than 11 points and less than 45 points and BCTQ-fss is analyzed to observe effected daily living activities. Subjects' mean BCTQ-sss score is 21, 56 ± 6, 35 which is included in mild symptoms and mean BCTQ-fss score is 14, 78 ± 6 which is included in mild difficulty of daily activities. The PCS measure responses of the subjects to pain and their mean PCS score is 16, 87 ± 9, 91 (Table 4.3).

Table 4.3. Boston Carpal Tunnel Questionnaire and Pain Catastrophizing Scale scores of the participants

	Participants n=32			
	mean	**SD**	**min**	**max**
BCTQ-sss	21,56	6,35	14	40
BCTQ-fss	14,78	6	8	30
PCS	16,87	9,91	1	37

BCTQ-sss: Boston Carpal Tunnel symptom severity scale, BCTQ-fss: Boston Carpal Tunnel functional status scale, PCS: Pain catastrophizing scale score.

To measure participants' pain status, VAS is analyzed and their mean pre-treatment VAS score is 4, 25 ± 2, 27, mean post-treatment VAS score is 1, 12 ± 2, 33 where their 1-week follow-up mean VAS score is 1, 25 ± 1, 96. There is a significantly difference according to repeated measures (p<0. 05). The results of Bonferonni post hoc tests are shown in Table 4.4.

Table 4.4. Visual Analogue Scale scores of the participants

	Measurements			**Repeated Measures ANOVA**				
	Pre-treatment mean±SD	**Post-treatment mean±SD**	**1-week follow-up mean±SD**	**F**	**p**	**Bonferonni**		
						I-II p	I-III p	II-III p
VAS	4,25 ± 2,27	1,12 ± 2,33	1,25 ± 1,96	35,76	**,00***	**,00***	**,00***	1,00

*: p<0, 05, VAS: Visual analogue scale

Subjects' sensory evaluation results are represented according to Semmes-Weinstein monofilaments. According to subjects' different filament levels of index and thumb fingers which are the median nerve innervated areas on the hand, subjects' normal, diminished light touch or diminished protective sensation are measured. Subjects' mean pre-treatment index finger score is 0, 71 ± 0, 58 and mean thumb finger score is 0, 78 ± 0, 65. The mean post-treatment index finger score is 0, 18 ± 0, 39 and the mean thumb finger score is 0, 31 ± 0, 47. The mean 1-week follow-up score of index finger is 0, 31 ± 0, 47 and thumb finger score is 0, 25 ± 0, 5. There is a significantly difference according to repeated measures of SWM scores and the results of Bonferonni post hoc tests are represented on Table 4.5.

Table 4.5. Semmes-Weinstein Monofilament measurement scores of the participants

	Measurements			**Repeated Measures ANOVA**				
						Bonferonni		
	Pre-treatment mean±SD	**Post-treatent mean±SD**	**1-week follow-up mean±SD**	**F**	**p**	I-II p	I-III p	II-III p
SWM Index	0,71±0,58 (0-2)	0,18±0,39 (0-1)	0,31±0,47 (0-1)	18,23	**,00***	**,00***	**,00***	0,48
SWM Thumb	0,78±0,65 (0-2)	0,31±0,47 (0-1)	0,25±0,5 (0-2)	18,04	**,00***	**,00***	**,00***	1,00

*: p<0, 05, SWM: Semmes-Weinstein Monofilament

Subjects' sensory evaluation results are represented according to joint position sense which is measured with previously determined joint angle of 45° flexion, 20° flexion, 45° extension and 20° extension. They are analyzed for the conscious sense of the joint. According to results, participants' pre-treatment mean values for 45° flexion is 7, 81±5, 24, 20° flexion is 6, 16±5, 75, 45° extension is 5, 76±4, 74 and 20° extension value is 7, 86±6, 48 . Post-treatment scores of the subjects: 4, 97±4, 45 in 45° flexion, 5, 23±5, 64 in 20° flexion, 4, 42±2, 87 in 45° extension and 6, 68±5, 94 in 20° extension. 1-week follow-up mean scores in 45° flexion is 4, 91±3, 8, in 20° flexion is 4, 06±4, 67, in

45^{o} extension is 4, 66±2, 53 and in 20^{o} extension is 4, 82±4, 14.

These results execute that, measurements of the JPS in 45^{o} flexion, 20^{o} flexion and 20^{o} extension are significantly different on the repeated measures ($p<0.05$). The results of Bonferonni post hoc tests are represented on Table 4.6.

Table 4.6. Joint Position Sense measurement scores of the participants

	Measurements			**Repeated ANOVA**				
	Pre-treatment mean±SD	**Post-treatent mean±SD**	**1-week follow-up mean±SD**	**F**	**p**	**Bonferonni**		
						I-II p	I-III p	II-III p
flex45^{o}	7,81±5,24	4,97±4,45	4,91±3,8	8,99	**,00***	**,00***	**,01***	1,00
flex20^{o}	6,16±5,75	5,23±5,64	4,06±4,67	3,87	**,03***	,63	,08	,18
ext45^{o}	5,76±4,74	4,42±2,87	4,66±2,53	2,46	,09	,18	,31	1,00
ext20^{o}	7,86±6,48	6,68±5,94	4,82±4,14	5,74	**,00***	,74	**,00***	,11

*: p<0, 05, JPS: joint position sense, flex: flexion, ext: extension.

5. DISCUSSION

The aim of our study was to investigate sensory evaluation by using SWM on median nerve innervated areas of the hand and JPS of wrist in healthy subjects who have CTS symptoms according to BCTQ after by using ULTT1.

32 participants who have mild CTS symptoms are involved in our study. The results allow to improvements and ULTT1 have beneficial effects on pain status, sensory evaluation on hand and joint position sensation of wrist.

Participants of our study, have functional status as mean score 14, 78 ± 6 according to BCTQ-fss. Their minimal value is 8 where maximal value is 30. They were assessed according to participants' daily activity difficulties such as writing, clothing, holding a book or telephone and carrying bags. Our participants have wide score range. This range can be correlated with their low level of physical activity. Only 7 of 32 participants exercise regularly in a week but their exercise duration is limited with minimal 30 minutes and maximal more than 1 hour. Low level of activity affects their independence in their daily life activities.

In addition to these variables, in our study, participants' mean BMI score is 26, 07±4,12 which is within the border of overweight. Most of authors have shown relationship between elevated BMI scores and CTS. The obesity is counted one of the causes of CTS in the literature (22). Although, being obese affects to have CTS, its mechanisms, reasons and responses to treatment protocols are not clear. There may be more than one causes and these are dependent on the patient.

Stalioraitis et al. made research to investigate inconsistency in side to side range of motion by using upper limb neurodynamic technique (79). They involved 51 healthy participants who have full upper limb range of motion and right hand dominant. They used electrogoniometer by measuring elbow extension range in end point during neurodynamic technique. According to results, there is no difference between dominant and non-dominant extremity joint range.

In present study, we have 30 right hand dominant hand participants and 2 left hand dominant participants. All participants have symptoms on their dominant side wrist and they had ULTT1 treatment on dominant side. According to Stalioraitis, there is no difference between upper limbs range of motion. Therefore, our study is focused on the symptomatic upper extremity. Because Stalioraitis used cervical lateral flexion to give maximal stress on nerve path, variation between extremities may decrease.

In the literature, Coppieters et al. aimed to investigate strain on median and ulnar nerve with various types of nerve gliding exercises on CTS and cubital tunnel syndrome with their study (65). They used different types of techniques which are sliding and tensioning technique on 2 cadavers and they mentioned that tensioning technique which involves ULTT1 have more strain on nerve bed than sliding techniques. Sliding of the nerve consists of united movements at least 2 joints. The movement of the joints lengths the nerve then other movement reduces the length of the nerve bed. Therefore this combination of movements decrease tension load on the nerve path. Tension technique involves one or more joint motions and results with nerve bed elongation. So, different types of nerve gliding and sliding exercises have different effects on the peripheral nerves for example elevation in length of nerve path continues with increase in strain on nerve. Tensioning of nerve evokes increment both topics which are nerve bed length and strain on the nerve. With the light of results, if tension technique is used with CTS, it shows its own effects by changing intraneural pressure and by creating pumping action or milking effects.

Our study results are observed to be in line with Coppieters' research. We used tensioning technique on the median nerve to improve its dysfunction. With the elongation and strain of median nerve, its symptoms are altered with sensory measurements.

In present study, we found pre-treatment VAS scores are meaningfully decreased according to post-treatment VAS scores. This decline continued after 1-week follow-up VAS scores. In addition that, when we analyze pre-treatment and 1-week follow-up VAS scores, there is a significant reduction observed. There is no meaningful difference between post-treatment and 1-week follow-up scores.

Bialosky et al. (73) in the study of neurodynamic technique and its effectiveness on grip strength, sensory evaluation, pain status and upper extremity functioning are assessed. They worked with sham therapy and neurodynamic technique on CTS patients to review these titles. After 3 weeks of both therapies, in the both groups there is pain reduction, improvements in functioning and increase grip strength. In the sham group, they observed placebo affect on patients and they suggest that being a participant of the therapy gives the positive results rather than using a neurodynamic technique.

Tal-Akabi et al. worked on physiotherapy management on CTS patients (80). They separated subjects in 3 groups and each group have 7 participants; 1st treated with ULTT1, 2nd group treated with carpal bone mobilization and 3rd group was control group. They analyzed pain status, active range of motion of wrist in flexion and extension. In results, 2 groups which have treatment have significantly improvement according to measurements when compared to control group but there is no significantly difference between 2 treatment protocols.

In our research, we have improvements in pain status of subjects. We show that neurodynamic technique on median nerve have essential role in pain which is one of CTS symptoms. Immediately after ULTT1 technique, subjects' pain statuses are decreased and reduction of pain was permanent after 1-week.

As another point of view, Kim et al. (78) worked on delayed onset muscle soreness (DOMS) with ULTT1. They involved 45 healthy people and separated them into 2 groups: experimental group had ULTT1 treatment and ultrasound therapy while control group had only ultrasound therapy. Before therapy, they induced DOMS into biceps brachii muscle on non-dominant side of the participants. They analyzed participants' lactic acid levels and pressure pain threshold. According to results, experimental group had significant positive effects in all measurements and there is meaningful difference between groups.

The therapeutic effects of neurodynamic techniques have been proven to be used in many areas. According to Kim et al (78) ULTT1 have effects on lactic acid in the blood and pressure pain threshold. It can be used to facilitate conduction of median nerve. This is efficient in reducing muscular pain.

According to light touch sensation measurements with SWM on median nerve innervated areas which are pulp of index finger and thumb, both of fingers have meaningful difference between scores. For the both fingers, pre-treatment and post-treatment sensory evaluations indicated that there is improvement according to sensory evaluation. And also, for the both fingers, pre-treatment and after 1-week follow-up evaluations prove that the improvements are continued within sensory evaluation values. However, on index finger and thumb, after treatment improvements are not permanent because post-treatment and after 1-week follow-up values are not meaningful.

In the previous studies, Wolny et al. (9) studied to adjust 2 point discrimination (2PD) on CTS patients for sensory evaluation. They used neurodynamic technique (ULTT1) and manual therapy technique modalities on 1st group and electrophysiological modalities which are laser and ultrasound therapy on 2nd group. Therapy was performed for 10 weeks. Final valuations indicate that, in the both groups there is meaningful therapeutic effect however ULTT1 technique has better effect on

2PD.

Wolny et al. presented another study with patients diagnosed with CTS to evaluate effectiveness of the neurodynamic techniques (81). They used for both groups sliding and tensioning neurodynamic techniques, in study group sessions are included ULTT1. To evaluate the effectiveness of the technique, they assessed subjects' pain status with VAS, 2PD for sensory development, BCTQ and grip strength. Therapy was performed 10 weeks and final evaluations indicated that pain reduction and improved sensory evaluation on study group with ULTT1.

In our study, we have the same therapeutic effect of ULTT1 on sensory evaluation which is measured with SWM and median nerve innervated areas rather than 2PD. ULTT1 indicated that, on the palm of the hand, improves light touch sensation However, we used only ULTT1 technique on healthy subjects who show CTS symptoms while Wolny used manual therapy modalities involved functional massage and also they included patients diagnosed with CTS. That's why; our research may show more clear effectiveness of ULTT1 on CTS symptoms.

The efficiency of the neurodynamic technique is shown with our study and we have observed the sensory evaluation and reduction of the pain with only ULTT1 despite Wolny used different therapeutic techniques in addition to ULTT1. We aimed to put forward effects of ULTT1 technique only but both studies have compatible results on pain and sensory evaluation.

Bialosky et al. as mentioned before studied with sham therapy and neurodynamic technique groups consist of CTS patients. They evaluated them by using SWM for sensory evaluation. They measured thumb, index and middle finger before and after therapy. Final results indicated that within all fingers there is no difference between groups.

According to our results, we have found improvements in light touch sensation measured by SWM despite Bialosky's results. We used only ULTT1 technique but they used in both groups prefabricated wrist splint.

On the assessment of the joint position sensation for sensory evolution, meaningful improvements were observed in the angle of 45^{o} flexion, 20^{o} flexion and 20^{o} extension. Pre-treatment and post-treatment measurements in 45^{o} flexion on wrist, there is significant improvement about joint position and also it continues in post-treatment and after 1-week follow-up values. While the improvement is not observed between repetitive measurements of the 20^{o} flexion, there is significant evolution in 20^{o}

extension between pre-treatment and after 1-week follow-up values.

Joint position sense which is determined as afferent input of the proprioception or awareness of motion or position of joint is reported by mechanoreceptors to central nervous system if there is a mechanical problem. If there is a ligamentous problem with increased pressure or mechanical problem, different types of mechanoreceptors uses afferent paths. So, when we use ULTT1 technique, we affected the nerve, surrounding structures, connective tissue around the nerve and its path and other physiological consequences such as edema or pressure. According to our results, ULTT1 have positive effects on JPS with pre-determined joint positions and this meaningful difference can be explained with its mechanism (82). In the literature, there is lack of JPS assessments on CTS with neurodynamic techniques.

In our study, to improve symptoms such as pain status, light touch sensation of the nerve innervated areas and perception of joint position through physiological and especially mechanical effects of ULTT1 on CTS. As Coppitiers mentioned that, patients who have CTS have changed somatosensory hand representations (66). To support in remapping process, ULTT1 can be used as an assistant treatment protocol.

To inquire effectiveness of neurodynamic technique on overall health status with RAND 36-Item Short Form Health Survey on CTS patients, Wolny et. al approach a study (83). They compare manual therapy group and control group after 10 week and final results showed that neurodynamic technique had positive effectiveness on physical and mental components of over health status on patients when compared to control group. In our study, we analyzed PCS and subjects included have high score before the ULTT1 treatment. It may show us subjects who have symptoms according to CTS, have fair of pain and so fair of physical activity.

In the literature, to work on pain with CTS patients, Nunez et al. used several questionnaires that include PCS, Patient Health Questionnaire–Depression Subscale, Pain Anxiety Symptoms Scale and the Pain Self-Efficacy Questionnaire. They found that, pain intensity is highly correlated with mood, cognitions, emotions, coping strategies and pain perception in a situation (84). In addition, in the case of CTS, they mentioned that wrist pain is not totally related with CTS pathology. Illness behavior includes pain catastrophizing and depression, is better decisive factor on pain intensity than other measurements.

Our study has limitations:

- The main limitation is lack of control group to compare results with other therapeutic managements or placebo therapy in our research.

As a result of our study where more studies are needed to investigating the effects neurodynamic techniques or ULLT1 technique on CTS symptoms to evaluate sensory evaluations. In our study we found that;

- Light touch sensation is improved after ULTT1 technique and its improvements were permanent after 1 week according to before treatment measurements
- Sensation of wrist joint position is improved after ULTT1 treatment protocol in most of reference points and they were found permanent after 1 week according to before treatment measurements
- Participants pain status were improved with ULTT1 treatment sessions and their pain status were continued with decreased level according to before treatment measurements
- There is an immediate and positive improvement of the ULTT1 treatment on participants with CTS symptoms according to sensory evaluations involved light touch and JPS and these positive effects have been shown to proceed

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APPENDIX

APPENDIX 1. Sempati Özel Eğitim ve Rehabilitasyon Merkezi Approval Form

20/12/2019

Marmara Üniversitesi

Sağlık Bilimleri Fakültesi

Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu Başkanlığı'na

Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Fizyoterapi ve Rehabilitasyon Anabilim Dalı yüksek lisans öğrencisi Hande Yolcu'nun Karpal Tünel Sendromu Bulgularına Median Sinir Nörodinamik Tekniğinin Etkisi adlı çalışması için Sempati Özel Eğitim ve Rehabilitasyon Merkezi'nin fizik tedavi salonunun kullanımına izin verilmiştir.

Sempati Özel Eğitim ve Rehabilitasyon Merkezi
Telsiz Mahallesi 71. Sokak No.58 34020
Zeytinburnu/İSTANBUL
0212 415 1919

Kurum Müdürü
Hilal Niğmet Erdoğdu

APPENDIX 2. Ethical Approval

T.C.
MARMARA ÜNİVERSİTESİ
Sağlık Bilimleri Fakültesi
Girişimsel Olmayan Klinik Çalışmalar Etik Kurulu

PROJENİN ADI	: "Karpal Tünel Sendromu Bulgularına Median Sinir Nörodinamik Tekniğinin (ÜETT1) Etkisi"
PROJENİN YÜRÜTÜCÜSÜ	: Dr. Öğr. Üyesi Çiğdem YAZICI MUTLU
PROJEDEKİ ARAŞTIRICILAR	: Doç. Dr. Gökhan MERİÇ, Hande YOLCU
ONAY TARİHİ VE SAYISI	: 31.01.2020/04

Sayın: Dr. Öğr. Üyesi Çiğdem YAZICI MUTLU

"04" protokol numaralı "Karpal Tünel Sendromu Bulgularına Median Sinir Nörodinamik Tekniğinin (ÜETT1) Etkisi" İsimli projeniz Fakültemiz Etik Kurulu tarafından incelenmiş oy birliği ile etik yönden uygun olduğuna karar verilmiştir.

Prof. Dr. M. Gülden POLAT
Etik Kurul Başkanı

Prof. Dr. Mehveş TARIM

Prof. Dr. Ayşen GARGILI KELEŞ	Prof. Dr. Ş. Burak BEKİROĞLU	Doç. Dr. M. Emin ALŞAHİN
Doç. Dr. Zübeyir SARI	Doç. Dr. Hasibe KADIOĞLU	Doç. Dr. Meltem BAL
Doç. Dr. Saime EROL	Doç. Dr. Aysel YILDIZ ÖZER	Doç. Dr. Ayşe KARAKOÇ
Dr. Öğr. Üyesi Murat D. ÇEKİN	Dr. Öğr. Üyesi K. Burcu ÇALIK	Dr. Öğr. Üyesi Şule AKTAÇ
Dr. Öğr. Üyesi S. Kumral ÖZÇELİK		

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APPENDIX 3. Informed Written Consent

Araştırmanın Adı: Karpal Tünel Sendromu Bulgularına Median Sinir Nörodinamik Tekniğinin (ÜETT1) Etkisi

"Sayın gönüllü katılımcı,

Yeditepe Üniversitesi Sağlık Bilimler Enstitüsü Fizyoterapi ve Rehabilitasyon Yüksek Lisans Tezi kapsamında planlanmış olan yukarıda adı yazılı araştırmaya katılmak üzere davet edilmiş bulunuyorsunuz. Bu araştırmada yer almayı kabul etmeden önce, araştırmanın ne amaçla yapılmak istendiğini anlamanız ve kararınızı bu bilgilendirme çerçevesinde özgürce vermeniz gerekmektedir. Aşağıdaki bilgileri lütfen dikkatlice okuyunuz, sorularınız olursa sorunuz ve açıkça yanıtlar isteyiniz."

Çalışma kapsamında, hakkınızdaki bilgiler size sorularak elde edilecektir. Bu sorular, fiziksel durumunuz, şuan ki sağlık durumunuz ve sizden elde edebileceğimiz bilgilerden oluşacaktır. Ayrıca Fizyoterapist tarafından uygulanacak bir dizi değerlendirmeye tabi tutulacaksınız. Bu değerlendirmede; sizlerin, el bileği semptomlarınızı, el ve el bileğindeki dokunma duyunuzu, ağrı ve ağrıyı felaketleştirme skorlamalarınızı değerlendirecek testler ve nörodinamik test yer alacaktır.

Bu araştırmada yer almak tümüyle sizin isteğinize bağlıdır. Araştırmada yer almayı reddedebilirsiniz ya da başladıktan sonra yarıda bırakabilirsiniz. Bu araştırmanın sonuçları bilimsel amaçlarla kullanılacaktır. Araştırmadan çekilmeniz ya da araştırmacı tarafından araştırmadan çıkarılmanız halinde, sizle ilgili veriler kullanılmayacaktır. Ancak veriler bir kez anonimleştikten sonra araştırmadan çekilmeniz mümkün olmayacaktır. Sizden elde edilen tüm bilgiler gizli tutulacak, araştırma yayınlandığında da varsa kimlik bilgilerinizin gizliliği korunacaktır.

“Yukarıda yer alan ve araştırmaya başlanmadan önce gönüllülere verilmesi gereken bilgileri içeren metni okudum (ya da sözlü olarak dinledim). Eksik kaldığını düşündüğüm konularda sorularımı araştırmacılara sordum ve doyurucu yanıtlar aldım. Yazılı ve sözlü olarak tarafıma sunulan tüm açıklamaları ayrıntılarıyla anladığım kanısındayım. Çalışmaya katılmayı isteyip istemediğim konusunda karar vermem için yeterince zaman tanındı. Bu koşullar altında, araştırma kapsamında elde edilen şahsıma ait bilgilerin bilimsel amaçlarla kullanılmasını, gizlilik kurallarına uyulmak kaydıyla sunulmasını ve yayınlanmasını, hiçbir baskı ve zorlama altında kalmaksızın, kendi özgür irademle kabul ettiğimi beyan ederim. ”

Gönüllü Katılımcı Adı Soyadı:	Araştırmacının Adı Soyadı:
İmza/Tarih:	İmza/Tarih:

APPENDIX 4: Demographic Form

YEDİTEPE ÜNİVERSİTESİ

Katılımcıların Sosyodemografik Statüleri, Genel Sağlık Statüleri ve Fiziksel Aktivite Statülerini Değerlendirmek Üzere:

A:GENEL BİLGİLER

1-Adınız Soyadınız:

2-Cinsiyet:

- o Kadın
- o Erkek

3-Doğum Tarihi: ……/……/……

4-Boy……… cm

5-Kilo………kg

6-BMI:………

B.SAĞLIK DAVRANIŞLARI

1-Sigara içiyor musunu?

- o Hiç içmedim
- o Sigara içtim ve bıraktım
- o Halen içiyorum

2-Günde kaç paket sigara içiyorsunuz'

Adet/Gün………………

Paket/Yıl……………….

3-Alkol kullanıyor musunuz?

- o Hiç kullanmadım
- o Az miktarda/ kısa süreli (nadir
- o Orta düzeyde/ 10 yıldan az
- o Fazla miktarda/uzun süredir

C. GENEL SAĞLIK BİLGİLERİ

1-Doktor tarafından teşhisi konulmuş herhangi bir sistemik hastalığınız var mı?

- o Evet
- o Hayır

2-Cevabınız evet ise teşhis edilen hastalığınız hangisidir/hangileridir?(Birden fazla şık işaretleyebilirsiniz)

- o Kalp-damar hastalıkları
- o Şeker hastalığı
- o Yüksek tansiyon
- o Kanser
- o Sindirim sistemi hastalıkları (karaciğer, safra kesesi, mide vb.)
- o Solunum sistemi hastalıkları (akciğer vb.)
- o Ruhsal sorunlar (depresyon, aşırı yeme, kusma vb.)
- o Kas iskelet sistemi problemleri (osteoporoz, eklem ağrıları)
- o Endokrin (hormonal) hastalıklar
- o Vitamin ve mineral yetersizlikleri (demir , B12 yetersizliği vb.)
- o Diğer (belirtiniz)…………………………………

3-Düzenli olarak kullandığınız ilaç var mı? Evet ise nedir belirtiniz.

- o Evet
- o Hayır

Belirtiniz…………………………………

4-Daha önce geçirmiş olduğunuz bir cerrahi operasyon var mı? Varsa nedir?

- o Evet
- o Hayır

Belirtiniz…………………

D. FİZİKSEL AKTİVİTE DURUMU

1-Egzersiz veya spor yapıyor musunuz?

- Evet
- Hayır

2-Evet ise; haftada kaç kes egzersiz veya spor yaparsınız?

- Ayda 1 defa
- Ayda 2 defadan fazla
- Haftada 1 defa
- Haftada 2-3 defa
- Haftada 4-5 defa
- Hergün

3-Yaptığınız egzersiz genel olarak kaç dakika sürer?(egzersiz yapanlar için)

- 20 dakikadan az
- 30 dakika
- 30-50 dakika
- 60 dakikadan fazla

4-Herhangi bir spor dalıyla ilgilendiniz mi?

- Evet
- Hayır

5-Evet ise hangisi?

- Futbol
- Basketbol
- Voleybol
- Hentbol
- Atletizm
- Tenis
- Su topu
- Yüzme
- Halk oyunları
- Diğer ……………………………………………

10-Baskın olarak hangi elinizi kullanıyorsunuz?

- Sağ
- Sol
- Her ikisi

APPENDIX 5: Boston Carpal Tunnel Questionnaire

BOSTON KARPAL TÜNEL ANKETİ
Ad-Soyad:
Tarih:
Skor:

Semptom Şiddeti Skalası

Aşağıdaki sorularda, son iki hafta süresince tipik 24 saatlik bir dönemdeki semptomlarınızı gösteren bir cevabı daire içine alınız.

Gece el veya el bileği ağrınızın derecesi nedir?
1-Gece el veya el bileğimde ağrı olmuyor
2-Hafif ağrı
3-Orta derecede ağrı
4-Şiddetli agrı
5-Çok şiddetli ağrı

Son iki hafta içinde el veya el bileği ağrısı nedeniyle bir gecede ortalama kaç, defa uyandınız?
1-Hiç
2-Bir defa
3-İki-üç defa
4-Dört-beş defa
5-Beş defadan fazla

Gündüz el veya el bileğinizde ağrınız oluyor mu?
1-Gündüz hiç ağrım olmuyor
2-Gün içinde hafif ağrım oluyor
3-Gün içinde orta derecede ağrım oluyor
4-Gün içinde şiddetli ağrım oluyor
5-Gün içinde çok şiddetli ağrım oluyor

Gündüz kaç defa el veya el bileğinizde ağrınız oluyor?
1-Hiç
2-Günde bir-iki defa
3-Günde üç-beş defa
4-Günde beş defadan fazla
5-Devamlı ağrım oluyor

Gündüz bir ağrı dönemi ortalama ne kadar sürüyor?
1-Gündüz hiç agrı olmuyor
2-10 dakikadan az
3-10-60 dakika arası
4-60 dakikadan daha uzun
5-Gündüz devamlı ağrı oluyor

Elinizde hissizlik (duyu kaybı) var mı?
1-Hayır
2-Hafif hissizlik var
3-Orta derecede hissizlik var
4-Ciddi derecede hissizlik var
5-Çok ciddi derecede hissizlik var

El veya el bileğinizde güçsüzlük var mı?
1-Güçsüzlük yok
2-Hafif güçsüzlük var
3-Orta derecede güçsüzlük var
4-Ciddi güçsüzlük var
5-Çok ciddi derecede güçsüzlük var

Elinizde karıncalanma hissi oluyor mu?
1-Olmuyor
2-Hafif karıncalanma oluyor
3-Orta derecede karıncalanma oluyor
4-Ciddi derecede karıncalanma oluyor
5-Çok ciddi derecede karıncalanma oluyor

Elinizdeki his kaybı ve karıncalanma gece ne kadar şiddetli oluyor?
1-Gece karıncalanma ve his kaybı olmuyor
2-Hafif
3-Orta
4-Şiddetli
5-Çok şiddetli

Son iki hafta içinde ortalama bir gecede kaç kez elinizde his kaybı veya karıncalanma ile uyandınız?
1-Hiç
2-Bir defa
3-Iki-üç defa
4-Dört-beş, defa
5-Beş defadan fazla

Anahtar veya kalem gibi küçük cisimleri tutmak ve kavramakta zorluk çekiyor musunuz?
1-Hayır
2-Hafif zorlanıyorum
3-Orta derecede zorlanıyorum
4-Şiddetli zorlanıyorum
5-Çok şiddetli zorlanıyorum

Fonksiyonel Durum Skalası

Son iki hafta içinde sıradan bir günde, el ve el bileği şikayetleriniz aşağıdaki aktiviteleri yapmakta ne kadar zorluk çekmenize sebep oldu? Aktiviteyi yapabilirliginizi en iyi tanımlayan rakamı yuvarlak içine alınız.

Yazı yazmak	1	2	3	4	5
Giysilerin düğmesini iliklemek	1	2	3	4	5
Okurken kitabı tutmak	1	2	3	4	5
Telefon ahizesini tutmak	1	2	3	4	5
Kavanoz açmak	1	2	3	4	5
Alışveriş torbalarını taşımak	1	2	3	4	5
Günlük ev işleri	1	2	3	4	5
Banyo yapmak ve giyinmek	1	2	3	4	5

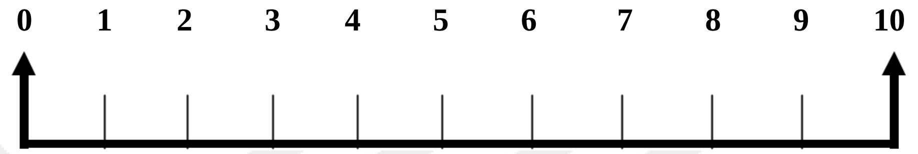
1-Zorlanmadan
2-Hafif zorlanarak
3-Orta derecede zorlanarak
4-Şiddetli zorlanarak
5-El veya el bileği şikayetlerim nedeniyle hiç yapamıyorum.

APPENDIX 6. Visual Analogue Scale (VAS)

Adınız Soyadınız: ________________________________ Tarih: ________________

Ağrı şiddetinizi aşağıdaki ölçek üzerinde işaretleyin.

Hiç ağrı olmaması En dayanılmaz



APPENDIX 7. Pain Catastrophizing Scale (PCS)

AĞRIYI FELAKETLEŞTİRME ÖLÇEĞİ

Adı / Soyadı____ Tarih: __________________

Hemen herkes hayatının bir döneminde ağrıya neden olan durumlar yaşamıştır. Örneğin baş ağrısı, diş ağrısı, eklem ya da kas ağrıları gibi. İnsanlar sıklıkla ağrıya neden olabilen hastalıklar, travmalar (kazalar), diş hastalıkları ile ilgili işlemler ya da cerrahi uygulamalar gibi durumlara maruz kalabilirler.

Biz ağrı yaşadığınız zamanlardaki duygu ve düşüncelerinizle ilgileniyoruz. Aşağıda ağrıyla ilişkili olabilen farklı duygu ve düşünceleri tanımlayan 13 durum sıralanmıştır. Lütfen ölçeği kullanarak, *ağrı yaşadığınız anlardaki* duygu ve düşüncelerinizin derecesini işaretleyiniz.

	Hiç yok	Hafif derece	Orta derece	Büyük ölçüde	Her zaman
Ağrının sona erip ermeyeceği konusunda sürekli endişelenirim	0	1	2	3	4
(Ağrı nedeniyle) Devam edemeyeceğimi hissederim	0	1	2	3	4
Ağrının korkunç olduğunu ve asla düzelmeyeceğini düşünürüm	0	1	2	3	4
Ağrı berbat bir şeydir ve beni bunalttığını hissederim	0	1	2	3	4
Ağrıya daha fazla dayanamayacağımı hissederim	0	1	2	3	4
Ağrının kötüleşeceğinden korkarım	0	1	2	3	4
Sürekli olarak başka ağrılı durumları düşünürüm	0	1	2	3	4
Endişeli biçimde ağrının geçmesini dilerim	0	1	2	3	4
Ağrıyı kafamdan atamıyorum	0	1	2	3	4
Sürekli olarak ağrının canımı ne kadar yaktığını düşünürüm	0	1	2	3	4
Ağrının geçmesini beklemenin ne kadar zor olduğunu düşünüp dururum	0	1	2	3	4
Ağrının şiddetini azaltmak için yapabileceğim hiçbir şey yok	0	1	2	3	4
Ağrının ciddi bir sorunla ilgili olup olmadığını merak ederim	0	1	2	3	4