T.C.
YEDİTEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF PHYSIOTHERAPY AND REHABILITATION

COMPARISON THE EFFECTS OF POWERBALL TRAINING ON HAND GRIP STRENGTH, PINCH GRIP STRENGTH AND PROPRIOCEPTION AMONG DENTISTS

MASTER THESIS

Sevgi Gamze FELEK, PT.

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ADVISER
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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 ..05./.05./2017... tarih ve 2017/08-11...... 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 except where due acknowledgment has been made in the text.

Sevgi Gamze FELEK

DEDICATION

I would like to dedicate my thesis to my altruistic parents Şükran and Ahmet Felek, my brothers Serdar, İbrahim and Özgür FELEK who were supporting me during my whole life and my lovely fiancé Hüseyin İri.

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Δ	Post variables minus pre variables
AbPL	Abductor Pollicis Longus
AbPB	Abductor Pollicis Brevis
AdP	Adductor Pollicis
AROM	Active Range of Motion
ADL	Activities of Daily Living
BMI	Body Mass Index
CI	Confidence Interval
cm	Centimeter
CMC	Carpometacarpal
CTD	Cumulative Trauma Disorders
CTS	Carpal Tunnel Syndrome
DASH	Disability of Arm, Shoulder, Hand
DIC	Dorsal Intercarpal
DRC	Dorsal Radiocarpal
DIP	Distal Interphalangeal
DRSN	Dorsa Radial Sensory Nerve
DRUJ	Distal Radioulnar Joint
DTM	Darthrowing Motion
ECU	Extensor Carpi Ulnaris
ECRB	Extensor Carpi Radialis Brevis
ECRL	Extensor Carpi Radialis Longus
ED	Extensor Digitorum
EDM	Extensor Digiti Minimi
EI	Extensor Indicis
EPB	Extensor Pollicis Brevis
EPL	Extensor Pollicis Longus
F	Female
FCR	Flexor Carpi Radialis
FCU	Flexor Carpi Ulnaris
FDP	Flexor Digitorum Profundus
FDC	Flexor Digitorum Communis

FDP	Flexor Digitorum Profundus
FDS	Flexor Digitorum Superficialis
FOTO	Focus on Therapeutic Outcome
FPB	Flexor Pollicis Brevis
FPL	Flexor Pollicis Longus
FPST	Flinn Performance Screening Tool
Hz	Hertz
IFSSH	The International Federation of Societies for Surgery of the Hand
IP	Interpahalangeal
JPS	Joint Position Sense
kg	Kilogram
lb	Pound
M	Male
m	Meter
min	Minute
mm	Milimeter
MCP	Metacarpophalangeal
MHQ	Michigan Hand Questionnaire
MMT	Manuel Muscle Testing
MSD	Musculoskeletal Disorders
NIOSH	National Institute of Occupational Safety and Health
NRS	Numeric Rating Scale
OP	Opponens Pollicis
OR	Odds Ratio
PIP	Proximal Interphalangeal
PROM	Passive Range of Motion
PRWE	Patient Rated Wrist Evaluation
PSP	Prolonged Static Posture
RMA	Reactive Muscle Activation
ROM	Range of Motion
SC	Scaphocapitate
SD	Standard Deviation
sec	Second
SLIL	Scapholunate Interosseous Ligament

SPSS	Statistical Package Analyze for Social Sciences
STT	Scaphotrapeziotrapezoid
TAM	Total Active Motion
TFCC	Triangular Fibrocartilage Complex
TPM	Total Passive Motion
TPS	Total Passive Motion
TqCH	Triquetro-capito- hamate
TTDPM	Threshold to Detection of Passive Movement
UEFS	Upper Extremity Function Scale
wk	Week
WMSD	Work related Musculoskeletal Disorders
VAS	Visual Analog Scale

ABSTRACT

Felek, S.G. (2017). Comparison the Effects of Powerball Training on Hand Grip Strength, Pinch Grip Strength and Proprioception Among Dentists, Yeditepe University, Institute of Health Sciences, Department of Physiotherapy and Rehabilitation, Master Thesis. Istanbul.

The aim of the study is to investigate the effects of the Powerball training program with six weeks on hand grip strength, pinch grip strength and proprioception among dentists. The study included 30 dentists (14F&16M; 31.23±5.10 years) who work at Yeditepe University Dental Hospital and 30 dental students (16F&14M; 22.67±1.42 years) studying in fourth and fifth classes at Yeditepe University, Istanbul, Turkey. This study was carried out between December, 2016 and February, 2017. The sosciodemographic features of participants were recorded by using a structured questionnaire. The hand grip strength of the participants was measured by using a Jamar Hand Dynamometer (Baseline) and pinch strength measurements were evaluated with Pinch gauge (Baseline) for followed by lateral key, tip (2-point) pinch, and palmar (C3-point pad) pinch. The participants' wrist vibration sense was measured by using 128 Hz diapason. Active Joint Position Sense (JPS) included in all axes of movement of the wrist (flexion-extension and radial-ulnar deviation) was assessed by using the goniometric platform. Pain of the participants was assessed by Visual Analog Scale (VAS) and the disability level was assessed by Disability of Arm, Shoulder and Hand (DASH) Questionnaire. Powerball training was carried out for six weeks for both right and left hands by the participants (3times/wk. with 5 min.). The mostly important results of our study revealed that all measurements were improved through Powerball training program with six weeks in both groups ($p<0.05$). There were not any significantly differences in all parameters except DASH and JPS for flexion comparing two groups. Disability/symptom scores of DASH showed greater improvement in dental students ($p<0.05$). The other result indicated that our program led more effectiveness on JPS for flexion of left hand among dentists (Table 4.15) ($p<0.05$). Consistent with hypothesis, we found that Powerball training is effective on hand grip strength, pinch grip strength and proprioception among dentists.

Key Words: dentists, dental students, MSD, WMSD, proprioception, hand grip strength, pinch grip strength

ABSTRACT (TURKISH)

Felek, S.G. (2017). Diş Hekimlerinde Powerball ile Eğitimin Pençe El Kuvveti, Parmak Ucu Kavrama Kuvveti ve Propriyosepsiyon Üzerine Etkilerinin Karşılaştırılması. Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü, Fizyoterapi ve Rehabilitasyon ABD., Yüksek Lisans Tezi. İstanbul.

Bu çalışmanın amacı diş hekimlerinde 6 haftalık "Powerball" ile eğitimin pençe el kuvveti, parmak ucu kavrama kuvveti ve propriyosepsiyon üzerine olan etkilerini araştırmaktır. Çalışmaya Yeditepe Üniversitesi Diş Hastanesi'nde çalışan 30 Diş Hekimi (14 B & 16 E; 31.23±5.10 yıl) ve Yeditepe Üniversitesi'nde eğitim gören 4. ve 5.sınıf 30 Diş Hekimliği öğrencisi (16 B & 14 E; 22.67±1.42 yıl) dahil edilmiştir. Bu çalışma, Aralık 2016-Şubat 2017 tarihleri arasında yürütülmüştür. Katılımcıların sosyodemografik özellikleri yapılandırılmış bir anket kullanılarak sorgulanmıştır. Pençe el kuvvetleri Jamar El Dinamometresi (Baseline) kullanılarak ve parmak ucu kavrama kuvveti, pinchmetre (Baseline) kullanılarak; lateral kavrama (anahtar), parmak ucu kavrama (2 nokta) ve palmar kavrama (C3-nokta ped) kuvvetleri değerlendirilmiştir. Katılımcıların vibrasyon duyuları 128 Hz diapazon kullanılarak ölçülmüştür. Aktif eklem pozisyon hissi gonyometrik bir platform kullanılarak el bileğinin tüm eksenleri (fleksiyon-ekstansiyon, radial-ulnar deviasyon) değerlendirilmiştir. Katılımcıların ağrıları Vizüel Analog Skala (VAS) ve disabilite seviyeleri kol, omuz ve el sorunları anketi (DASH) ile değerlendirilmiştir. Katılımcılar tarafından Powerball çalışması, altı hafta, sağ ve sol el için uygulanmıştır (3 gün/hafta; 5 dk). Çalışmamızda, altı haftalık Powerball eğitim programıyla her iki grubun tüm ölçüm değerlerinde gelişme olduğu bulundu ($p<0.05$). Gruplar karşılaştırıldığında, DASH disabilite/semptom skoru ve fleksiyon eklem poziyon hissi dışında hiçbir parametrede anlamlı fark yoktu. DASH disabilite/semptom skorları, dişhekimi öğrencilerinde daha fazla gelişme gösterdi. Diğer bir sonuç olarak, programın diş hekimleri arasında sol el fleksiyon eklem pozisyon hissi üzerinde daha etkin olduğunu gösterildi (Tablo 4.15) ($p <0.05$). Hipotez ile uyumlu olarak, Powerball eğitiminin diş hekimlerinde pençe el kavrama kuvveti, parmak ucu kavrama kuvveti ve propriyosepsiyon üzerinde etkili olduğunu tespit ettik.

Anahtar Kelimeler: diş hekimi, diş hekimliği öğrencisi, kas iskelet problemleri, meslek ile ilgili kas iskelet problemleri, propriyosepsiyon, pençe el kavrama kuvveti, parmak ucu kavrama kuvveti

1. INTRODUCTION & PURPOSE

Dentistry is a high risk profession, especially for the development of musculoskeletal system disorders (MSD), characterized by high visual demands which cause adaptation of fixed postures [1-3]. Repetitive movements including hand grip, static postures, overhead work position and overuse of arms and hands are particular tasks for cashiering, assembly line work, construction, computer use and dentistry [2]. The overall prevalence of musculoskeletal disorders ranges from 63 to 93 percent worldwide among dentists [4]. Hayes et al.[5] reviewed the prevalence of musculoskeletal disorders for dentists. It has been shown 64-93 percent for back region, 36.3–60.1 percent for neck region, in addition the prevalence of musculoskeletal problems of hand and wrist found at 60–69.5 percent.

Faiscal et al.[4] has also proven that dentists are at higher risk for having musculoskeletal discomfort in the lower back, neck, shoulder, wrist and hand regions. The frequency of the wrist and hand discomfort were even higher by 65.1%. In the U.S., 13% of dentists were diagnosed with a median mononeuropathy and 4.8% of the study group had the diagnosis of Carpal Tunnel Syndrome (CTS), while 29% of the subject reported pain, tingling and numbness which suggested in the peripheral region. CTS, ulnar nerve entrapment, pronator syndrome, tendinitis, vibration syndrome (especially in the hands), tenosynovitis, thoracic outlet syndrome, and rotator cuff tendinitis are defined as MSDs which can be frequently seen among dentists.

In dental professionals, hand/wrist complaints which are the most important work related musculoskeletal system disorders (WMSD) and the most common distal upper extremity disorders occurs at higher risk with comparison to other professions [1, 6, 7]. Dental practice mainly leads to muscular imbalance, neuromuscular inhibition, dysfunction and pain due to cumulative micro trauma, repetitive using the musculoskeletal structure and awkward posture.

Anderson et al. stated that pain can be attributed to numerous risk factors, including prolonged static postures (PSP) with rotation and flexion of the cervical spine and the flexion position at elbow, repetitive movements (forceful hand grip), suboptimal tightening, poor positioning, mental stress, individual physical status and age [8, 9].

When the pain becomes a regular occurrence, the cumulative damage could arise leading to debilitating injuries[8].

Hand-arm MSDs are seen highly prevalent for dental students (60% pain, 46% upper extremity pain, 13% numbness, 13% white or painful fingers in cold temperatures) due to long working hours with manual instruments having vibration[2]. Prevention of WMSD is becoming crucial and requires the identification and modification of risk factors through a combination of ergonomic strategies, educational interventions and therapeutic approaching [1]. Treatment may serve various kinds of treatments such as pharmacological treatment 67.1%, physiotherapy 77.5%, and neurological consultations 41% [2, 10].

The study of Valachi et.al. [11] on preventing musculoskeletal disorders among dentists suggested the positioning strategies, postural awareness techniques, importance of periodic breaks, stretching and strengthening exercises for diminishing musculoskeletal discomfort. Physical exercise has various effects involving improvement in muscular strength, speed and coordination skills for performing of movement, flexibility of connective tissues, and reduction of risk for overburdening and degenerative changes in the locomotor organ [12]. The exercise training program may reduce the risk for secondary surgery and prevent long-term disability[13]. In the upper extremity especially wrist and hand grip and pinch grip strength improvement has been found to significantly predictor factors for performing activities of daily living (ADL). Physiotherapy and rehabilitation programs provide active movements, strength, endurance and proprioceptive skills etc. [14].

Considering the impact of joint proprioception on function is an important part of rehabilitation following orthopedic injuries. There is a substantial evidence suggesting that aberrations in muscle activity subsequent to joint injury are a result of disrupted neural pathway. Therefore, ligamentous injury or any joint pathology not only demotes mechanical stability, but it also diminishes the capability of the dynamic system. This also actually leads to decreased neuromuscular control and proprioceptive deficits. Proprioception is defined as the specialized variation of the sensory modality of touch that encompasses the sensation of joint movement (kinesthesia) and joint position [15]. Broadly defined, proprioception refers to the conscious awareness of the body and limbs and has several distinct properties which are passive motion sense, active motion sense, limb position sense, and the sense of heaviness. However, it has been established that proprioception has an unconscious component in which proprioceptive signals are utilized for the control of the muscle tone. Human proprioception consists of three major senses as follows joint position sense (JPS), kinesthesia and neuromuscular control. The approach of neuromuscular rehabilitation proposes to rebuild the unconscious activation of muscles and restoring joint balance which is commonly put to use in proprioceptive rehabilitation for shoulder, knee, ankle and wrist joints. This therapy type has been referred to as ‘‘perturbation training, sensorimotor activation,’’ and recently, ‘‘reactive muscle activation (RMA).’’ which focuses on reintegrate the neuromuscular reflex patterns that exist in a normal joint. RMA exercises restore the electromyography pattern and neuromuscular activation to the muscles around the joint [13]. Several orthopedic and neurological conditions are related with kinesthetic and proprioceptive impairment.

Proprioceptive training that aims to restore motor function after injury focuses on the utilization of the somatosensory signals such as tactile or proprioceptive afferents in the lack of information from other modalities such as vision. The aim is to improve or restore sensorimotor function. In healthy clinical populations, especially with orthopedic or neurological conditions apply conscious or unconscious neuromuscular training program [16, 17]. In hand rehabilitation, it is required to improve to get patients functionally independent, either sudden overload or repeated stress to the hand muscles. Although the application of RMA is probably the most difficult in hand therapy, it is likely the most important in the wrist proprioceptive function which is developed by the use of a so-called Powerball. The Powerball is a type of gyroscope using centrifugal forces to produce inertia thus exercises the muscles acting on the wrist joint. The purpose of the Powerball using in hand rehabilitation is to improve unconscious proprioception skills [18].

The aim of the study is to investigate the effects of the Powerball training program with six weeks on hand grip strength, pinch grip strength and proprioception among dentists.

H0: Powerball training is not effective on hand grip strength, pinch grip strength and proprioception among dentists.

H1: Powerball training is effective on hand grip strength, pinch grip strength and proprioception among dentists.

H2: There are not any significantly differences in hand grip strength, pinch grip strength and proprioception after Powerball training program between dentists and dental students.

H3: There are significantly differences in hand grip strength, pinch grip strength and proprioception among after Powerball training program between dentists and dental students.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1. Wrist

The wrist is the collection of soft tissue structure and bones which is localized between the forearm and the fingers. This joint complex is capable of a substantial arc of motion that provides hand and finger functions. The wrist addditionaly performs as an important stabilizing task [19-21].

2.1.1. Osteology of the Wrist

The wrist is the region between the distal ends of the ulna, radius and the bases of the metacarpals, which consist the triangular fibrocartilage complex (TFCC), carpals and carpal ligament [22]. The wrist contains eight carpal bones and the proximal bases of the five metacarpal bones (Figure 2.1.) [23]. The eight carpal bones are arranged in two rows as a proximal and a distal row on the basis of their kinematics during global wrist motion [23, 24]. These bones provide flexibility of wrist. The four carpal bones from medial to lateral in the proximal row are the pisiform, triquetral, lunate and scaphoid. The proximal carpal row bones can be identified as an intercalated segment because there is not any tendons inserted upon them and their motion is completely dependent on mechanical forces from their surrounding articulations [23]. The hamate, capitates, trapezoid, and trapezium. are the four bones in the distal row from medial to radial [24]. The distal row of carpal bones are tightly bound to one another by way of stout intercarpal ligaments. The motion between the distal carpal bones can be considered insignificant. Likewise, distal row functionally as part of a fixed hand unit moves in response to the musculotendinous forces of the forearm because of the nearly rigid ligamentous connection of the trapezium and capitate to the index and middle metacarpal bones and lack of motion between these bones [23].

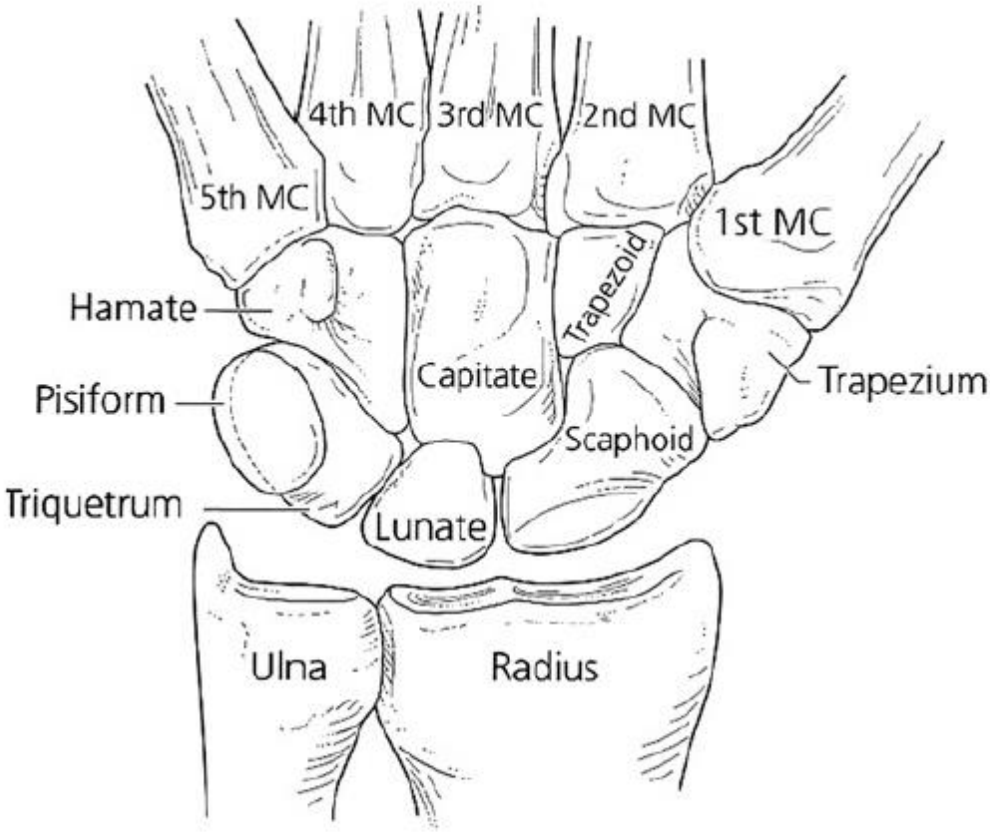


Figure 2.1. Osseous Anatomy of the Wrist [25].

2.1.2. Arthrology of the Wrist

The wrist joint that is the one of the most complex joint in the body consists of the multiple articulations of the eight carpal bones with the distal radius, the structures within the ulnocarpal space, the metacarpals, and each other [21, 26]. The wrist joint is formed between the radius and carpal bones of the hand and between an articular disc, distal to ulna and carpal bones. The wrist joint permits movement around two axes. The hand can be abducted, adducted, flexed, and extended at the wrist joint [27].

2.1.2.1. Distal Radioulnar Joint

The articular surface of the distal radius is typically tilted with of 22˚ radial inclination, 11˚ of volar tilt and 12 mm of radial height. The ovoid shaped lunate fossa and triangular scaphoid fossa which articulate with the lunate and scaphoid bones, respectively compose its articulation. On the ulnar side of the distal radius, the sigmoid notch articulates with the distal ulna to form the distal radioulnar joint (DRUJ) [25]. DRUJ that is the type of pivot joint promotes rolling and gliding movements between the radius and ulna, resulting in forearm pronation and supination. This movement is taking charge mainly by the triangular fibrocartilage complex (TFCC) which consists of a combination of fibrocartilage, ligaments, meniscus homologue and an articular disc. Stabilizing and separating the DRUJ from the carpus and distal radius, reinforces the ulnar side of the wrist contributes transfer part of compression force crossed the hand to forearm are the functions of the TFCC. The joint capsule, interosseous membrane, pronator quadratus, and extensor carpi ulnaris (ECU) provide the joint stability. The ligamentous portion of the TFCC consists of the dorsal and palmar radioulnar ligaments that are taut at the end ranges of pronation and supination. Their function is to helping stabilize the TFCC [25, 28, 29].

The distal ulna does not typically articulate with the corpus. The triangular fibrocartilage covers its distal surface. The midcarpal joint is the articulation between the proximal and distal carpal bone rows. The scaphoid, lunate, and triquetrum form the proximal row has no muscular attachments; it articulates with the trapezium, trapezoid, capitate, and hamate while the scaphoid engages both rows. The pisiform that is a sesamoid bone of the flexor carpi ulnaris does not contribute to midcarpal joint motion [25].

2.1.2.2. Radiocarpal Joint

The Radiocarpal joint is located between carpal bones and radius. The more mobile proximal row articulates with the distal radius except psiform and soft tissue triangular fibrocartilage to form the radiocarpal joint [21, 24]. The joint allows multiple axes of motion including flexion, extension, radial deviation, ulnar deviation and circumduction [25]. The range of motion (ROM) of extension is smaller than flexion, because not only radiocarpal joint but also the joint between distal and proximal carpal row bones take part of the movement through the flexion [24].

2.1.2.3. Intercarpal and Midcarpal Joints

The joint is located between same direction carpal bones which have small amounts of gliding movement. This movement increases the ROM of the wrist [24].

Between the proximal and distal rows of carpal bones is the midcarpal joint, and between adjacent bones of these rows is the intercarpal joints. The midcarpal joints is divided into two compartments; lateral and medial. The medial compartment is larger and formed by the apex of hamate and convex head of capitate. The lateral compartment is formed by distal pole of scaphoid (slightly convex) and proximal surface trapezoid and trapezium (slightly concave) [21, 29].

2.1.3. Muscles of the wrist

Flexor carpi ulnaris (FCU) is the only muscle, which inserts into the carpal bones of the wrist. All of wrist flexor and extensor muscles bypass the corpus, which moves the carpus like a segment of the intercale affected by muscles that are not attached to it. Hence, the position of the carpal bones depends on the relative stresses applied around them [24].

Extensor carpi radialis longus (ECRL), extensor carpi radialis brevis (ECRB), extensor carpi ulnaris (ECU) are the primary wrist extensor muscles which act only on the wrist joint. The main function of these muscles is to stabilize and position the wrist throughout activities containing active flexion of fingers. They have an important role in producing strong grip and making a fist. FCU, flexor carpi radialis (FCR) and palmaris longus are the primary flexor muscles of the wrist [29].

2.1.4. Ligaments of the Wrist

The carpal ligaments have been divided into extrinsic and intrinsic groups on the basis of their location. Extrinsic ligaments connect the distal radius and ulna to the carpal bones, and intrinsic ligaments have their origins and insertions within the carpal bones (Figure 2.2).

2.1.4.1. Extrinsic Ligaments

The ligaments originates from the palmar edge of the distal radius and lying toward to the scaphoid, lunate, and capitate [25].

Dorsal ligaments: The dorsal ligaments are important secondary stabilizers of the scapholunate joint.

Dorsal radiocarpal ligament: The dorsal radiocarpal ligament proximally arises from the ulnar and dorsal portion of the distal end of the radius, from Lister's tubercle to the level of the interfossal ridge between the scaphoid fossa and the lunate fossa. The proximal and dorsal tubercle of the triquetrum and the lunate are attached distally by this ligament.

Volar ligaments: Volar extrinsic ligaments have a major functions in stabilizing the wrist and providing greater constraint to instability. There are three strong palmar extrinsic radiocarpal ligaments those are the radioscaphocapitate, the long and the short radiolunate ligaments.

Radioscapholunate ligament: The radioscapholunate ligament is found in the region between the long radiolunate and short radiolunate ligaments. It is attached on the volar edge of the distal radius proximally [23].

Ulnocarpal ligament: It consists of ulnolunate, ulnotriquetral and ulnocapitate ligaments. They are stabilizers of the corpus of ulna thus complement the function of the TFCC [28].

Intrarticular ligament: The third-fourth metacarpal-capitate-hamate intraarticular ligament: The ligament is between and connected to, the third metacarpal, the fourth metacarpal, the capitate, and the hamate. The main part of this ligament passes from the center of the ulnar side of the third metacarpal base in the center of the radial side of the hamate [28].

2.1.4.2. Intrinsic Ligaments

The intrinsic ligaments of the wrist are arranged between the carpal bones. The lunotriquetral and scapholunate ligaments are the most important ligaments. Tears of these ligaments lead to altered biomechanics, within the proximal carpal row, alongside with damage of wrist movement and injury. The fascia of the forearm becomes thicker at the level of the distal carpal row which is called the flexor retinaculum.

It forms proximally the volar carpal ligament, which correlate medially to the pisiform and laterally to the scaphoid. Distally the flexor retinaculum that is thicker composes the transverse carpal ligament which arrays laterally to the trapezium and medially to the hook of the hamate. The fascia constitute a compartment known as the carpal tunnel which includes thumb flexor tendons, extrinsic finger tendons, and the median nerve [28]. The intrinsic ligaments can be grouped into three categories; short, long, and intermediate according to their length and permitted the relative intercarpal movement. Palmar, dorsal, and interosseous are the three short intrinsic ligaments. They are stout, firm fibers that attach the adjacent carpal bones tightly. Maintaining the bones of the distal carpal row as an integrated kinematic unit is responsibity of these strong ligaments.

Three intermediate intrinsic ligaments are present between the triquetrum and lunate, the trapezium and scaphoid, the scaphoid and lunate [21].

Dorsal ligaments consist of intercarpal ligament, trapeziotrapezoid ligament capitotrapezoid ligament capitohamate ligaments and triquetrohamate ligament.

Volar (Palmar) ligaments that is called the deltoid, or V, ligament is more important than dorsal ligaments. It stabilizes the capitate because it binds to its neck and fans out proximally to insert into the scaphoid and triquetrum. Volar ligaments consist of lunotriquetral ligament, volar trapeziotrapezoid ligament, scaphotrapezial ligament scaphotrapezoidal ligament, scaphocapitate ligament, volar capitotrapezoid ligament, triquetrocapitate ligament, volar triquetrohamate ligament [21, 23].

Interosseous ligaments consist of scapholunate interosseous ligament, lunotriquetral interosseous ligament, trapeziotrapezoid interosseous ligament, capitotrapezoid interosseous ligament, capitohamate interosseous ligament.

Scapholunate interosseous ligament (SLIL): The scapholunate interosseous ligament joins the scaphoid and lunate along the proximal edge of the joint surface. It is described as a three part structure with dorsal, volar and proximal components. The dorsal part is the strongest and most critical joint stabilizer. The proximal SLIL is a considerably thinner ligament that makes important contributions to the rotational stability of the scapholunate joint.

The SLIL is the primary stabilizer the radioscaphocapitate and scaphotrapezial ligaments and also secondary stabilizers of the scapholunate articulation.

Lunotriquetral interosseous ligament: The lunotriquetral interosseous ligament units the lunate and triquetrum along the proximal edge of the joint surface. It is also described as a three part structure with a proximal, dorsal and volar [22].

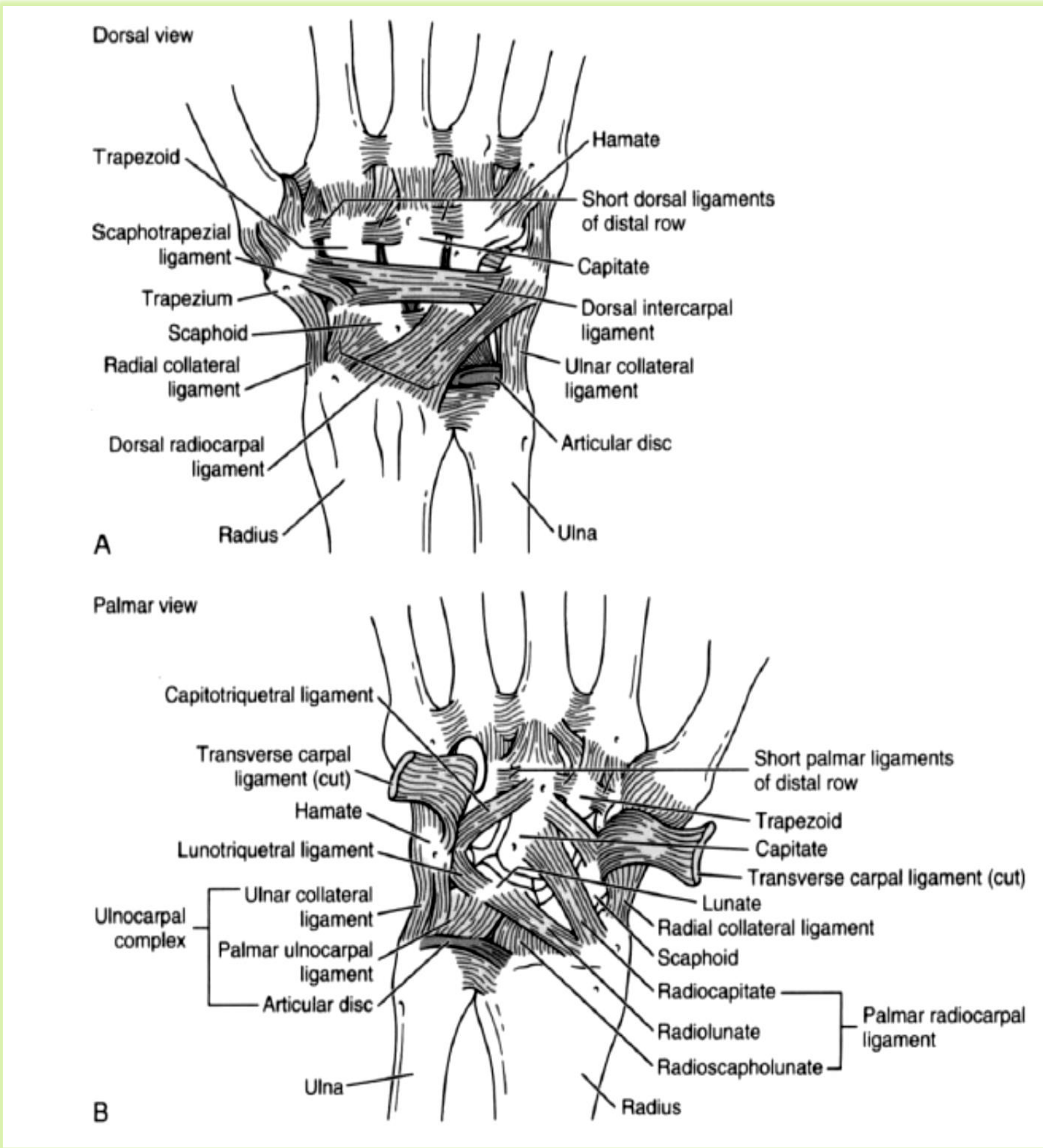


Figure 2.2. Ligaments of the wrist. A. Dorsal aspect of the right wrist, B. Volar Dorsal aspect of the right wrist [30].

2.2. Hand

2.2.1. Osteology of the Hand

The hand is the distal end of the upper extremity [26]. Bones of the hand are organized to maximize the functional efficiency of the intrinsic muscles and the tendons of the extrinsic muscles of the hand. There are nineteen major bones distal to carpals which are the phalanges and the metacarpals. These bones are long bones. The expanded proximal and distal ends (epiphyses) and central shafts. Sesamoids, additional small bones are usually located in the tendons of certain intrinsic thumb muscles. Each digit has a carpometacarpal (CMC) joint and a metacarpophalangeal (MCP) joint and two interphalangeal (IP) joints, while the thumb has only one [31, 32].

While one metacarpal and three phalanges compose to each finger, one metacarpal and two phalanges compose the thumb. The digits are numbered from the radial to the ulnar side: I (thumb), II (index finger), III (middle finger), IV (ring finger), and V (little finger). Each digital array articulates proximally with a particular carpal bone to form the CMC joint. The other joint in each array the MCP joint attaches the metacarpal bone to the proximal phalanx. A proximal (PIP) and a distal (DIP) interphalangeal joint are located between the phalanges of the fingers.

2.2.1.1. Metacarpals

One metacarpal is related to each digit, but the thumb is considerably shorter than the others. These bones form the bony base of the hand. The integrity of them is necessary for both its natural form and function. Each bone has a head (distally) and dorsally bowed shaft with an expanded base (proximally). The bones diverge distally to their heads from closely positioned bases. The shape of hand is determined by this arrangement and separated the digits so it can provide to manipulate large objects independently. The metacarpal of the thumb is located anteriorly to the others and rotated approximately 90˚ thus, it is ideally position to oppose. The shaft of each metacarpal is triangular in cross section, with the apex of this triangle directed volarly and composed of more dense bone than the dorsal aspect of the shaft. This concentration of dense bone projects the significant compressive force on the flexor side of the bone. The overall shape of each metacarpal (along with that of the phalanges) provides to the longitudinal arch of the hand [31].

2.2.1.2. Phalanges

The hand consists of 14 phalanges (Figure 2.3.); the thumb has only two, while each of the other digits has three. The proximal and middle phalanges, as similar the metacarpals, are bowed dorsally along their long axis so contribute to the longitudinal arch of the hand. The shafts of the phalanges function as anchors for the long digital flexor tendons. The volar aspect of the shaft that is flat from side to side rounded dorsally. The junctions of the rounded and flat surfaces are signed by longitudinal ridges that act as the attachments for the fibrous part of the digital tendon sheath [31].

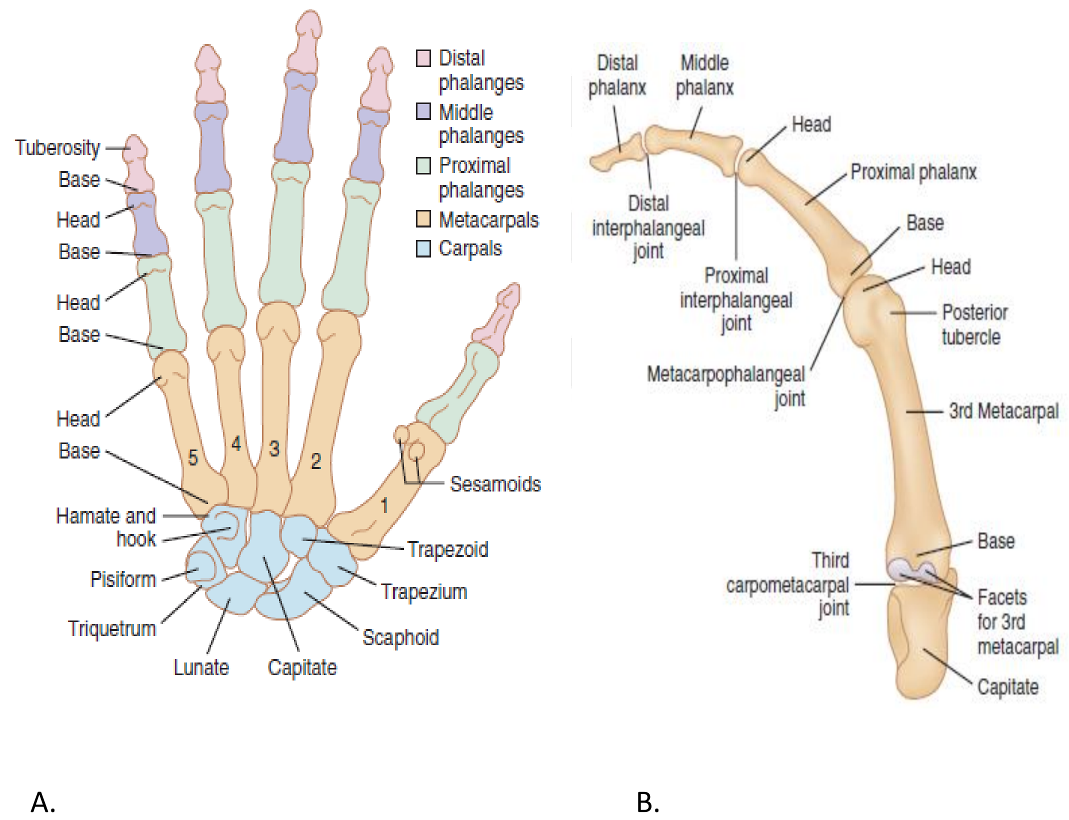


Figure 2.3. A. Volar view of the bones of the hand and wrist. B. Lateral view of the middle finger and the capitate [31].

2.2.1.3. Arches of the Hand

In relax position of the hand, a natural cavity is observed, which permits the hand to manipulate and hold the objects securely. The bones of the hand are composed in three arches, one longitudinal and two transverse. The shapes of the metacarpals also contribute to the proximal and distal transverse arches of the hand (Figure 2.4.). The proximal transverse arch is at the level of the distal row of carpal bones with the capitate as its keystone and the bases of the metacarpals. The bases of the metacarpals as well as the distal row of carpals are wedge shaped in cross section and the apex of each wedge is directed volarly. Since the metacarpal bases and distal carpals are positioned very close to one another and are held tightly together, they collectively form a dorsal convexity and thus a side-to-side arch. This rigid and static arch forms carpal tunnel. The distal transverse arch that is more mobile is at the level of the metacarpal heads with the head of the third metacarpal as its keystone and has also a dorsal convexity. This arch is larger than the proximal arch and merely reflects the orientation of the metacarpals and the fact that the metacarpal heads are farther apart than their bases [30]. The rigid portion of the longitudinal arch connect to two transverse arches, which is composed of the proximal carpus and the four digital rays. The longitudinal arch is completed by the individual digital rays, and the mobility of the thumb and fourth finger and fifth finger rays around the second and third fingers allows the palm to flatten or cup itself to manipulate objects of various sizes and shapes. Although the extrinsic flexor and extensor muscles are largely responsible for changing the shape of the working hand, the intrinsic muscles of the hand are primarily responsible for maintaining the configuration of the three arches. A collapse in the arch system resulting from bone injury, rheumatic disease, or paralysis of the intrinsic muscles can contribute to severe disability and deformity [21].

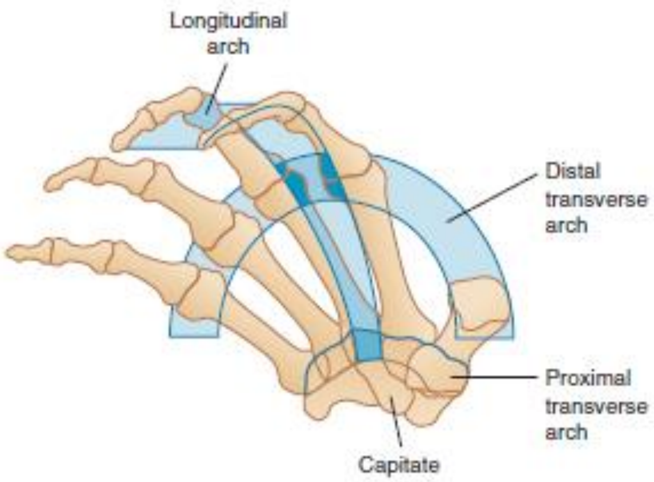


Figure 2.4. Arches of the hand [31].

2.2.2. Arthrology of the Hand

2.2.2.1. Carpometacarpal Joints (CMC)

There are five carpometacarpal joints between the metacarpals and the related distal row of carpal bones that forms a relatively immobile transverse unit that articulates with the metacarpals to form the CMC joints. CMC joints are the most proximal joints in the hand and connect it to the wrist. When the hand takes the shape of a fist, slight flexion is observed on 4th and 5th CMC joint, but there is almost no movement in the 2nd and 3G joints. Although they are all synovial joints, the thumb CMC joint is significantly different from those of the four medial digit which permits significant and complex motion. There is essentially no motion allowed at the CMC joints of the index and middle fingers. These two metacarpals along with the distal carpal row form the rigid and stable central base of the hand. A small amount of motion is allowed at the CMC joints of the ring and small fingers. This motion, primarily a bit of flexion, warrants slight cupping of the medial side of the to fit and both manipulation and grip objects. The joint between the metacarpal of the thumb (metacarpal I) and one of the carpal bones permit greater mobility than the limited sliding movement that occurs at the carpometacarpal joints of the fingers. The first CMC joint is sellar type joint that permits movement in various directions. Through this movement, the thumb has the ability to encircle objects held within the palm. Opposition greatly enriches the dexterity of human prehension [20, 21, 26, 27, 29, 31].

2.2.2.2. Metacarpophalangeal (MCP) Joints

The metacarpophalangeal (MCP) joints of the four medial digits are formed by the bases of the proximal phalanges and the heads of the metacarpals. This condylar type of joint allows flexion, extension, abduction, adduction, circumduction, and limited rotation [33].

The articular surface of the metacarpal head is biconvex, cam-shaped so it extends farther volarly than dorsally, and it is wider volarly than dorsally. The articular surface of the phalangeal base is biconcave, shallow and smaller in area than the articular surface of the metacarpal head. These shapes would appear to permit the phalanx to move in virtually any plane on the metacarpal head.

The mechanical stability is important biomechanics of the hand. MCP is strengthened by palmar plates which limit extreme extension. Active motion is limited to flexion and extension, adduction and abduction due to soft tissue constraints.

There are both differences and similarities between the MCP joint of the thumb and the other MCP joints. The motion available at the thumb MCP is similar in direction to the other MCP joints, but more limited because of the stability of the joint. Flexion and extension are less free, and adduction and abduction are significantly more limited [31].

2.2.2.3. Interphalangeal Joints (IP)

Interphalangeal joints are divided into two subtypes as proximal ınterphaleangeal and distal ınterphalangeal joints [31].

2.2.2.3.A. Proximal Interphalangeal Joints (PIP)

The proximal interphalangeal (PIP) joint is formed by the head of the proximal phalanx. The head of proximal phalanx has a shape of a short transverse cylinder and the base of the middle phalanx, which is concave from dorsal to ventral hence, conforms to the cylindrical head. In addition to these, the phalangeal head has sagittally directed groove and the phalangeal base has sagittally oriented ridge. These surfaces provide the stability of the joint and assure that the motion is limited to one degree of freedom, which are flexion and extension in the sagittal plane. Some degree of PIP joints is reinforced by the components of the extensor mechanism. The triangular membrane and central band are located dorsally, and the lateral band and retinacular ligament positioned on the sides. The tendons of both the FDP and FDS pass volar to the joint [31].

2.2.2.3.B. Distal Interphalangeal (DIP) Joint

The distal interphalangeal (DIP) joint is quite similar to the PIP joint. The construction of the articular surfaces is similar, so the motion is limited to only the sagittal plane (flexion and extension). The collateral ligaments, joint capsule, volar plate, and supporting mechanism are also similar. The volar plate ensures an attachment for the fibrous part of the flexor digital tendon sheath; in this case it is the fifth annular ligament (A5 pulley) [31].

2.2.3. Muscles of the Hand

2.2.3.1. Extrinsic Muscles of the Hand

Extrinsic muscles of the hand originate in forearm from the humeral epicondyles as well as the radius and ulna, and become tendinous just proximal to the extensor and flexor retinacula. These muscles are further divided into the flexor or pronator group as illustrated in figure 2.5. and extensor or supinator group muscles as illustrated in figure 2.6 [28]. The extrinsic finger flexors consist the Flexor digitorum profundus muscle (FDP) and Flexor digitorum superficialis muscle (FDS). The extrinsic finger extensors include the Extensor digitorum muscle (ED) which extends metacarpophalangeal, distal and proximal interphalangeal joints. The Extensor digiti minimi (EDM) and Extensor indicis (EI) extend the 5th and 2nd digits respectively. [32]

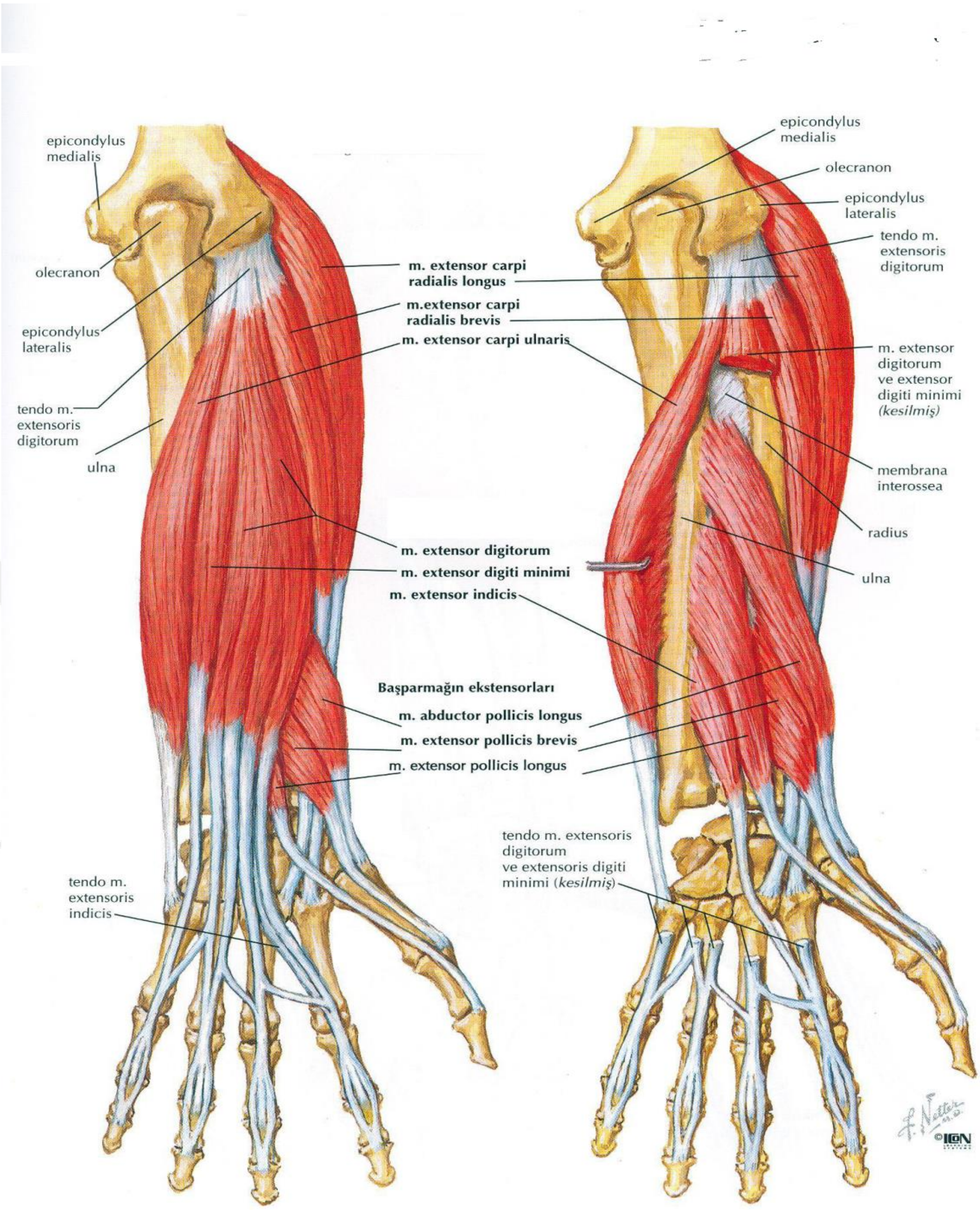


Figure 2.5. The extrinsic muscles of the hand (Extensor groups) [34].

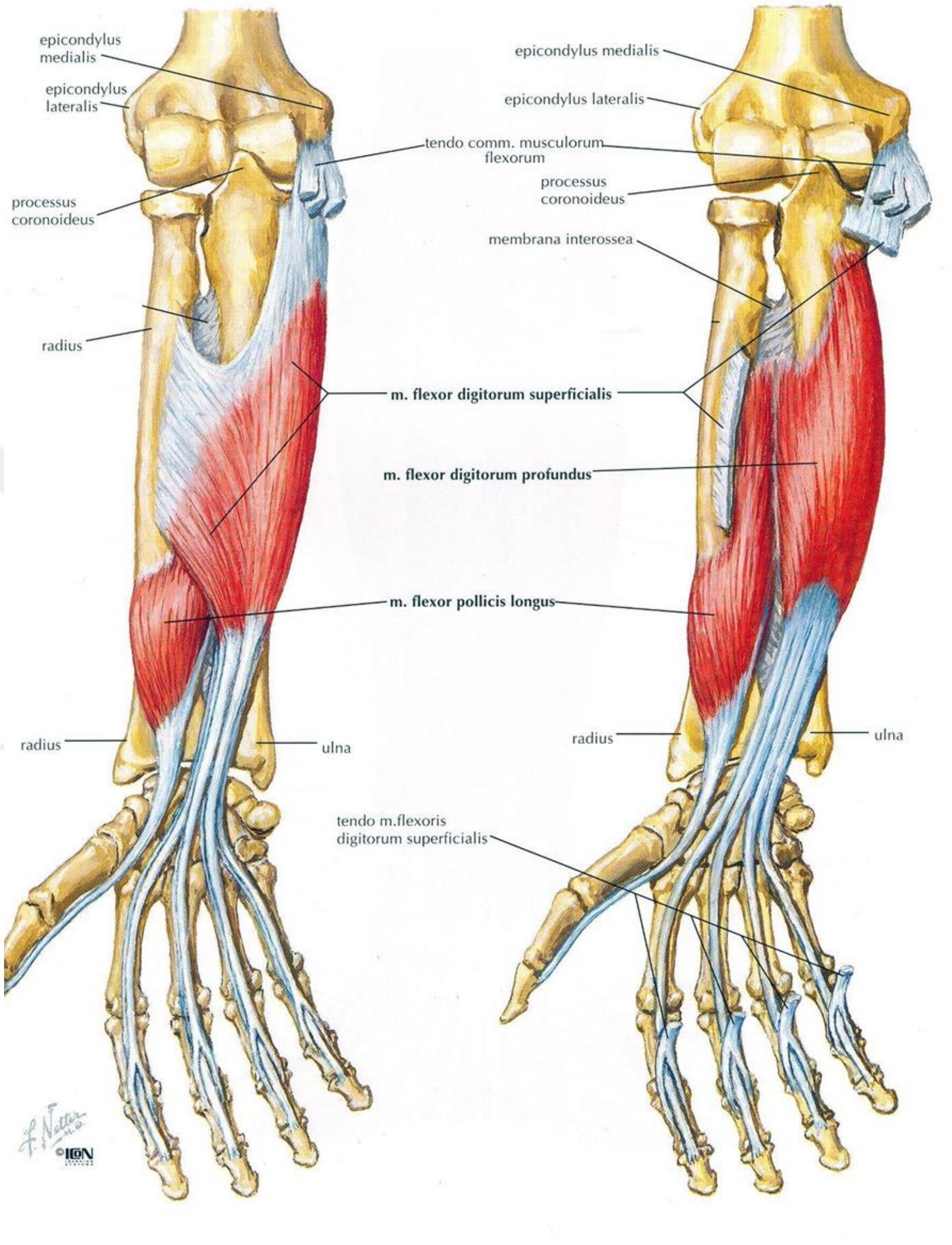


Figure 2.6. The extrinsic muscles of the hand (Flexor groups) [34].

2.2.3.2. Intrinsic Muscles of the Hand

Twenty intrinsic muscles that are small muscles arise between the wrist and the MCP joints. They provide the balancing force between the extrinsic extensor and flexor muscles. They generally are involved in the finer movements (precision grip) of the digits [31]. Intrinsic muscles are divided into two muscle groups; central intrinsic muscles which consist of the Interossei and Lumbrical muscles and the peripheral intrinsic muscles included the Thenar and Hypothenar muscles [28].

There are 4 dorsal Interossei muscles which join in the 2nd to 4th digits and abduct the digits from the axial line of the hand and serve with the Lumbrical muscles to flex the MCP joints and extend the IP joints. The palmar Interossei muscles attach to the 5th, 4th and 2nd digits so they adduct the digits toward the axial line of the hand, also support the Lumbrical muscles to flex the MCP joints and extend the IP joints. The Lumbrical muscles enhance flexion of the MCP joints and extension of the IP joints of the 2nd to the 5th digits. The 5th digit has further short muscles, being the Abductor digiti minimi, Flexor digiti minimi brevis, and the Opponens digiti minimi muscles [32].

2.2.3.3. Muscles of the Thumb

The thumb has its own muscles which allow movement. The thumb flexors consist the Flexor pollicis longus (FPL) and Flexor pollicis brevis (FPB) muscles. Extensor pollicis longus and brevis muscles are the thumb extensors. The muscles for adduction are the Adductor pollicis longus and brevis muscles while the Abductor pollicis brevis and the Abductor pollicis longus muscles abduct the thumb. The only other muscle of the thumb is the opponens pollicis muscles which provide the opposition of the thumb (Figure 2.7.) [24, 32].

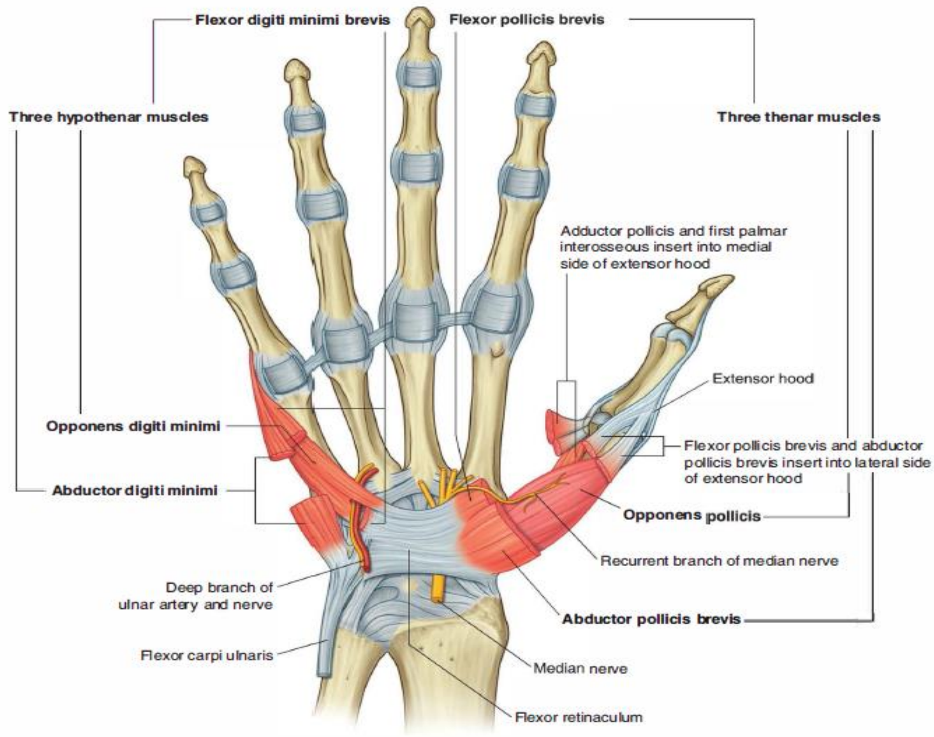


Figure 2.7. The muscles of the thumb [26].

2.2.4. Ligaments of the Hand

2.2.4.1. Collateral Ligament

The collateral ligament has a triangular shape and contains of two distinct parts, both attach proximal to the dorsal tubercle of the metacarpal. From that attachment, the fibers of the ligament diverge when they pass distally. The true, or band, that is the strongest part of the ligament extends more distally. From the dorsal tubercle it passes obliquely volarly and joins to the volar aspect of the side of the proximal phalangeal base. This ligament is somewhat loose in extension allowing abduction and adduction. While the proximal phalanx is flexed, this part tightens because of the cam shape of the metacarpal head and volarly wider head. In flexion, abduction and adduction are very limited resulting of the tightness. The accessory, or fan, part of the ligament that is more obliquely oriented binds to the volar plate. As the fibrous tendon sheath also binds to the volar plate, the accessory collateral ligament has an important role in stabilizing the long digital flexor tendons. The accessory ligament loosens slightly as flexion occurs.

The collateral ligaments are similar to those of the MCP joints that are triangular in shape consist of true (band) and accessory (fan) parts. From their attachment to the dorsal tubercle of the proximal phalanx, the two parts diverge as they cross the joint. The true part binding to the side of the base of the middle phalanx and the accessory part binding to the volar plate. The true part is taut throughout the range of motion, thus stabilizes the joint in all positions; the accessory part stabilizes the volar plate [30].

2.2.4.2. Ulnar Collateral Ligament

The ulnar collateral ligament that is on the volar and medial aspects of the joint extends from the transverse carpal ligament to the palmar-medial aspect of the first metacarpal base.

2.2.4.3. Intermetacarpal Ligament

An intermetacarpal ligament (or pair of anterior and posterior ligaments) interconnects the bases of the first and second metacarpals.

The dorsoradial ligament extends from the dorsolateral aspect of the trapezium to the dorsal base of the first metacarpal [31].

2.2.4.4. Anterior Oblique Ligament

The anterior oblique, or beak, a ligament is a strong ligament. It interconnects the palmar tubercle (beak) of the metacarpal base and the distal part of a ridge on the tubercle of the trapezium. This ligament that is generally considered a major stabilizing ligament of the joint is taut in extension, abduction, and opposition.

The posterior oblique ligament is on the dorsal aspect of the joint and interconnects the dorsal aspect of the trapezium and the ulnar (medial) base of the metacarpal [31].

2.3. Innervation of the Wrist and Hand

There are three nerves which give sensory and motor innervation to the forearm, wrist and hand. These nerves as the Radial, Ulnar and Median nerve.

2.3.1. The Radial Nerve

The radial nerve originates from the posterior cord of the brachial plexus and receives contribution from the fifth through eighth spinal nerve root levels. Just proximal to the elbow, it divides into the superficial and deep terminal branches. The superficial radial nerve continues down the forearm along the lateral border of the brachioradialis and becomes subcutaneous at its middle 1⁄3, innervating the skin on the radial aspect of the forearm and the dorsal aspects of the radial three and one half digits [28, 35]. The superficial branch innervates the ECRB and ECRL.

The deep branch innervates all the forearm supinator muscles as well as the Extensor pollicis brevis (EPB), Extensor pollicis longus (EPL), Extensor Carpi Ulnaris (ECU), Abductor pollicis longus (AbPL), EI, EDC muscles [28].

2.3.2. The Ulnar Nerve

The medial cord of the brachial plexus gives off contribution to the median nerve. The terminal branch continues into the axilla as the ulnar nerve (Figure 2.9) with contributions from the eight cervical and first thoracic, and arises from the medial cord of the C8 and T1 spinal nerve root levels [28, 35]. The ulnar nerve moves into a position that is posterior to the medial humeral condyle, wrapping around the medial epicondyle at the level of the elbow. As the nerve passes posterior to the epicondyle, it is encased within a fibrous sheath (Osborne's ligament) laterally, and the head of the FCU posteromedially. Cubital tunnel is formed by these two structures together [35].

It innervates the motor branches of FCU as well as the FDP to the 4th and 5th digits in the forearm. In the hand the Radial nerve innervates the hypothenar muscles as well as all the intrinsic muscles of the hand, except those supplied by the Median nerve [28]. Near the wrist the ulnar nerve rises superficial to the flexor retinaculum and lies under the tendon of the FCU before its attachment to the pisiform. The ulnar nerve then turns radial to the pisiform to lie in a fibrous tunnel known as Guyon's Canal [35].

2.3.3. The Median Nerve

The Median nerve originates from the medial and lateral cords of the C5, C6, C7, C8 and T1 spinal nerve root levels (Figure 2.9).

The Median nerve gives off the Anterior interossus nerve which supplies the FPL, FDP to the 2nd and 3rd digits and Pronator quadratus muscle. The Median nerve supplies all the extrinsic flexors of the wrist and hand except those supplied by the Ulnar nerve (Ulnar half of FDP and FCU muscles) [28]. Distal to the elbow, the median nerve courses down the forearm deep to the FDS and superficial to the FDP. In the distal 1⁄3 of the forearm, the median nerve emerges from beneath the FDS to lie medial to the FCR and lateral to the palmaris longus, before entering the carpal tunnel.

The most consistent order of branches off the median nerve is the FCR, pronator teres, FDS, palmaris longus, anterior interosseous nerve, and terminal or recurrent branches to the FDS and palmaris longus. The median nerve gives a palmar cutaneous branch that provides sensation to thenar skin of the palm, and is most commonly branches 4 to 5 cm proximal to the wrist, located on the ulnar side of the FCR. Within the carpal tunnel, the median nerve divides into three terminal branches. The lateral branches supply the thumb and radial side of the index finger and the terminal branches of the medial division supply the middle finger and radial aspect of the ring finger. The lateral-most division gives off the terminal motor innervation of the median nerve, the recurrent motor branch, that innervates the Abductor Pollicis Brevis (AbPB), FPB, opponens pollicis (OP) and the lateral two lumbricals before to dividing into its terminal sensory branches (Figure 2.8-2.9.) [35].

Radial Nerve	Posterior Interosseous	Median Nerve	Anterior Interosseous	Ulnar Nerve
Brachioradialis Extensor Carpi Radialis Longus	Supinator Abductor pollicis longus	Pronator teres Palmaris longus	Flexor pollicis longus Pronator quadratus	Flexor carpi ulnaris Flexor digitorum profundus (ring and small)
Extensor Carpi Radialis Brevis*	Extensor pollicis longus	Flexor carpi radialis	Flexor digitorum profundus (index and middle)	Adductor pollicis (deep head)***
Anconeus	Extensor pollicis brevis Extensor indicis proprius Extensor digitorum communis Extensor digitorum minimus	Flexor pollicis brevis** Abductor pollicis brevis** Opponens pollicis** Abductor pollicis (superficial head)** Lumbricals 2,3**		Opponens digiti minimi*** Abductor digiti minimi*** Flexor digiti minimi brevis*** Lumbricals 4,5*** Interossei***

*Controversial; **Recurrent Motor Branch of the Median Nerve; ***Deep Motor Branch of Ulnar Nerve.

Figure 2.8. Motor Innervation by Radial, Ulnar And Median Nerve [35].

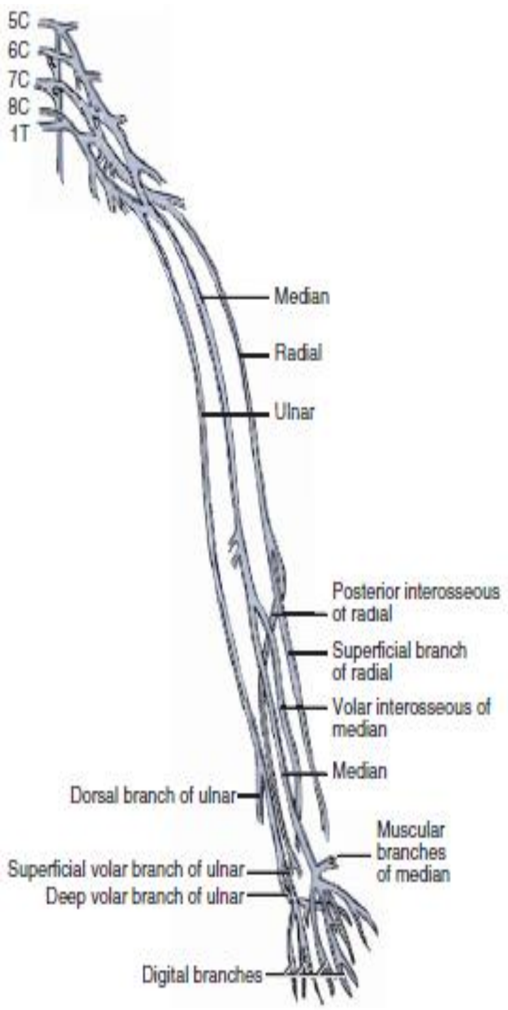


Figure 2.9. The branches of the wrist and hand nerves [21].

2.4. Biomechanics of Wrist and Hand Movement

Movement at the wrist is a result of motion occurring at the radiocarpal articulation between the carpal bones at the carpal-metacarpal junction and at the varying amounts of TFCC [28]. Except for anatomical variations, average movement degrees are 65˚-80˚ flexion, 55˚-75˚ extension, 35˚-40˚ ulnar deviation, 15˚-20˚ radial deviation, 80˚ forearm pronation, 80˚ forearm supination. Necessary activities requiring an arc of wrist motion, such as eating, drinking, using a telephone, and reading were accomplished by motion of 5˚ flexion, 30˚-40˚ extension, 15˚-30˚ ulnar deviation and 10˚ radial deviation [21].

Even though the wrist, hand and finger joints have the ability to move through a relatively large ROM, most functional daily tasks do not need a full ROM. Brunfield and Champoux stated that the optimum functional ROM at the wrist was 35˚ extension and 10˚ flexion. The wrist is generally held in slight extension (10˚-15˚) and slight ulnar deviation. It is stabilized in this position to provide maximum function for the fingers and thumb. Functional flexion at the metacarpophalengeal and interphalangeal joint is approximately 60˚ and distal interphalengeal joint is 40˚. For the thumb, functional flexion at the metacarpophalengeal and interphalangeal joint is approximately 20˚. The hand is able to perform most of its grip and other functional activities within these ROM [36].

In the anatomic position, extension of CMC joint is 10˚ to 15˚, the thumb metacarpals flexes from full extension at about 45˚-50˚. MCP joint allows the finger better adapt to the shape of holding objects so rising the grasping control. At MCP joints of the ring and small finger axial rotation is 30˚-40˚. The range of extension and flexion of the MCP joints increases gradually from the 2nd and 5th digit flexes 90˚ and 110˚-115˚ respectively. Extension at MCP joints can measured beyond the neutral (0 degree) position to 30˚-45˚. According to reference point of 3rd metacarpal, abduction and adduction occur about 20˚ [29].

2.5. Functions of the Wrist and Hand

The wrist functions kinematically by permitting for changes in the location and orientation of the hand relative to the forearm and kinetically by transmitting loads from the hand to the forearm and vice versa. Even though the function of all joints of the upper extremity is to position the hand to allow it to perform daily life tasks, the wrist appears to be the key to hand function. Stability of the wrist is essential for proper functioning of the digital flexor and extensor muscles, and wrist position affects the ability of the fingers to flex and extend maximally and to grasp effectively during prehension [21].

The hand is the final link in the mechanical chain of levers that begins at the shoulder. It is a highly complex and multifaceted mobile effector organ whose functions can be divided into two subtitles as prehension and other function of manipulation of objects included pushing, pulling, compression, touching, feeling etc.

The hand manipulation skills with the thumb and the fingers (supported by the interplay between the muscular and sensory system) facilitates our understanding of and appreciation for small objects such as the ability to clasp a necklace together, ready a contact lens, and so onIy is valued for its performance and appearance in delicate prehensile tasks to powerful grasp patterns. Sensory-motor and kinesthetic control integration is required for prehension skills which is one of the most important functions of the hand depending on the type of grasping. Prehension is described as a grip or grasp, in which all digits are performed, or as a pinch, in which index finger and thumb are primarily used [19, 21, 29].

Stages of Grip

1. Opening of the hand, which demands the simultaneous action of intrinsic muscles of the hand and the long extensor muscles
2. Closing of the thumb and the fingers to grasp the object and accomodate to the shape of the object, which involves intrinsic and extrinsic flexor and opposition muscles
3. Exerted force, which varies depending on the weight, surface features, fragility, and use of the object, involving opposition muscles and intrinsic and extrinsic flexor
4. Release, in which the hand opens to drop of the object, involving the same muscles as for opening of the hand [36].

2.5.1. Functional Assessment of The Hand (Grip)

2.5.1.1. Power Grip

The power grip is a palmar opposition grasp in which all digits are flexed around the object to ensure high stability and wrist is in ulnar deviation and slight extension [36, 37]. Power grip requires significant amount of force. A power grip that gives greater flexor asymmetry to the hand requires firm control. The object is maintained against the palm; the thumb may or may not be involved, then extrinsic (forearm) muscles are more important during power grip. Power grip is used whenever strength is the primary consideration and the ulnar side of the hand has to work together with the radial side assure static control and support. Power grip as illustrated figure 2.10 can be sub-divided into three types cylindrical grip, spherical grip, and hook grip [36].

Figure 2.10. Power Grip [26].

2.5.1.1.A. Cylindrical grip

The thumb is localized across the index and middle fingers and fingers take the flexion position. Cylindrical grip almost exclusively uses flexors of the hand to carry the fingers around and maintain to grasp on an object (Figure 2.11.). The function in the fingers is performed largely by the FDP that is primary responsible muscles, especially in the dynamic closing action. In the static phase the FDS and interossei muscles that are considered to be functioning as MCP joint flexors and adductors/abductors contributes gripping in situations where the intensity of the grip needs greater force. The magnitude of the force of the interossei muscles in metacarpal flexion has been found to be nearly equal to that of the extrinsic flexors in a strong grip [19, 20, 24, 38].

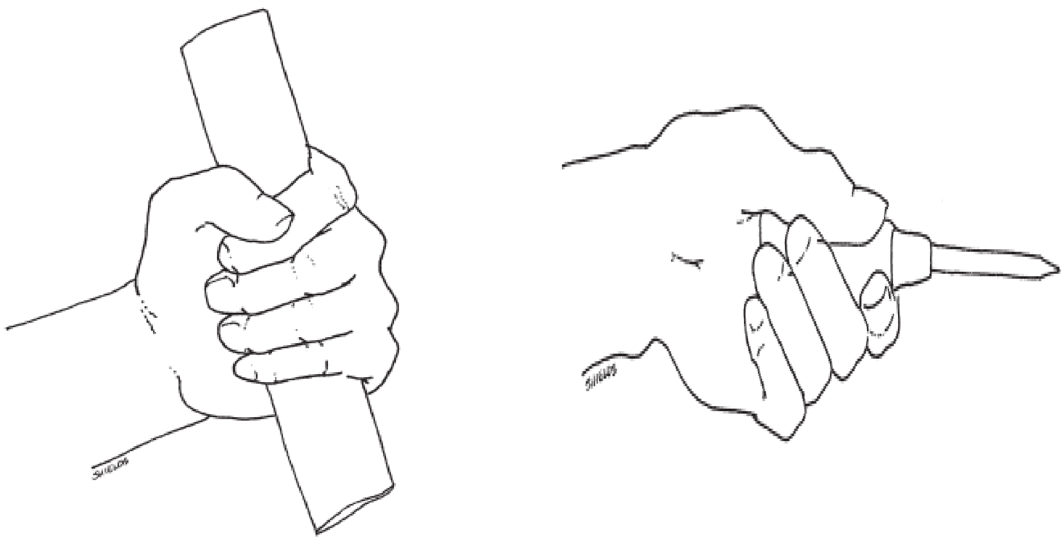


Figure 2.11. Cylindrical grip [26].

2.5.1.1.B. Spherical Grip

Spherical grip is similar in most respects to cylindrical grip (Figure 2.12). The main difference can be made by the greater spread of the fingers to encompass the object. This evokes more interosseous muscle activity than in other forms of power grip. In cylindrical grip the extensor muscles also play a part in providing a balancing force for the flexors as well as playing an essential role in the smooth and controlled release of the object. This activity involves the ED, lumbricals and the thumb extrinsic muscles [32]. Activities consisting a spherical grip are holding a doorknob or an apple, picking up a glass by its top.

Figure 2.12. Spherical Grip [26].

2.5.1.1.C. Hook Grip

In hook grip, the thumb is in abduction and proximal interphalangeal joints of the other fingers are in flexion position. FDP and FDS muscle are pimary responsible for hook grip. Carrying handbag or bucket can be given an example (Figure 2.13.) [19, 20, 24].

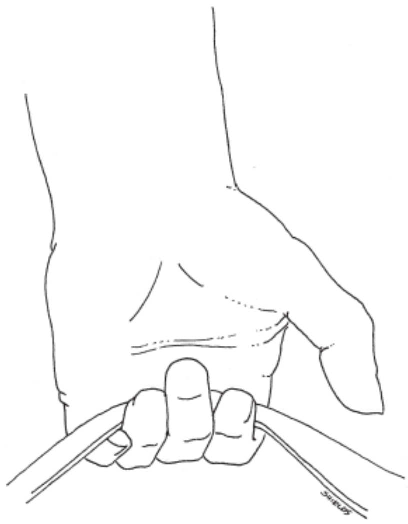


Figure 2.13. Hook Grip [26].

2.5.1.2. Precision Grip

The precision grip has developed in primates for the manipulation of small objects with the tips of the fingers and thumb. It demands for stability independent finger movements that comprise magnitudes of fingertip forces and fine control of the directions [37]. In a precision grip the object is pinched between the fingers and opposing thumb. It is limited mainly to the MCP joints and consist primarily the radial side of the hand. Index 2nd and 3rd middle digits (The radial digits) ensure control by working in concert with the thumb to form a ’’dynamic tripod’’ for precision handling. The intrinsic muscles are more important in the precision grip than in power grip. For precision grips, thumb that can act as a butress is essential because of providing stability and controlling of the direction.

There are three types of pinch grip as follows; three-point chuck, tip pinch, and lateral key [36].

2.5.1.2.A. Three-Point Chuck

Three-point chuck is also called three-fingered, three-jaw chuck digital prehension in which palmar pinch, or subterminal opposition, is achieved. There is pulp-to-pulp pinch and opposition of thumb and fingers is necessary with this grip. The palmar pinch is carried out with reciprocal contraction with volar muscles, dorsal interosseous muscle and thenar muscles. Grip a pencil may be an example of this grip (Figure 2.14.)[19, 36].

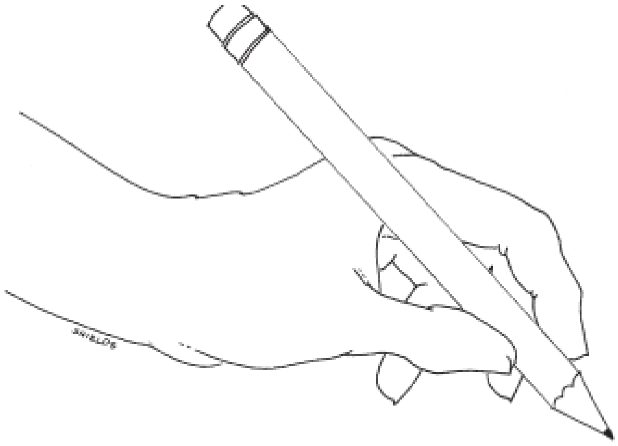


Figure 2.14. Three Point Chuck [26].

2.5.1.2.B. Tip Pinch

The tip pinch is also called the tip-to-tip prehension, or terminal opposition. The tip of the thumb is brought into opposition with the tip of another finger with this positioning. IP joints of all digits are in flexion position. The FDP, Pollicis Longus and ınterosseous muscles are active. This pinch is used for activities requiring fine motor skill and coordination than power. Nail holding may be an example of this type of grip in activities of daily living [19, 36].

2.5.1.2.C. Lateral Key

The third pinch grip is termed lateral key, pulp-to-side, lateral prehension, or subterminolateral opposition. While the thumb is in adduction and extension position, radial side of the middle phalangeal joint of index finger executes opposition. Adductor pollicis and flexor pollicis muscles participate actively in this movement. An example of this pinch grip is holding keys or a card. This grip is considered the most powerful pinch grip type (Figure 2.15) [19, 36].

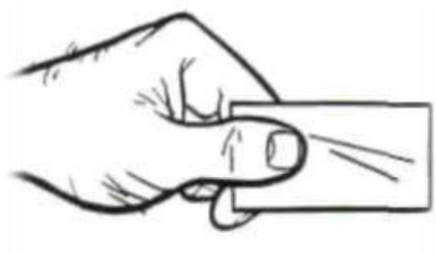


Figure 2.15. Lateral key [26].

2.6. Importance of Hand Function and Grip Strength

The hand is an extremely complex and multifaceted mobile effector organ. It has various functions to carry out the ADL. The loss of a hand has the effect of increasing the upper limbs functional impairment by 90%. This is due to the fact that the upper limb's primary function is to move the hand in space so that the most complex daily tasks can be performed to the most mundane.

Functionally, thumb is the most important digit because of its relation with other digits, its mobility, and the toleration to the force, therefore the loss of the thumb can affect hand function negatively. The index finger is the second most important digit on account of its musculature, strength, and interaction with the thumb. Its loss greatly affects the lateral key, pulp-to-pulp pinch and power grip.

The middle finger is the strongest and most important digit in both precision and power grip while the other digits are in flexion position.

The ring finger is the least functionally important digit and aids in the stability of gripping. Because of its position, it can support gripping and increase the functional capacity of the hand.

The little finger is important due to its position at the end of the hand as it enhances power grip greatly. It also affects the holding capacity of the hand and holds objects against the hypothenar eminence. Loss of any digits of the hand accounts for the following functional impairment. During prehension, the contribution of each finger was evaluated in terms of physical strength and then was measured as the average value. According to these measurements, the middle finger 33%, the ring finger 28%, while the index finger 24% and the little finger 15% get a grasp impact during the grip. In the powerful grip, ulnar side of the hand performs actively. Therefore the devices that are used in slow and strength required works are designed to be kept on the ulnar side of the hand while the devices that are used in speed and subtility required works works are designed to be kept on the radial side of the hand [19, 20, 24, 36].

2.7. Evaluation of the Wrist and Hand

2.7.1. History

An accurate patient history is a guidance of the clinician for assessing the development of the treatment and determination of the patient's overall status, specific functional performance. The process of history is commenced at registration, using a written questionnaire after that therapist carries out an interview with the patient. This communication that is patient-centered is focused on symptom and activity. Symptoms, stiffness and numbness are described by the patient. A short answer form included definition of the mechanism and date of injury, the type of pain and location, the length of immobilization, the date and type of surgery, the symptoms such as tingling, numbness, abnormal sounds prior treatment, the medications being taken, other medical conditions. The history is necessary to identify sites for palpation, comprehend postural imbalances and to decide on measures for the objective examination [30, 31].

2.7.2. Physical Examination

2.7.2.1. Postural Imbalances

The kinematics of the extremity depends on the contributions of the efficiency of the neuromuscular system and the articular structure. Hence, hand and wrist imbalances are the foundation for comprehension the complex nature of hand dysfunction. During static posture and dynamic movement, postural imbalances can be observed. In progress of time, the imbalance can become less malleable-supple and fixed. Primary or secondary neuromuscular and orthopedic problem may lead to resting and dynamic imbalances. The wrist is progressively flexed with the increased demands of power grip against resistance. The EDC and ECU are influenced by the unexceptionable extrinsic finger and wrist flexors, during active effort this resulting in wrist flexion. Increased wrist flexion cause increased postural balance which will diminish flexion of the digit joints owing to the tenodesis norm. The patient reported mechanical advantages lost that objects dropped and the grip loosens [30].

2.7.2.2. Observation, Inspection, Palpation

While observation of the wrist and hand, both posterior and anterior aspects should be viewed. Cosmetic appearance and reactions are important. Localized swelling on the dorsum of hand and IP, effusion, synovial thickening, changes should be noted. The changes observed containing loss of hair on the hand, increase or decrease sweating of the palm, brittle fingernail, shiny skin, temperature difference of two limbs. Any vasomotor, pilomotor, sudomotor and trophic changes may indicate that sympathetic nerve function is affected [36]. Shoulder, arm, forearm and hand must be observed when examining a patient's upper extremity. The gross appearance of the entire extremity is inspected [31].

Muscle, bone, edema and nerves can be palpated by the therapist for understanding these structure properties. In assessing the quality of the tissue and determining an isolated pathologic condition, palpation is beneficial. Assessing the features of the joint movement (accessory and PROM) is practiced for palpation of soft tissue. Palpation is carried out to determine the characteristic of muscle activation in prime mover through static joint resistance. The consistency and type of inflammation are determined by palpating swelling, nodule, tumors. Also, the therapist palpate the skin compared extremities for sensory disturbances. While evaluating vascular instability, local infection and joint irritability, describing warmer and colder part are useful. The moisture patterns such as dry, normal, slippery are indicators of peripheral nerve function. Eventually, palpation is a therapeutic art to comprehend complex nature tissue equilibrium and response to injury and disease [30, 31].

2.7.2.3. Pain and Edema

Qualities of a patient's pain perception are beneficial in conceiving How soft tissue responds to injury. As planned the treatment program, movement and positions that relieve or exacerbate symptoms are important. The location, radiating, quality, quantity, duration, frequency, aggravation/relief and associated symptoms are components of the pain assessment process.

The assessment of wrist pain consists of various tests such as the sitting hand test, the windmill test, and the carpal shake test.

The aim of edema testing is to determine the amount of swelling present localized in a digit or generalized inflammation in the extremity. Swelling of the hand is the initial stage of healing and body's enterprise to immobilize a segment.

Resistance from everyday activities, any trauma or excessive repetition can result in edema which cause to fibrosis, joint stiffness, infection risk, deformity, deformation of cellular nutrition.

Volumetric displacement and circumferential measures are used to assess the edema. The volumetric displacement test is proper for upper limbs because of utilization in open wounds or with external devices. The patient is asked to place his hand in the water filled bar, then the test is applied both of hands. This process has provided to compare the injured and noninjured hand and to form baseline scores throughout the ongoing treatment. Circumferential measures are useful for isolated swelling of digits. Sturdy tape measures, finger circumference gauge or caliper can be used by clinicians [30, 31].

2.7.2.4. Wound Assessment

Patients who exposure an acute flare-up of disease or an open traumatic injury can be apparent signs of inflammation and healing process. The body initiates inflammatory phase by cleaning up dead and injured cells after injury. The information of odor, size, depth and type of tissue in the wound is useful for objective comparable situations. The color of the wound is important for care. For example; necrotic tissue that is black will proceed to yellow stage, the angiogenesis and granulation tissues are classified as red which indicates reepithalized and healthy wound. Complications of the normal healing process are excessive, abnormal and delayed scar formation which affects functional mobility adversely.

2.7.2.5. Vascular Issues

Testing of vascular system provides to define the healing potential of highly traumatized tissues and the response to rising levels of resistive activity. There are technological instruments for managing revascularization and replant of hands and digits. Color and trophic changes, extended time to heal wounds and poor temperature regulation can occur in hand with vascular comprise. A majority of patients reported and described pain as aching, tightness, cramping, or cold intolerance. Allen’s test and recording peripheral pulses in various positions such as scapular adduction, neck rotation, overhead activities and glenohumeral abduction, after exercise and at rest are valuable in assessing blood flow [30].

2.7.2.6. Range of Motion

Range of motion (ROM) testing is applied to provide measurable alterations over time and data about the arc of permissible motion and to monitor articular motion and musculotendinous function. The motion of the cervical region and entire upper extremity should be examined after hand injuries and compared the opposite side. Passive range of motion (PROM), active range of motion (AROM) and torque range of motion (TROM) are various and appropriate methods. PROM corresponds to total flexibility of a joint as moved by external sources. PROM is similar to TROM which is except of external force of 200 g and series of increasing forces to a stiff joint to quantify measurement of PROM. Similar torque device or an orthotic gauge applies to the joint. The patient can achieve the total motion which represents AROM. Total active motion (TAM) and total passive motion (TPM) are computed as composite digital motion. TAM is the sum of simultaneous (full fist) active flexion measurements of the metacarpal, and PIP and DIP joints of a digit, minus the simultaneous (full finger extension) active extension deficits of the same three joints. TPM is computed in a similar manner except that passive measurements are used. At initial evaluation, measurement of hand and wrist joint are taken. Forearm and elbow position has an effect on the measurement of wrist range of motion. While elbow is in flexion, forearm pronation position and relaxed fingers, ROM of the wrist extension may change compare with extended fingers, forearm supination, elbow extension. ROM of wrist should be measured by using goniometer and metal finger goniometer for measuring digital motion [31].

2.7.2.7. Strength

Evaluation of the impairment resulted from specific musculotendinous and nerve injuries is done by using manuel muscle testing (MMT) of synergist and antagonist muscles. The hand is powered by extrinsic and intrinsic muscles so each extrinsic and intrinsic muscle-tendon unit should be measured. FPL, FDP, FDS, AbPB, FPB, OP, and the adductor pollicis (AdP) etc. are tested for each hand. The flexors and extensors of the wrist can be tested by having the patient flex the wrist against resistance in a radial and then in an ulnar direction while the examiner palpates each tendon. After examination of wrist and intrinsic and extrinsic musculature of the hand, the next step is the hand grip and pinch strength measurements which are more often used after acceptable healing of hand injuries, tendon repairs and fractures.

The hand grip dynamometer (Jamar dynamometer) is used to evaluate the force grip. The left and right hands are tested alternatively then avarage of three trials is recorded. Pinch strength is measured by a calibrated pinch meter/ pinch gauge. Chuck or three fingered pinch, lateral or key pinch and tip pinch that are three basic types of pinch can be tested. Three trials are taken for each hands [30].

2.7.2.8. Sensibility

The purpose of the sensibility examination is to determine the patient’s skill discriminate and identify sensory input and to screen for possible nerve compressions in the upper extremity. The test should be done in distraction-free and quiet area of the clinic. The wrist, hand and fingers are supported sufficiently to avoid cueing from proprioceptive receptors. Except functional and objective pick up test, patient’s eyes are open and then vision occluded. The type of injury, the recovery period, the amount of time after injury is depending factors for selection of a test. Sensibility test should be done within 6 to 24 weeks of a nerve injury.

There are various tests to assess sensibility, consisting monofilaments, Moberg’s Picking-up Test, the moving two-point discrimination test, Semmes-Weinstein light-touch threshold test, Ninhydrin and wrinkle test, Tinel’s test.

Semmes-Weinstein light-touch threshold test that used for detecting nerve compression is the most sensitive clinical test. Compression or irrittation occur at the level of the wrist of median, ulnar, and dorsal radial sensory nerve (DRSN).

Tinel’s test can represent the level of nerve regeneration and recommend proper timing for functional test and threshold. Localized site of radiating and tingling pain are signs of positive Tinel’s test [30, 31].

The neurological examination should be included joint position sense and vibration sense which can supply important information regarding specific cutaneous sensory receptors, peripheral nerves, central nervous system pathways and dorsal roots. Clinical testing of these modalities have a need of simultaneous stimulation of tactile receptors [39].

2.7.2.8.1. Vibration Sense

The vibration sense is the ability to perceive the presence of vibration as an oscillating tuning fork which is placed over certain bony prominences.

The sense of vibration that is specific type of sensation can be considered resulting from a combination of other sensations for clinical purposes. Bone may pretend largely as a resonator. It originates from the sinusoidal oscillation of objects placed against the skin. Skin mechanoreceptors reciprocate to the oscillations by evolving action potentials that are transmitted through their neural afferents, with a pulse code in which each action potential signals one cycle of a sinusoidal wave.

The frequency of action potentials in the afferent nerve fiber signals the vibration frequency. The perception of vibration as a series of rapidly repeating sensation results from the simultaneous activation of multiple receptors, leading to synchronous discharge among many afferent fibers. The receptors responsible for vibration sense consist Meissner's corpuscles and Merkel disk receptors in the superficial layers of the skin and pacinian corpuscles in deeper layers of skin, in the periosteum and between layers of muscle. The receptor afferents that are myelinated and include both large diameter (group Aa, diameter 12–20 mm, conduction velocities 72 to 120 m/s) and medium diameter (group Ab, diameter 6–12 mm, conduction velocities 36 to 72 m/s) fibers. Pacinian corpuscles respond to high frequencies (60– 400 Hz), Meissner's corpuscles to mid-range frequencies (20–50 Hz), and Merkel disk receptors respond maximally to low frequencies (5–15 Hz), Receptor tuning thresholds assign the capacity to detect vibration. The total number of sensory nerve fibres activated by a vibrating stimulus determines the intensity of vibration; the frequency of firing determines the vibration frequency perceived. Humans are most susceptive to vibration at frequencies of 200–250 Hz. Fibres mediating vibration sense enter the spinal cord by coursing through peripheral nerves and dorsal roots. These fibres bifurcate, with one branch terminating upon neurons in the deeper layers of the dorsal horn and the other entering the dorsal columns.[48]

Although the central pathways mediating vibration sense and joint position sense appear to be identical, they terminate upon different thalamic and cerebral cortical neurons. Moreover, different receptors mediate these sensory functions. Some neurological disorders affect one of these sensory functions while partially or completely sparing the other.

A tuning fork of 128 Hz, with weighted ends, which is most frequently utilized. Sensation can be tested on the metatarsal heads, the malleoli, great toes, the tibia, sacrum, anterior superior iliac spine, sternum, spinous processes of the vertebrae, clavicle, the finger joints and styloid processes of the radius and ulna [50].

2.7.2.9. Dexterity

The aim of the evaluation of dexterity is to determine the capability of hand and fingers to complete more complex movements including manipulating small objects rapidly and accurately, placing and turning objects skillfully. American Society of Hand Therapist develops a classification system included large/small test area, handling, finger dexterity, tool use, ADL, and job simulation. Box and blocks, Purdue pegboard, Nine hole peg, Minnesota rate of manipulation test are some of dexterity tests [30].

2.7.3. Outcome Measures

The purpose of assessing outcome measures is to determine the patient's overall health status and quality of life and to cope with diversities that can occur between the symptoms, severity and limitation stated by patients and clinically evaluated by hand specialist. Assessing limitations in ADL and instrumental activities of daily living (IADL) are used to identify experiences of patients with upper extremity disorders.

There are several various outcome measures such as Carpal Tunnel Instrument, Disabilities of the Arm, Shoulder, and Hand (DASH), or Michigan Hand Outcomes Questionnaire (MHQ), Patient Rated Wrist Evaluation (PRWE) / wrist and hand evaluation (PRWHE), Focus on Therapeutic Outcome (FOTO), Flinn Performance Screening Tool (FPST), are worthy tools for gathering information on function, pain, disability, activity participation, and patient satisfaction. Symptom severity scale, Visual Analog Scale (VAS), Numeric Rating Scale (NRS) are focussed on symptoms and pain. DASH, Quick DASH, Upper Extremity Function Scale (UEFS) and Carpal Tunnel Symptom [CTS] Severity Scale and Functional Scale are used to determine the disability level of upper extremity especially in wrist and hand [30, 31].

2.8. Work Related Musculoskeletal Disorders (WMSD)

The work-related musculoskeletal disorders (WRMD) is defined as a condition where work related tasks affect the nerves, tendons, muscles, bones, ligaments, joints, cartilages, and spinal discs associated with exposure to risk factors [1]. WMSD includes clinical syndromes such as tendon inflammations and related conditions (tenosynovitis, epicondylitis, bursitis, peritendinitis, tenosynovitis, synovitis, De Quervain' disease, Dupuytren's contracture and Trigger finger,) nerve compression and related disorders (carpal tunnel syndrome, sciatica Guyon canal syndrome, Thoracic outlet syndrome, Pronator teres syndrome, Radial tunnel syndrome, Cervical syndrome, Digital neuritis, Cubital tunnel syndrome, ganglion cyst), and osteoarthrosis, myalgia, low back pain and other regional pain syndromes and muscle related disorders (muscle sprain and strain, myositis, myalgia). During the past decades, MSD have become increasingly common worldwide. [40, 41] Repetition, awkward or static postures, extreme movements of each joint, high forces and contact stress lead and exacerbate MSD. These conditions result in pain and functional impairment which may affect the neck, shoulders, elbows, forearms, wrists and hands. Upper limb postures and movements during repetitive tasks are of basic importance in leading to the risk of various MSDs [8].

The cumulative nature of disorders causes a response in the body, such as increased circulation, local muscle fatigue and other different responses of a physiological and biomechanical nature. If there is not enough time to allow the body tissue capacity to regenerate, a series of responses may further reduce the convenient capacity. This cumulative circuit may go on until the structural tissue deformation occurs like swelling, pain, limited movement). The cumulative nature of disorders whereby worker activity produces internal forces acting on the body tissue (termed a dose). Repeated loading may lead to tendon inflammation because of increased friction due to the uniaxial tensile forces generated or transmitted to the muscle and the reaction forces acting transversely where the tendon passes over adjacent hard and soft structures such as bursae, pulleys and retinaculae. This occurs when adaptation of awkward postures or at the end of the ranges of motion. It was stated that the surface degeneration in tendons causes the friction between the tendon and its adjacent surfaces. The collagen fibers within the tendon can become separated and impose upon increased trauma. Swelling and pain are created by a subsequent release of calcium salts. The biomechanics of the tendon and the changes probably that would occur should the supporting synovia become inflamed. Inflammation and swelling would be aggravated by the changing coefficient of friction repeated compression.

Non-neutral wrist and forearms postures and force exerted at the fingertips increase extraneural pressure within the carpal tunnel. This pressure is consistent with the impairment of intraneural microvascular blood flow. Inhibition of intraneural microvascular flow, axonal transport, nerve function occur in the condition of elevated pressures around the nerve. Therefore, it can lead to endoneurial oedema with escalated displacement of myelin and intrafascicular pressure. As a result of extraneural pressure, effects on nerve structure and function can eventuate within minutes. After the release of extraneural pressure maintained for two hours the effects in the intraneural blood flow are remarkable. Prolonged or very high pressure can culminate irreversible effects while acute effects are usually followed by rapid recovery. Extended period of exposure to hand spreaded vibration of power tool can be result in alterations to the vascular system of the upper limbs. The vascular alterations that are described by symptoms of finger blanching are identified as a secondary form of Raynaud’s phenomenon known as vibration-induced white finger. Working with vibrating hand tools can lead to consisting nerve injury. Structural changes in myelinated and unmyelinated nerve fibres and intraneural edema, as well as functional changes of both the non-neuronal cells and nerve fibers occured in the peripheral nervous system have shown in animal models and human biopsy experiments. WMSD related behavioral changes have been observed in both humans and animal models. Animal study outcomes have shown that corresponding to tissue degeneration, injury, and inflammation in an exposure-dependent manner result in sensorimotor behavioral changes. [29, 39, 41].

Barbe et al.[42], stated in their study on rat that high or low repetition exposure has greatly affected the exposure dependent differences in proinflammatory cytokines/chemokines, macrophages, and grip strength. The motor performance and median nerve conduction velocity decrease after exposure to high-force repetitive reaching versus negligible-force repetitive reaching. Continuing reinjury or microtrauma can ensue in ineffective tissue healing or the propagation of chronic inflammation via immune cell activity resulting in secondary tissue injury. Degenerative tissue changes, including collagen degradation and fibrosis take place due to ongoing exposure. Progressive degradation of function may occur when the threshold of exposure exceeds a certain level thus CNS reorganization or inflammation-mediated sickness response occurs following global declines in function. Repetitive and forceful tasks cause to tissue reorganization, musculoskeletal tissue injury, and CNS reorganization. If microtraumatic events endure, tissue injury stimulates inflammatory pathways, fibrosis or degeneration followed by developing musculoskeletal injuries. The effect on CNS organization may lead to sickness behavior or widespread symptoms, including chronic pain [29, 39, 41].

The most common complaint of musculoskeletal disorders is muscle pain. The sensitivity of the injured tissues may increase following painful and non-painful chemical stimuli. This sensitization is important with respect to several WMSD has been observed in clinical cases experienced consistent symptoms and continuing musculoskeletal problems. The increase in pain can result by way of muscle afferent supraspinal projections and gamma muscle spindle system therefore, motor control, stiffness regulation and proprioception deteriorate. Muscle tension and pain spread due to increases of metabolites and inflammatory chemicals (Figure 2.16) [41, 43, 44].Intervention under investigation should be included ergonomic modification, pharmaceutical interventions, physical and occupational therapy to cope with complaints of the WMSD [31].

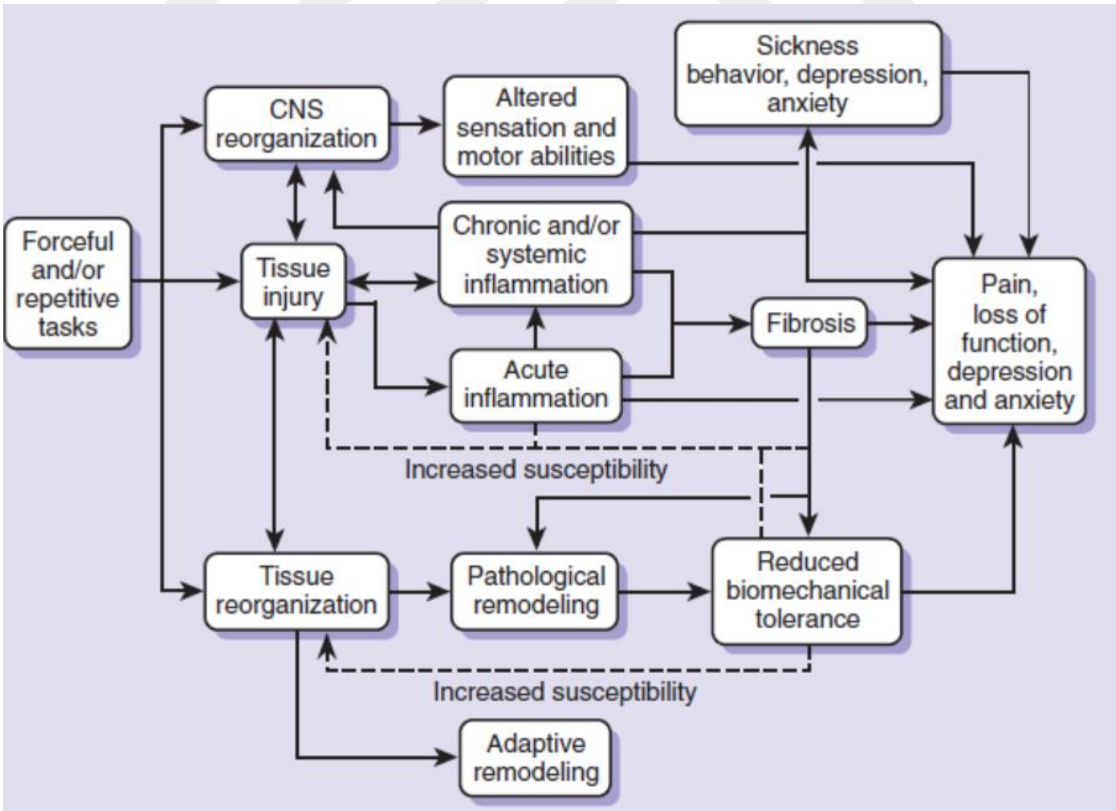


Figure 2.16. Causing Factors to WMSD of Conceptual Pathway [31].

WMSD causes including static posture, repetitive movements, overhead work and overuse of arms and hands are particular tasks for cashiering, assembly line work, construction, computer use and dentistry. The National Institute of Occupational Safety and Health (NIOSH) reporteed that heavy physical work, computer work and vibration are risk factors for the development of wrist/hand pain and WMSD [2].

Researchers investigated MSD among dentists with different methodologies about the prevalence of MSD among dental professionals, the region of the injury/disorders and the risk factors. Exposure of the occupational hazards such as chemical, biological and legal as well as ergonomic is frequently observed in dental professionals. Dental work involves a high degree of visual and manipulative elements, which is sometimes combination with the exertion of force, consists of precision tasks. These tasks turn into occupational hazard which creates MSD. Dentistry is a high risk profession for the development of musculoskeletal disorders as it is characterized by high visual demands which result in the adoption of fixed postures [4]. Musculoskeletal disorders were based on numerous risk factors including prolonged static or awkward posture, repetitive movements, suboptimal lighting, workplace designs, poor positioning, genetic predisposition, inadequate operating tools, mental stress, physical conditioning, lack of exercise and age [1, 2].

Hayes et al., [4] estimated the prevalence of musculoskeletal problems found 64-93% for back region, 36.3–60.1 % for neck region, 60–69.5 % for hand and wrist among dentists [9]. The frequency of wrist & hand discomfort and low back symptoms were even higher with 65.1% and 65.4% respectively. The incidence of WMSD is experienced at higher amount among dentists than other human service workers. Hand and wrist complaints are the most significant in terms of occupational related musculoskeletal disorders. Prolonged Static Posture (PSP) cannot be avoided by dentists, thus it causes to joint hypomobility and muscle imbalances of the hand because of prolonged muscle contractions and performing static work. Dentists spend their working days in a statically sustained postures including hunched over their patients with arms raised and their positioned relative to their patients' mouths, rotation and flexion of the cervical spine, flexion of the elbow, and repetitive forceful hand grip. Common awkward postures include elbow and wrist flexion and thumb hyperextension, which have been shown to stress neurovascular structures and ligaments. Repeated similar movements performed over a period of time can lead to over-exertion and overuse of certain muscle groups, which could cause to muscular fatigue. Symptoms usually relate to stabilizing or antagonistic tendon and muscle groups used to position and stabilize the extremity in space, but not to tendons and muscle groups involved in repetitive motions. [2]

Repetitive forces that eventuate to swelling lead to micro trauma which triggers the inflammatory process. On account of insufficient rest periods, damage exceeds the rate of repair. Since the dentists have to remain in the same posture for a long time, even with optimal postures muscle tension elevates to lead muscle ischemia and joint hypomobility. This results in altered the biomechanics in which occurs tightness of one group of muscles and weakness in the opposite group of muscles [9].

WMSD are are also referred to as repetitive strain injury, Cumulative Trauma Disorders (CTD), repetitive trauma disorders, which are injuries of the musculoskeletal and nervous systems. It may be caused by repetitive tasks including forceful pinching or gripping, forceful exertions, fine manipulative hand movements, use of vibrating tools, mechanical compression (pressing against hard surfaces), a sustained non-neutral position, or sustained or awkward positions. They include carpal tunnel syndrome, tendinitis, tenosynovitis, De Quervain's disease, ulnar and radial nerve entrapment syndromes. In dental professionals, hand/wrist complaints and Carpal Tunnel Syndrome (CTS) are the most common distal upper extremity disorders in comparison with other human service workers. In general, dentists tend to lose flexibility in the direction opposite to that which they are postured statically during the day. Over time, the muscle functions become compromised and are less able to meet the demands placed upon them due to longer these static positions and adaptive shortening of normal muscle length. So, there is a higher risk for acquiring an injury in the median nerve. Consequently, CTS leads to decreased ability to carry, move, and handle objects and diminishes quality of life [1, 45]. CTS, such as awkward postures, repetitiveness of the work, forceful exertions, pinch-grip, mechanical stress, posture, temperature and vibration are associated with their daily work [2].

Hand-arm MSDs are high among dental hygiene students with some indications that 60% pain, 46% upper extremity pain, 13% numbness, 13% white or painful fingers in cold temperatures due to long working hours with vibrating or manual instruments. The pinch grip used to hold instruments may be potentially hazardous and CTS is also reported to be high among dental technicians. Madaaan et al. [45] in their study on dental students found that maximum pain was observed in the hand (%92) following by the wrist (%85) and lower back (%72). Third years (%88) and final year (%98) students reported severe pain in hand and wrist. In the event of the pain becomes a regular occurrence, the cumulative damage could arise leading to debilitating injuries.

Prevention of WRMD is becoming crucial and requires the identification and modification of risk factors through a combination of ergonomic strategies, educational interventions and specific therapeutic programs. Treatment may provide successful results and various kinds of treatments (e.g. physiotherapy 77.5%, pharmacological treatment 67.1%, and neurological consultations 41%) are received by dentists.[2]. Exercises should aim at increasing the overall fitness of a dentist. Fitness is a general term used to describe the ability to perform physical work. Performing physical work efficiently requires a good cardiopulmonary functioning (aerobic fitness), musculoskeletal strength, endurance and flexibility [9].

2.9. Proprioception

Proprioception that is the ability to conduct and sense position of the body, explicate the data processed and respond consciously or unconsciously to stimuli of appropriate execution perceived the position of the limb or joint in space with movement.[46, 47] The term proprioception was first demonstrated by Sherrington as sensations arising in the deep areas of the body, contributing to conscious sensations ("muscle/sense"), total posture ("postural/ equilibrium") and segmental posture ("joint/stability") [48, 49]. Since the early 20th century, this term has been used to show the subsequent audiovisual motor coordination, motor control and balance, stability of the joint and sensory perception of posture [48]. Proprioception has a a lot of various properties those are active and passive motion sense, sense of heaviness and limb position sense. These refers to the conscious awareness of body and limbs [16]. Proprioception gives opportunity to write properly, jumping, running and throwing something. Proprioceptive system manages the agility allows person quickly to change direction of movement, the balance provides stability, the mechanism allows person to make the activity correctly and harmoniously [47].

Proprioception based on signals from the receptors embedded in muscles, tendons, joints and skin are important for the undamaged neural control of the movement [16, 50]. When determining the effects of sensory deafferentation on motor function for upper limb, postural and gait control become obvious. For example, patients with large fiber sensory neuropathy cannot control the force during grasping and manage even simple multi-joint movements, in spite of intact motor pathways.

The lack of proprioceptive afferents may affect the agitate postural reflexes, control of muscle tone, and tremendously damage spatial and temporal features of volitional movement [16]. There is musculoskeletal receptors that provided information to the brain to reproduce movement give information about the force and movement in joints and muscles. These are called proprioceptors. Sensory end organs reactive to motion, velocity, joint pressure, (so-.called mechanoreceptors) requision to be exist in ligaments joint or joint capsule [48, 51].

During stimulation, the mechanoreceptors convey the afferent information to the dorsal horn of the spinal cord, where the information takes one of two paths. The instant path ensuring fast control of muscles around the joint which is a monosynaptic transmission of information from the dorsal to the anterior horn. Another pathway is a segmental polysynaptic relations, in which afferent information is transmitted along the dorsolateral and spinocerebellar tracts of the spinal cord to supraspinal targets. Some of information is convey to the cerebellum, that is the primary area for the proprioception and regards the unconscious neuromuscular control of a joint and multipart integration of somatosensation. Moreover, information is delivered to the sensory cortices and primary motor, in which the conscious appreciation of the joint motion is produced [48].

2.9.1. Types and Functions of Joint Mechanoreceptors

2.9.1.1. Ruffini Ending

Angelo Ruffini first described ruffini in the 19th century, which is low threshold receptor and slowly adapting, incessantly active through joint motion.[48, 52] Ruffini endings have been reactive to tensile strain and axial loading on the ligament, yet not to vertical compressive joint forces, enlightening their significance in signaling joint rotation and position, rather than direct pressure. These features are important for the preparatory control and regulation of stiffness of the muscles.around the.joint.

The Ruffini ending is the prepordenant mechanoreceptor type in wrist ligaments which indicates main accent of wrist sensorimotor function in holding to wrist positions and movements [48]. The mechanoreceptors are prepordenant in all articular structures of the shoulder except the glenohumeral ligaments in which Pacinian corpuscle are the most amly [12].

2.9.1.2. Pacini Corpuscle

Pacini corpuscle is stated as lamellated sensory corpuscle, which characterizes the thick, layered capsule. The features of the Pacini corpuscle are rapidly adapting high threshold receptor susceptible to joint acceleration and/or deceleration which has ability to perceive mechanical disruption arising even at a distance and sensitive to compressive forces while Ruffini type mechanoreceptor is susceptible to tensile forces. Pacini corpuscle is able to perceive sudden joint perturbations by virtue of these features. It also designate during potential noxious.joint movement. While Pacini corpuscle has negligible importance in neuromuscular stability of the wrist, it is the most abundant receptor present in the lateral ankle ligaments, in which its purposes are providing for rapid signal of possibly damaging joint perturbations in a ligament system recurrently subjected to injury and distortion [48, 53].

2.9.1.3. Golgi-like Receptor

Camillo Golgi, who defined and discovered this sensory end organ as the ‘‘Golgi tendon organ’’ present in myotendinous junctions which contain receptors in tendons that impel group of muscle fibers or contractile force. Myelinated and large in diameter (12–20 mm), the afferent effort from a fibers of Golgi tendon organs (group Ib, Aa) carry out at velocities equal to those of muscle spindle primary afferent [38]. Golgi tendon organs have an inhibitory effect on the generation of tension connected to the motor neurons of the muscle in the muscle. It can relax to protect muscle from excessive loading. [48, 51] Golgi tendon and Muscle spindles are found in the muscle. However, joint position sense is further the responsibility of the muscle spindles [12]. The golgi-like ending is only active at the extremes of joint motion when muscles suddenly stop creating tension but silent in the immobile joint [51].

The Golgi-like ending has only been identified in the dorsal radiocarpal (DRC), dorsal intercarpal (DIC) ligaments and the large dorsal wrist ligaments which traverse both the midcarpal joints and radiocarpal. While DIC.is contribute the importance in perpetuating the transverse stability of the proximal carpal row and also provides indirect stability of the dorsal midcarpal joint space, the DRC is important for stabilizing the wrist in flexion and pronation. The Golgi-type endings in these ligaments arises rational, as this receptor is utter in monitoring tensile strain in the ligament during ultimate angles of joint motion [48]. The joint capsule receptors and golgi tendon organs are also contribute to kinaesthesia sense, while minimally affected on limb position sense as clinically tested [39].

2.9.1.4. Muscle Spindle

Muscle spindles are sensory receptors existed between muscle fibers which respond and sense the rate and change of length. Muscle spindles that are sensible to stretch that send excitatory messages to activate the muscle hence protect it from stretch-related injury. The inhibition of the antagonist muscle (opposing muscle action) as muscle shortening is an important neuromuscular effect of muscle spindles. This phenomenon is called reciprocal inhibition [51].

A muscle spindle consists specialized muscle fibers called intrafusal fibers surrounded by a coil of sensory nerve endings. The afferent fibers, or sensory nerves, monitor the magnitude and rate of stretch within the muscle [54]. Myelinated and large in diameter (12–20.mm), the muscle spindle primary afferents conduct at velocities of 72 to 120 m/s. These fibers are determined as group Ia as they emerge in muscle, nevertheless same size of fibers that emerge in the skin receptors are designated group Aa. Secondary afferent fibers innervating muscle spindles get possession of little.rate.sensitivity therefore ensure information about limb position sense and length of muscle. Myelinated and.smaller in diameter (6–12 mm) than muscle spindle primaries, secondary afferent.fibers (group II, Ab) convey at velocities of 36 to 72 m/s [39].

2.9.2. Distribution of Innervation in the Wrist

It was stated that the mechanoreceptors exist in wrist ligaments. Mechanoreceptive nerve endings were designated in three volar.wrist ligaments by using light microscopy and a gold-chloride staining technique. Nerve endings are close to the ligament insertions into bone, in which the higher stiffness in collagen fibers within the ligament provides a firing of the receptors only at the extremes of joint angles.

Mechanoreceptors are also found in the flexible epifascicular regions, particularly DIC and DRC ligaments. They can indicate throughout the ROM of the wrist. The innervation is the.most indicated in the triquetral and dorsal wrist ligament which are important for sensory structures including the triquetrocapitate/hamate, dorsal scapholunate (SL,) DRC, DIC, and palmar lunotriquetral. Intensely packed collagen fibers with little to no innervation are exist in the volar and radial wrist ligaments. The ligaments of the radial column, dense structured, have the ability of counteracting the axial loads through the wrist.

The International Federation of Societies for Surgery of the Hand (IFSSH) was recently enlighten physiological and anatomical arrangement of the wrist ligament on the biomechanics of the dartthrowing motion (DTM) of the wrist. The scaphocapitate (SC) and scaphotrapeziotrapezoid (STT) ligaments that stabilize the distal pole of the scaphoid have mechanically importance in constraining and guiding the DTM. Densly innervated volar triquetro-capito-hamate ligaments (TqCH) and DIC are crucial in a sensory feedback to he muscles, primarily ECRB/L and FCU active in the DTM [48].

2.9.3. Proprioceptive Reflexes and Pathways

The existence of reflexes between ligaments acting on the joint and the muscles was exhibited by Palmer in 1958. The reflexes are founded out from ligaments which are transmitted to the dorsal horn of the spinal cord for local (spinal) mono- or polysynaptic reactions or supraspinal transmission of information. The spinal and supraspinal reflexes are highly complex reactions providing control the wrist joint appropriately [48].

2.9.3.1. Spinal Reflexes

2.9.3.1.A. Monosynaptic Reflex

The monosynaptic reflex, called the H-reflex, is the simplest and fastest spinal reflex. The information from the joints, skin and tendons is directly relayed to the anterior horn for immediate muscle control and transmitted through the dorsal horn.

Patellar tendon reflex is the most common known H-reflex. The effectiveness of the defense reflex depends entirely on the instancy of the ligamento-mechanical reaction, so afferent-efferent information transfer must be fast enough to break a potentially harmful joint movement. Stimulation of the ulnar or median nerves at the level of the wrist joint ascertain monosynaptic excitations of the FCU/FCR, occurring within 20 milliseconds after stimulation which have shown in experiments about the excitation of human flexor motoneurons. The ulnar nerve, in especially, is important for contributing proprioceptive feedback to spinal motoneurons [48].

2.9.3.1.B. Polysynaptic Reflexes

The polysynaptic reflexes are conveyed through two or more interneurons, before and efferent muscular reaction occurs. Local interactions from Homonymous/heteronomynous interneuron connections and Renshaw cells have effects on these reflexes at any time. The explanation of some terminology related to polysynaptic reactions is important:

Feed-forward inhibition that is indentified as the modulation of a reflex from descending (cortical) control believed to be important in controlling the specificity of hand and arm movements.

Feedback inhibition is the modulation of reflexes from peripheral input and continuing wrist extension while muscle spindles in wrist flexors respond to stretch. Feedback inhibition is important for controlling the of onset, velocity, and termination of motions.

Reciprocal inhibition provide inhibition to antagonist muscles during voluntary movement through Ia or Ib inhibitory interneurons which is inhibition of the wrist extensor muscles during voluntary wrist flexion.

Recurrent inhibition is provided by specialized interneurons controlling the repeated firing of motoneurons through Renshawcells. Recurrent inhibition eventuates inhibition of synergistic motoneurons. This action is inhibition of flexor motoneurons, after prolonged wrist flexion.

Reflexes occur at the spinal level to control muscle activity of both agonist and antagonist muscles (recurrent and reciprocal inhibition, respectively). These interactions are influenced by both central and peripheral stimuli (feed-forward and feedback inhibitions), which arise from receptors in the skin, tendons, ligament and the muscle control of the upper extremity, especially forearm and hand. Ia and Ib inhibitory interneurons contribute to short-latency (mono-/ disynaptic) reflex control of the forearm muscles acting on the wrist. For example, stimulation of Ia and Ib inhibitory interneurons (which inhibit antagonist muscles) ascertain reflexes from the ECR to the FCR during voluntary wrist extension. However, this inhibitory pattern does not only move from the ECR to the FCR, but in the human act in a bidirectional manner (so-called heteronymous connection) during voluntary wrist flexion this ECR to FCR activity is decreased, whereas the inhibition is completely abolished during co-activation of agonist and antagonist muscles. The ECR and FCR interneurons can additionally inhibit one another simultaneously, which is thought to be of importance during wrist ulnar deviation where the EC is the primary motor. All of these action occurring in voluntary wrist motion permits adaptation of wrist stability for specific tasks [46].

2.9.4. Wrist Proprioceptive Reflexes

In wrist extension, radial and ulnar deviation, the immediate reactions were seen in FCR/FCU, while in wrist flexion, the first reaction was observed ECR. Later reactions were predominately co-activations of the wrist extensors and flexors, serving simultaneous excitation of FCR, FCU, and ECR which provide a global stability of the wrist joint. After stimulation, these reactions that comprise from 50 to 150 milliseconds are equivalent to the polysynaptic reflexes emerging at the spinal cord, with or without additional descending control. The co-contraction of agonist and antagonist muscles around a joint will compose a general joint stiffness, by that effectively decreasing the risk of joint damage. The co-contraction ability to maintain an adequate joint equilibrium in patients with anterior cruciate ligament injury, thus neuromuscular recruitment is inadequate which results in changes in knee kinematics. Co-activations are important for providing reflexive joint protection [46].

2.9.5. Supraspinal Reactions and Interactions

The complex tasks of the cerebellum are coordinating and planning the movements and integrating afferent information from the periphery with the processed information from the higher cortical areas hence, the generation of unconscious proprioception is primarily provided by the site of cerebellum which requires the neuromuscular control of a joint through reflex regulations as well as preprogramming of muscle stiffness in anticipation of coming motor actions. The afferent signals maintain their path to the motor, sensory cortices and dorsal premotor cortex. The afferent signals from primarily muscle spindles and cutaneous receptors are perceived consciously as limb movement (kinesthesia) and limb position (joint position sense) [46].

2.9.6. The Proprioception Senses and Therapeutic

Kinesthesia, joint position sense and neuromuscular control are major senses of proprioception. The afferent information from muscle spindles and cutaneous receptors primarily affect the conscious senses in addition supported by information from intraarticular nerve endings (Figure 2.17.) [48].

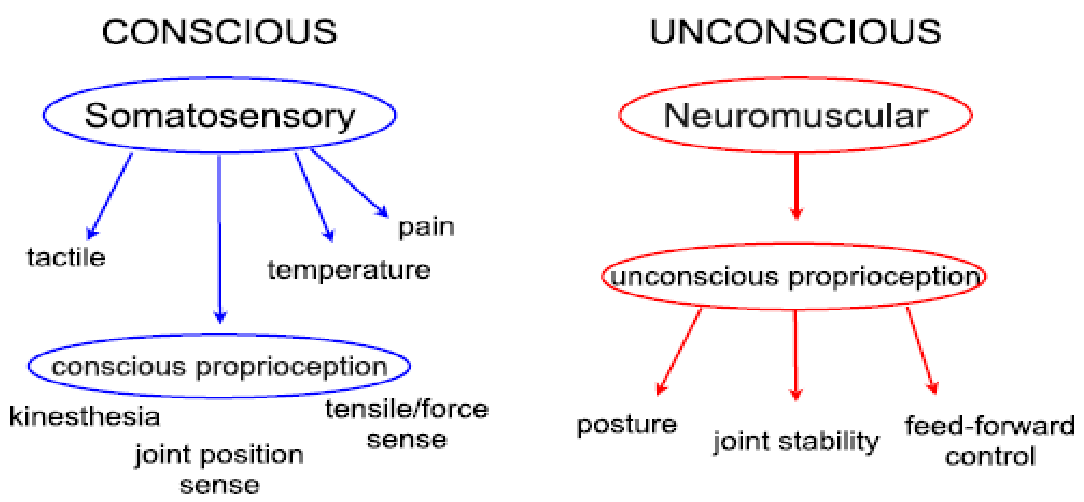


Figure 2.17. Schematic Presentation of the Different Senses of Proprioception [48].

2.9.6.1. Kinesthesia

In the 19th century, Bastian defined kinesthesia as the ability to sense both position and movement of the limbs and trunk. The term referred to both joint position sense and kineshesia which is primarily influenced by the action of muscle spindles with some contributions from skin receptors, thus limiting the sensitivity of the muscle spindle in detecting motion. Skin receptors have been shown to be primarily of importance in the kinesthesia of finger joints, since the muscles controlling the fingers are located at a distance from the joint itself, in the forearm and hand. Vibration of tendons affects the sense of kinesthesia distinctly.

Vibrations applied over tendons have been shown to elicit deceptive joint motions, as well as cortical changes in the areas related to kinesthesia. Vibration of a unilateral wrist extensor tendon has even been shown to cause bilateral kinesthetic illusions of wrist motion.

In practice, the sense of kinesthesia is measured as the smallest change in joint angle needed to elicit a conscious awareness of joint motion, as related to time. The terminology frequently used in proprioception training is ‘‘threshold to detection of passive movement (TTDPM)’’. Since limb movement is greatly influenced by visual cues, the patient should be blinded during testing (Figure 2.18). Furthermore, to adequately control the speed of joint motion and the degree of motion, it is advisable to use a professional training device, such as an Upper Limb Exerciser or a Biodex Dynamometer.

Figure 2.18. Assessment of Kinesthesia for Upper Extremity [48].

2.9.6.2. Joint Position Sense (JPS)

The sense of position is influenced by muscle command and muscle conditioning JPS and kinesthesia are affected by the action of muscle spindles, but the central processing and interpretation of them are different. Although tendon vibration has been shown to cause significant changes in the perception of kinesthesia, the same has not been shown for JPS. In proprioception training, JPS is defined as the ability to accurately reproduce a specific joint angle. This can be done either passively or actively, with visual cues or blinded. Passive JPS is when the therapist moves the wrist and the patient signals when the target position is reached.

Active JPS is when the patient moves the wrist actively to the predetermined target position. JPS exercises are easily assessed using a goniometer to determine the accuracy of reproducing a specific joint angle [48].

2.9.6.3. Unconscious or Neuromuscular Sense

Neuromuscular sense that is the feed-forward anticipatory control of muscles around a join is the ability to unconsciously retain an adequate posture and maintain joint stability and equilibrium. The neuromuscular sense is greatly influenced by spinal reflexes for immediate joint control, as well as integrations in the cerebellum for planning, anticipating, and executing joint control. Although the neuromuscular control of a joint is the hardest to objectively quantify or assess, it is important for maintaining joint stability

2.9.7. Neuromuscular Training

Various types of exercises that include isokinetic, isometric, eccentric, coactivation, and reactive muscle activation have been advocated in the neuromuscular training after ligament/joint injury [48].

The purpose of a wrist neuromuscular rehabilitation program should be threefold:

1) To regain a smooth and balanced global motion of the wrist after trauma/surgery,

2) To use dynamic muscular compression to compensate a joint where the ligamentous restraints are inferior,

3) To promote motion in the muscles that are joint protective while avoiding activation of muscles that are potentially joint damaging.

2.9.7.1. Conscious Neuromuscular Rehabilitation

In proprioception training in athletes, the isokinetic exercises are most frequently used because they are easy to instruct and assess using a commercial isokinetic exerciser (i.e., Biodex dynamometer) The term implies a muscle contraction performed at constant angular speed, and independent degree of muscle velocity and amplitude. It promotes endurance, permits for a controlled training and develops muscle strength throughout joint motion. In the proprioception rehabilitation of a patient, especially a professional athlete or musician with extreme demands on wrist function, it is probable to be of value to strengthen proper muscles and provide to return to training earlier.

In the common hand therapy program, isokinetic exercises are tending to have a small role in basic wrist proprioception training, because it requires knowledge and special equipment.

Isometric exercises that are static provide to strengthen muscles at specific joint angles. Isometric exercise is applied when an active muscle contraction is performed at a fixed joint angle with a constant muscle length. Isometric exercises of the wrist have been shown to increase voluntary muscle activation bilaterally, possibly by descending neuromuscular control and stimulating the motor cortex, thus the isometric exercises are important for wrist proprioception reeducation. For example, a controlled isometric activation of pronator quadratus in supination and neutral wrist position will serve to stabilize the DRUJ. It can be used both pre- and postoperatively in patients with TFCC injuries.

Eccentric exercises are prepared to strengthen the muscle when it is lengthened, by virtue of an opposing load. Eccentric training is most frequently performed in the rehabilitation of chronic tendinopathies, in which significantly decrease pain and build tendon strength. It is in a dynamic action throughout joint motion with the isokinetic exercises, that eccentric exercises are favourable. Eccentric training serve primay gain due concurrent effects on antagonist muscles. Eccentric exercises of wrist extensors have been shown to affect the co-activation pattern of wrist flexors, which will absolutely influence the global stability of the wrist joint. After ligament injury, periarticular muscles weaken, so this results in a neuromuscular imbalance during concentric contractions. It must be remembered that the balance of wrist motion is brittle, where agonist and antagonist muscles constantly work in harmony to produce joint equilibrium.

Co-activation is the concurrent contraction of antagonist and agonist muscles across a joint. Co-activation exercises need to use isometric eccentric and concentric exercises in hand therapy practice. This is produced by performing balance exercises with both hands on a ball, where controlled and slow motion of the ball on a table will allow the patient to simultaneously exercise flexors and extensors to create a balanced wrist motion. Similar to the balance plate exercises applied in ankle instabilities, which increase greatly the proprioception and co-activation patterns around the ankle joint. The re-education of wrist ‘‘balance’’ will probably produced by using these exercises [48].

2.9.7.2. Unconscious Neuromuscular Rehabilitation

The approach of neuromuscular rehabilitation aimed at reconstructing the unconscious activation of muscles to restore joint balance is commonly used in proprioception rehabilitation of both the shoulder, knee, and ankle joints. This type of therapy has previously been referred to as ‘‘sensorimotor activation, perturbation training,’’ and recently, ‘‘reactive muscle activation.’’ Reactive muscle activation (RMA) is possible the most difficult to apply in hand therapy, in spite of that likely the most important in wrist proprioceptive function.

In essence, RMA proposed restoring the neuromuscular reflex patterns that exist in a normal joint. RMA have been shown to be disrupted in a ligament-deficient joint. RMA exercises,in which using perturbation exercises such as the balance plate for knee and ankle injuries, are considered to restore the neuromuscular activation hence the electromyographic pattern to the muscles around the joint.

The reflex patterns arising from the SLIL have now been described which was the sustained reflex inhibition of the ECU during ulnar deviation of the wrist. This pattern of inhibition varied greatly from the investigations of co-contractions that were observed in other wrist positions. Salva and Garcia-Elias (2013) carried out in a laboratory study about the role of muscles on carpal stability which was found the contraction of the ECU increases the pronation tendency of the distal row by an average of 58 %. As a result of this increase resulted in a tension of the SLIL and a widening of the SL interval. In the case of a SLIL injury, RMA training must aid to enhance FCU and ECRL muscles which protecting the SL joint, while degrading activity in the potentially harmful ECU. Reflexive plyometric exercises can accomplish it in an exercise machine, using the Dart throwing Motion (DTM). As DTM is a motion from extension-radial deviation to flexion-ulnar deviation, the SLIL friendly muscles will be exercised whereas the ECU will remain relaxed. Another strategy that will possibly achieve to stimulate RMA is the use of a Powerball.

2.9.7.2.A. Powerball

The Powerball is a non-impact device which is the size and shape of a tennis ball and weights approximately 400gr.(Figure 2.18.). The Powerball is a type of gyroscope using centrifugal forces to generate inertia and thus exercise the muscles acting on the wrist joint. The Powerball gyroscope consists of spherical inner and outer housings, connected by one central axis. The axis connects the two housings in such a way that the inner housing can spin around the axis. When the inner housing is brought into a steady centrifugal circular movement compared to the outer housing, each point the outer housing travels at a certain spreed per second. This generates a force that, according to Newton can give a mass, namely the inner housing of the Powerball, a certain acceleration.

The weight of the inner housing of the Powerball multiplied by the speed of rotation will generate a force of up to 17 kilograms per second. As the Powerbal is held in the clenched fist, a counter force is generated in the hand (action has an equal and opposite reaction) the so-called centripetal force, which is aimed from the hand to the wrist. Muscular activity is needed to resist this force. The agonistic flexors of the hand will incite antagonistic reactions in the other muscles in order to maintain the balance of the arm. Moreover, synergistic muscles are activated to keep the gyroscope moving. The true benefit of the Powerball lies most likely in the multidirectional motion generated by the gyroscope, which demands a reflex activation of the wrist muscles and an unconscious activation of both agonist and antagonist muscles [30]. Additionally, this instrument is easy for the patient to use at free and may promote an adherence to RMA training.

The intended use of this possible exercise tool is to strengthen the wrist and hand with minimal impact on the hand, wrist and forearm with an exercise routine of a recommended 5 minutes per day [18].

Figure 2.19. The Powerball

Proprioception Training Stages	Rehabilitation Concept	Purpose	Techniques	Assessments
1-BASIC	Basic Rehabilitation	Oedema and pain control, Promote motion	Basic Hand Therapy Techniques	Visual analogue scale (VAS), Degree of joint motion (ROM)
2-BASIC	Proprioception awareness	Promote conscious joint control	Mirror therapy	VAS & ROM
3-CONSCIOUS	Joint Position Sense (JPS)	Ability to replicate a predetermined joint angle	Blinded passive and active reproduction of joint angle	Accuracy of joint motion, measured with goniometer or exercise machine
4- CONSCIOUS	Kinesthesia (TTDPM)	Ability to sense joint motion without audiovisual cues	Motion detection using an exercise machine (preferable) or manual passive motion	Degree of joint angle at which motion was sensed, measured with goniometer or exercise machine
5- CONSCIOUS	Conscious Neuromuscular Rehabilitation	Strengthening of specific muscles to enhance joint stability	Isometric training Eccentric training Isokinetic training Co-activation	Evaluation of specific muscle strength, wrist stability during co-activations, joint stability during isometric exercises
6-UNCONSCIOUS	Unconscious Neuromuscular Rehabilitation	Reactive muscle activation (RMA)	**Powerball Exercises**	Muscle activation patterns using EMG

Figure 2.20. Therapy Protocol of Wrist Proprioception [48].

3. MATERIAL AND METHOD

3.1 Participants

The study included 30 dentists who work at Yeditepe University Dental Hospital and 30 dental students studying in fourth and fifth classes at Yeditepe University. The mean ages of dentists (n=30; 14W & 16M) were 31.23±5.10 years, weight 68.23±1.51 kg, height 1.72±0.11 cm, and body mass index (BMI) were and 22.82±3.86 kg/cm^2 and the mean age of dental students (n=20; 16W & 14M) were 22.67±1.42years, weight 68.69±1.39, height 1.72±0.09 cm, BMI 22.75±2.95 kg/cm^2. The dominant hands of all participants were determined as right. A wrist and hand regional examination was performed on all candidates to rule out of the exclusion criteria. The procedures were adequately explained to the subjects before filling the questionnaire. They gave their own written consent to participate in the test protocols of the study voluntarily. The study was approved by the Bahçeşehir University Ethics Committee. The power analysis was done for determination of study sample size. According to analysis, twenty five participants needed to perform this study.

3.1.1. Inclusion criteria:

√ 24-50 ages of dentists

√ Dental students who are studying in 4th and 5th classes

√ The value of VAS below 5.

3.1.2. Exclusion criteria:

Hand or wrist pathologies or injuries that are still present indicate below;

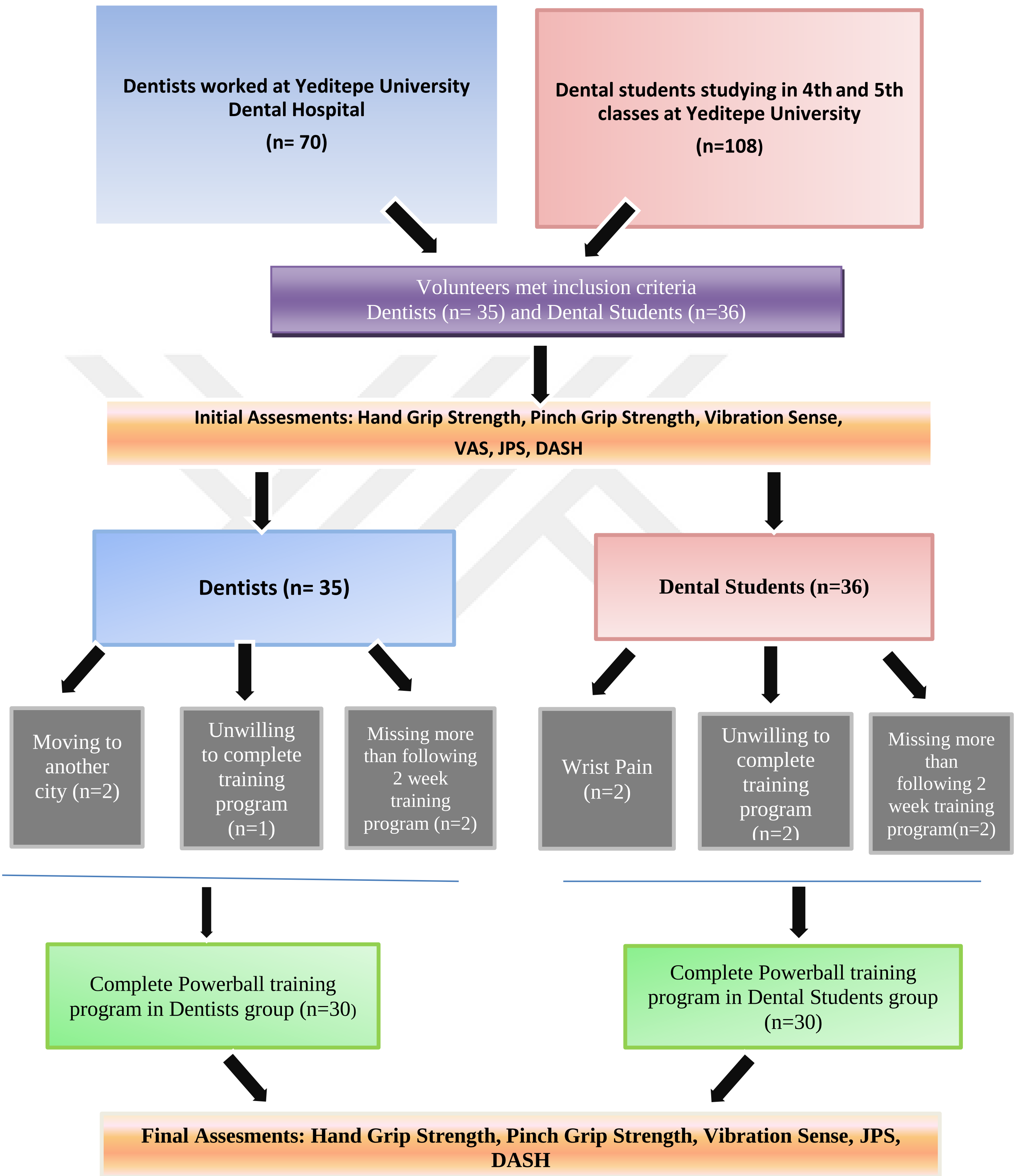
- Acute Colles’s fracture
- Carpal tunnel syndrome
- Dislocation of the Lunate or Scaphoid bones
- Rheumatoid arthritis
- Grade 2 and Grade 3 wrist sprain
- Triangular fibrocartilage complex tear
- De Quervain’s tenosynovitis
- Osteoarthritis of the hands.

3.1.3. Flow Chart

Totally 30 dentists and 30 dental students were participated to the study according to inclusion criteria. The participants were asked whether they were willing to be volunteer in the study. Participants who met inclusion criteria in dentists group (n=35) and dental students (n=36) were involved in the study. Then the initial assessment included hand grip and pinch grip strength, vibration sense, JPS and DASH questionnaire were completed.

Two of the participants were excluded due to moving to another city, one of them were unwilling to complete exercises, and two of them were missed more than following 2 weeks exercise program for the dentists' group. Moreover, two participants were excluded because of having wrist pain after 2 weeks Powerball training program, two of them were unwilling to complete exercise training with Powerball, two of them were missed more than following 2 weeks exercise program for dental students group.

Table 3.1. Flow Chart of the Study



JPS: Joint Position Sense, DASH: Disability of Arm, Shoulder and Hand Questionnaire, VAS: Visuel Analog Scale.

3.2. Evaluation

3.2.1. Structured Questionnaire

The structured questionnaire prepared by researchers applied face to face interviews. The first part of the questionnaire includes sosciodemographic features of participants such as age, height, weight, gender, smoking habits, taking medications, having chronic diseases and exercise status. The second part of the questionnaire was about their previous injury or operation at upper and lower extremities, experienced balance and vision problem last six months.

3.2.2. Hand Grip Strength

Hand grip strength; was measured by using a Jamar Hand Dynamometer (Baseline). The test was performed in the sitting position with the shoulder of the testing arm adducted, the elbow flexed at 90°, whereas the forearm and wrist were set in neutral position. The testing protocol consisted of two maximal isometric contractions for 5 s, on both hands. The highest value was used for determination of maximal grip strength. To obtain maximum grip force the participants were requested to compress the two bars of the dynamometer as hard as possible, alternating both hands. The parameters used for analysis were: peak absolute strength (kg) and relative hand grip strength (kg/kg of body mass). All measurements were performed for both left and right hands. The measurement followed by calculation of the mean of three trials of grip strength for each hand. One-minute rests were given between each attempt and hands were alternated to minimize fatigue effects. All the subjects were evaluated in the same position [55, 56].

Figure 3.1. Hand Grip Strength Measurement.

3.2.3. Pinch Grip Strength

Pinch grip strength measurements were performed using Pinchmeter (Baseline) for followed by key (lateral) pinch, tip (2-point) pinch, and palmar (C3-point pad) pinch. Participants were requested to squeezing maximally three times and the mean of the three readings obtained. The subjects were seated with their shoulder adducted and neutrally rotated, elbow flexed at 90°, forearm in a neutral position, wrist between 0° and 30° dorsiflexion and 0° and 15° ulnar deviation. The pinch gauge (0-60 lb) was held by the examiner at the distal end to prevent it from being inadvertently dropped. Scores were read on the needle side of the readout marker [57, 58].

A. **B.** **C.**

Figure 3.2. Pinch Grip Strength Measurements A. Lateral Key, B. Tip Pinch, C. Palmar Pinch

3.2.4. Vibration Sense Measurement

A tuning fork (diapason) is an acoustic resonator in the form of a two-pronged fork with the prongs (tines) formed from a U-shaped bar of elastic metal (usually steel). The main reason for using the fork shape is that it produces a very pure tone, with most of the vibrational energy at the fundamental frequency and little at the overtones (harmo nics) [59].

The participants' wrist vibration sense was measured by using 128 Hz diapason. The participant performed a standardized warm-up that included two or three preliminary trials for familiarization with the recording procedure and instrumentation. The examiner stroke the end of diapason hard enough that the sides touched, and immediately placed the vibrating tuning fork firmly on the bony prominence of the site of interest. At the same time, the examiner record the time (seconds) for which the patient could perceive the vibration the examiner by using a chronometer. The participant was instructed to tell the examiner when the patient feels the vibration stop. The examination was repeated three times per site, and the vibratory sensation at a site is evaluated by the mean value of the three records at the site. Note that before the examinations, the examiner applied the vibrating tuning fork on the patient's wrist, to make sure that the patient could recognize the vibration.

The hands of dorsal ulnar and radial styloid processes in terms of mechanoreceptors with extremely rich dorsal radiocarpal were used as two reference points. Radial and ulnar styloid processes were determined reference points for vibration sense evaluation [60-63].

Figure 3.3. Vibration Sense Evaluation with 128 Hz Diapason

A. **B.**

Figure 3.4. Vibration sense perceived sites, A. Ulnar Styloid Process, B. Radial Styloid Process

3.2.5. Joint position sense (JPS)

Active JPS was assessed by using the goniometric platform that is designed in such a way that the 1° accuracy is improved by the examiner. Joint position sense (JPS) platform based on gonimetric measurement is constructed specially by an architect using the instructions of the physiotherapist. Measurements in all axes of movement of the wrist (flexion-extension and radial-ulnar deviation) were established. Before each axes of movement, examiner taught the target position to the participant by bringing the wrist of participant to target angle passively. The participant moves the wrist actively to the predetermined target position; 30° for flexion-extension, 10° for radial deviation is determined as 15° for the ulnar deviation. All the movements of the wrist axes were performed for both left and right hands and three times for each different position angle. The degree of error for three trials was recorded as the amount of proprioception error [64, 65].

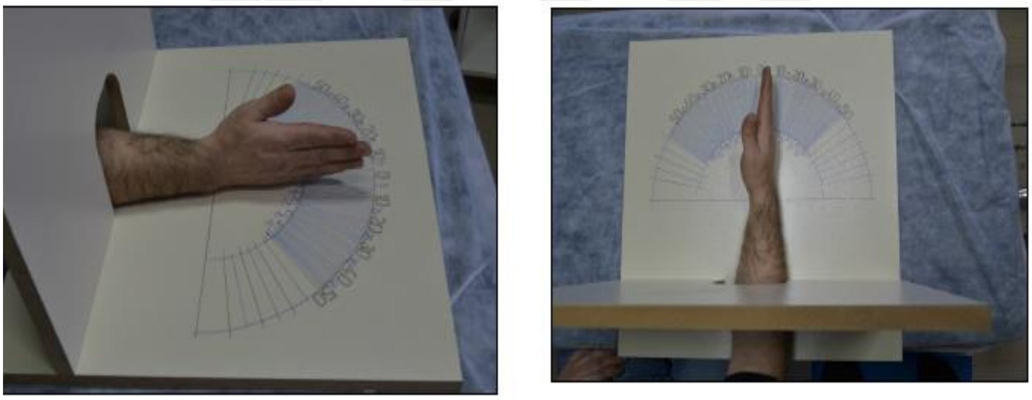


Figure 3.5. Assessment of joint position sense using the goniometric platform

3.2.6. Visual Analog Scale (VAS)

Visual Analogue Scale (VAS) was used to estimate the severity of participants' wrist pain. VAS translate used for some values cannot be measured numerically digitized [66]. It consists of a line, usually 100 mm long, whose ends are labeled as the extremes (no pain and worst pain imaginable); the rest of the line is blank.

The patient is asked to put a mark on the line indicating their pain intensity (at the present time, over the past week, or over the past 2 weeks, etc.) [67]. 100 mm at both ends of a line definitions are written to the two extremes of the parameter to be evaluated and patients of their condition on the line where it is appropriate, draw a line, or by putting a dot or mark is asked to specify, where there is no pain from the patient's length of the distance from the mark to the point where the patient's pain symptoms. Testing is recognized and proven in the literature of all the world. A higher score indicates greater pain intensity [66]. The results of VAS was used as one of inclusion criteria in this study.

3.2.7. Disabilities of Arm, Shoulder and Hand (DASH) Questionnaire

DASH was established to measure physical disability and symptoms of the upper extremities in people with upper extremity disorders (shoulder, elbow, wrist and hand). There are 30 items that addresses difficulty in performing various physical activities that involve an upper extremity function (physical function, 21 items); symptoms of pain, activity-related pain, weakness, stiffness and tingling (pain symptoms, 5 items); or effect of disability and symptoms on social activities, sleep, psychological well-being and work (emotional and social function, 4 items) which form disability/symptom score. Another subdivision of DASH is optional modules (sport/music or work) which consists of four items. The optional model may or may not be used by individuals because of the nature of the questions. The score ranges from 0 to 100, where 0 = no disability and 100 = most severe disability. A higher score indicates greater disability. If more than 10 percent of the items (more than three items) are blank, DASH disability/symptom score cannot been to calculate [68]. The Turkish version of DASH was used to assess the disabilities of upper. extremity in this study [69].

Scoring DASH;

DASH disability/symptom score = [(sum of n responses) - 1] x 25,

n equal to the number of completed responses[68].

3.2.1. Training Program

3.3.1. Exercise Training with Powerball

After all measurements and evaluation procedures were completed in the first session, a 250 Hz gyroscope and the demonstration about how to use the Powerball was given each participant. The Powerball training was performed while seated, with the elbow flexed at 90◦, and leaning on a firm surface because of the prevention to use shoulder musculatures. Rotation of the gyroscope was driven with wrist turning clockwise in the case of the right arm dominant participants and counter-clockwise for left-handed participants (Figure 3.6.). Each participant used the Powerball at least for 30 seconds with each hand in comfort and correct position [70]. After the practice session, participants use the Powerball with the right hand for 5 minutes and then for 5 minutes with the left hand for three times per week. The training program took six weeks.

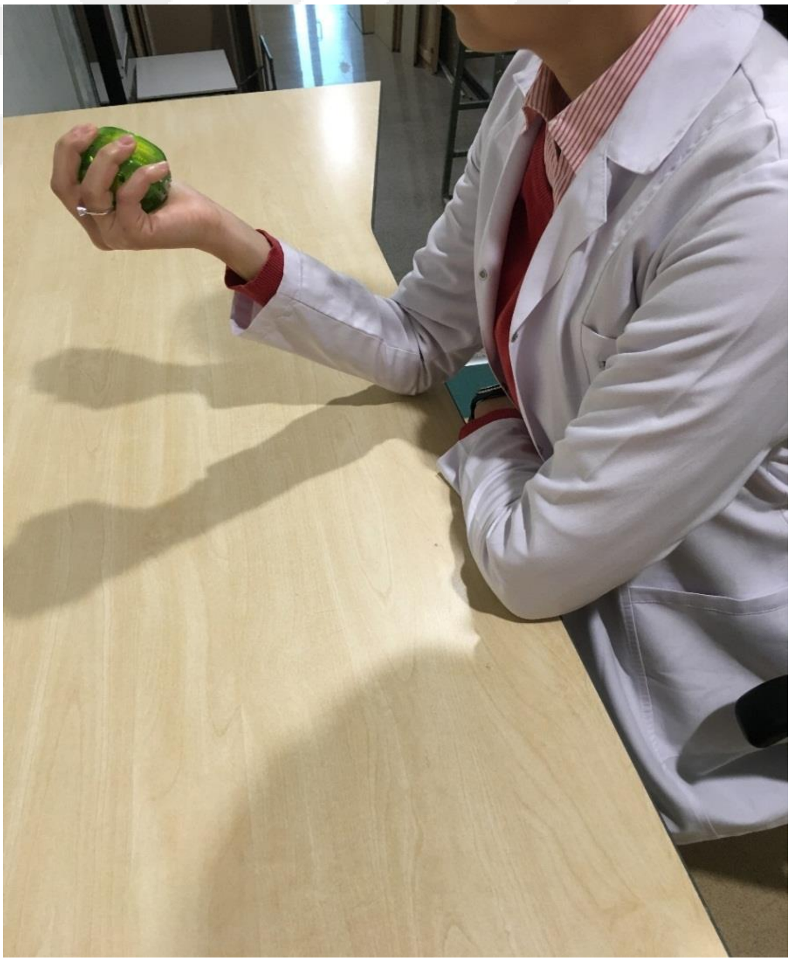


Figure 3.6. Exercise Training with Powerball

Data Analysis

Statistical Package Analyze for Social Sciences (SPSS) version 21.0 was used for data analyses. The Kolmogorov-Smirnov test was used to test the numerical variables for normality. The summary of numerical data was showed mean ± standard deviation and ratio was used for categorical data. Statistical analysis was performed before and after training program for parametric and non-parametric data with respectively Paired Sample T-test and Wilcoxon test. The backward regression model was constructed to determine the predictors of DASH. Independent variables were age, working years, days and hours, hand grip strength, pinch grip strength, joint position sense and vibration sense. The significance level was accepted 0.05.

4. RESULTS

The study included 30 dentists (16 F, 14 M) who work at Yeditepe University Dental Hospital and 30 dental students (14 F, 16 M) studying in fourth and fifth classes at Yeditepe University, Istanbul, Turkey.

The physical features (age, weight, height and body mass index (BMI) of dentists and dental students are presented in Table 4.1. While there were no differences in weight, height and BMI. However, the age of participants had statistically difference in the two groups ($p<0.05$).

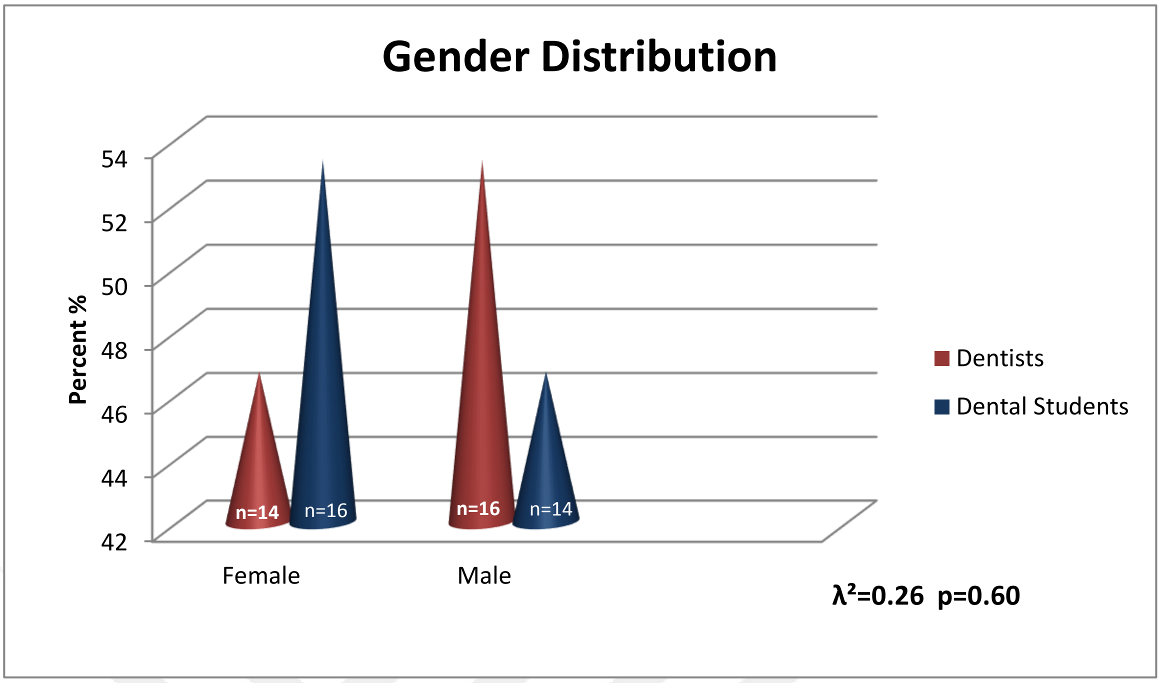
Table 4.1 Physical Features of Participants

	Dentists Mean ± SD	**Dental Students Mean ± SD**	**t/Z**	**p**
Age (year)	31.23±5.10	22.67±1.47	Z= -6.35	**0.00**
Weight (kg)	68.23±1.51	68.63±1.39	t= -0.10	0.76
Height (m)	1.72±0. ±11	1.72±0.09	t= -0.29	0.91
BMI (kg/m²)	22.82±3.86	22.72±2.95	t= 0.11	0.90

Data expressed as mean ± standard deviation, BMI: Body mass index

In the population of the study, there were 14 females and 16 males (n=30) in the dentist group and 16 females and 14 males (n=30) in the dental student group. The percentile ratio of female and male dentists were 46.7% and 53.3%, respectively. The gender ratio of dental students was 53.3% for female and 46.7% were male. There was no statistically significant difference in gender distribution between two groups (Graph 4.1.) $p>0.05$).

Graph 4.1. The Gender Distribution between Dentists and Dental Students



The smoking, alcohol and physical activity habits and physical activity frequency in the study groups were illustrated in Table 4.2. There were no statistically significant differences according smoking and alcohol habits between dentists and dental students. Additionally, no statistically differences were seen between two groups in relation to physical activity habits and physical activity frequency (Table 4.2).

Table 4.2. Comparison of Smoking, Alcohol and Physical Activity Habits and Physical Activity Frequency Between Dentists and Dental Students

		Dentists % (n)	Dental Students % (n)	λ²	p value
Smoking Habits	Yes	36.7 (11)	43.3 (13)	3.35	0.34
	Cessation	30 (9)	13.3 (4)		
	No	33.3 (10)	43.3 (13)		
Alcohol Habits	Yes	90 (26)	86.6 (26)	2.34	0.50
	No	10 (4)	13.3 (4)		
Physical Activity Habits	Yes	56.7 (17)	73.2 (22)	1.83	0.10
	No	43.3 (13)	26.7 (8)		
Physical Activity Frequency	Everyday	3.3 (1)	6,7 (2)	10.10	0.07
	≥ 2 times/month	6.7 (2)	6.7 (2)		
	< 3 times/wk.	26.7 (8)	33.3 (10)		
	≥ 3 times/wk.	26.7 (8)	43.3 (13)		
	Never	43.3 (13)	10 (3)		

Data expressed as % (n)

The participants were asked whether having a diagnosed disease which was prevalent such as digestive systems, pulmonary system and musculoskeletal system. The distributions of having systemic diseases were analyzed in two groups by Chi Square test. There were not seen as statistically significant differences (Table 4.3).

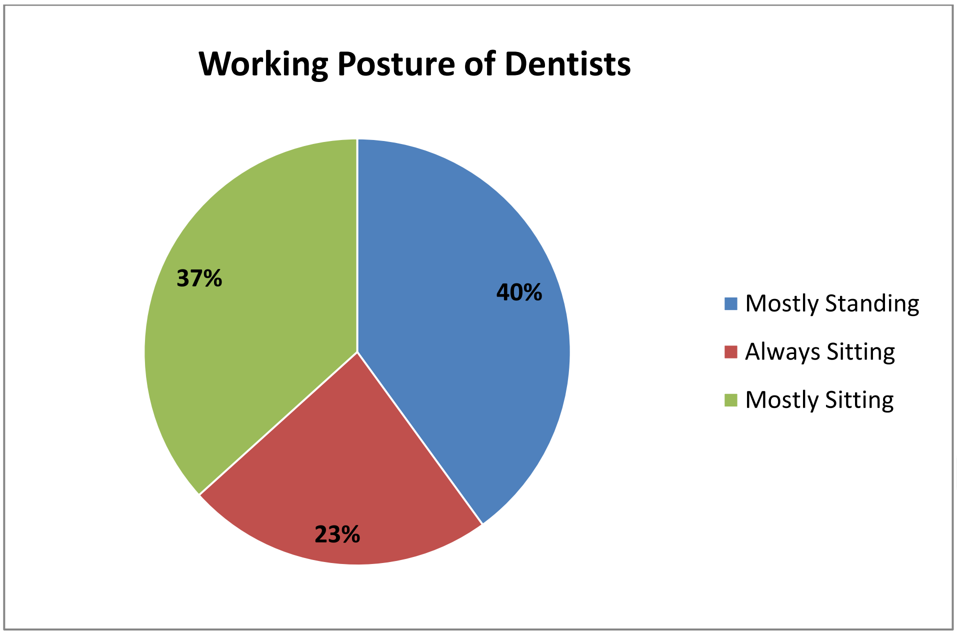
Table 4.3 Distribution of Systemic Diseases for Dentists and Dental Students

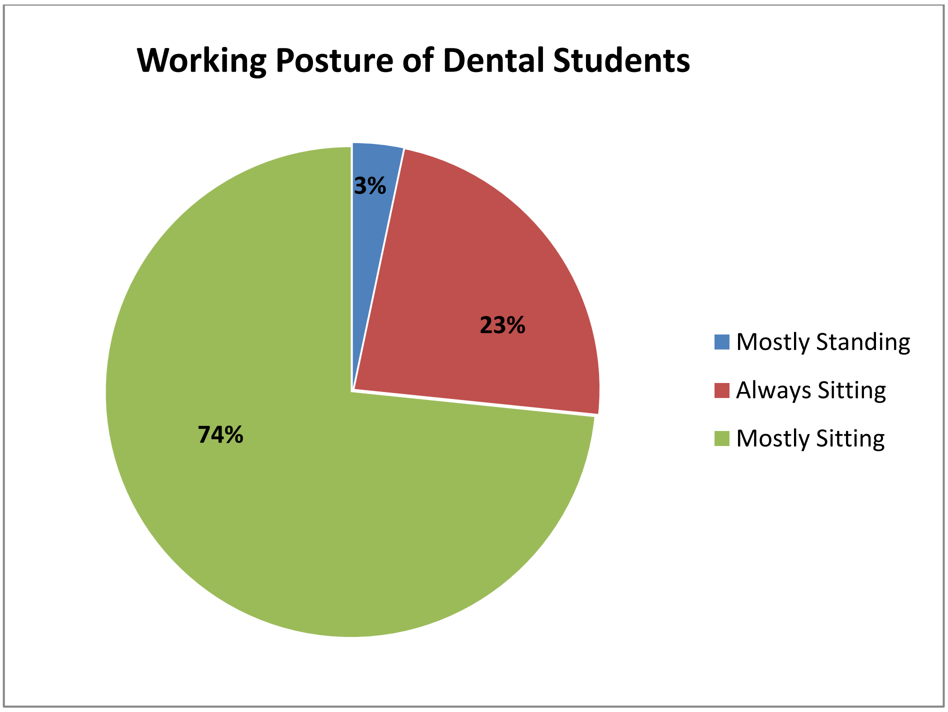
			Dentists	Dental Students	λ²	p value
Systemic Disease	Digestive System	Yes	3.3(1)	10.0 (3)	1.07	0,30
		No	96.7(29)	90.0 (27)		
	Pulmonary System	Yes	3.3 (1)	3.3 (1)	0.00	1.00
		No	96.7(29)	96.7(29)		
	Musculoskeletal System	Yes	3.3 (1)	10.0(3)	1.07	0.30
		No	96.7 (29)	90.0(27)		

Data expressed as % (n).

The working postures of study group were illustrated in Graph 4.2. 40% of dentists were mostly working in standing position, 37% of were always in sitting position, and the rest of them was mostly in sitting position. On the other hand, 74% of dental students mostly working in sitting position in the clinic.

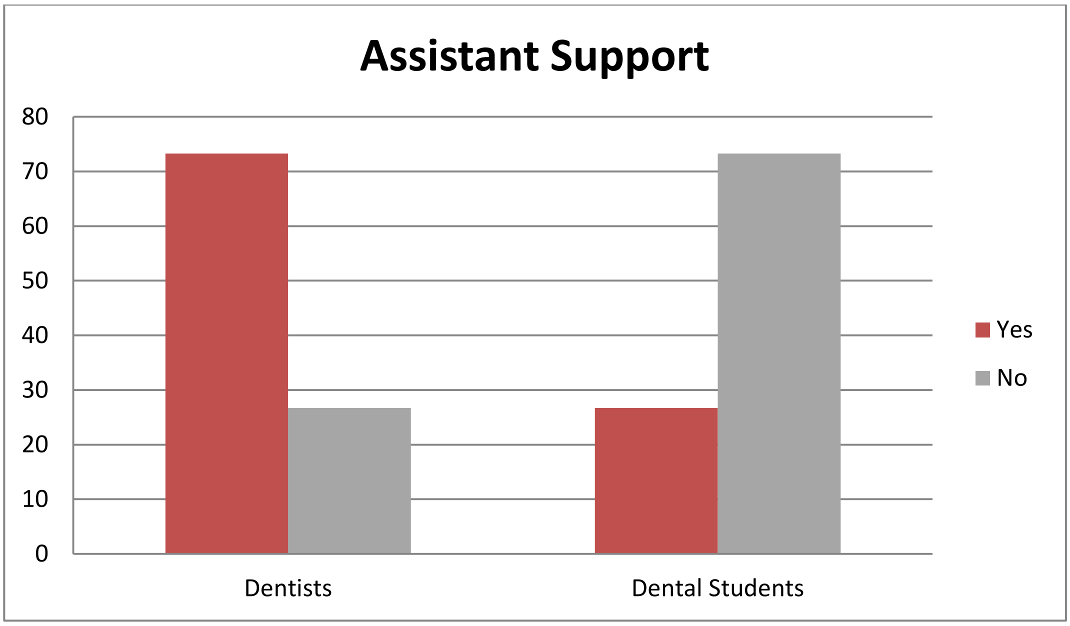
Graph 4.2. The Distribution of Working Postures during Treatments in the Clinic among Dentists and Dental Students





The distribution of having dentist assistant during the treatment session between dentists and dental students was shown in Graph 4.3. 73.3% of dentists and 22.7% of dental students had an assistant or nurse support during treatments.

Graph 4.3. The Distribution of Having Dentists Assistant During the Treatment Session in the Study Group



A Wilcoxon test was used to determine the differences on working days and hours in two groups. The results showed statistically differences in working days in a week and total hours in a week between dentists and dental students ($p<0.01$) (Table 4.4.)

Table 4.4. Comparison of Working Days and Working Hours Between Dentists Dental Students

	Dentists (Mean±SD)	**Dental Students** (Mean±SD)	**Z**	**p value**
Working Days (days/wk)	5.7±0.53	4.63±0.85	-5.30	**0.00**
Working Hours (total/wk)	42,3±9.54	20.73±11.70	-5.45	**0.00**

Data expressed as mean± standard deviation, wk: Week

A paired t-test and Wilcoxon test were used to compare the means of values for hand grip strength and pinch grip strength during the pre and post training in the study group (n=60). As a result, the mean of hand grip strength for both right and left showed improvements during post evaluation compared with pre evaluation. The difference between pre and post evaluation was statistically difference ($p<0.01$). Lateral key and Palmar pinch grip strength for both hands, and tip pinch for right indicated statistically differences in pre and post-tests ($p<0.05$), while tip pinch for left hand showed no statistically difference (Table 4.5).

Table 4.5. Comparison of Pre and Post Powerball Training for Hand Grip Strength and Pinch Grip Strength in the Study Group (n=60)

			Pre (Mean±SD)	**Post** (Mean±SD)	**t/Z**	**p value**
HAND GRIP STRENGTH	Right (kg)		36.16±11.48	43,14±12.14	t=-10.53	**0.00**
	Left (kg)		34.37±12.10	40.40±13.09	t=-8.51	**0.00**
PINCH GRIP STRENGTH	Lateral Key (lbs)	Right	17.27±4.94	18.26±5.27	t=-2.08	**0.04**
		Left	16.12±5.27	17.77±4.68	t=-5,38	**0.00**
	Tip Pinch (lbs)	Right	12.11±3.29	13.27±3.07	Z=-3.35	**0.001**
		Left	11.99±3.09	12.52±2.76	t=-1.98	0.05
	Palmar Pinch (lbs)	Right	13.20±3.74	15.20±4.23	Z=-5.23	**0.00**
		Left	12.76±3.76	15.10±3.90	Z=-4.90	**0.00**

Data expressed as, mean± standard deviation, kg: Kilogram, lbs: pound

In the whole study group (n=60), comparison of pre and post measurement findings of vibration perception evaluated where assessed the point of ulnar styloid process for both left and right hands and radial styloid for right were demonstrated statistically significant difference at the end of 6 weeks ($p<0.05$). However, there was no significantly difference measurement from radial styloid process of left hand (Table 4.6).

Table 4.6. Comparison for Vibration Sense during Pre and Post Powerball Training in the Study Group (n=60)

			Pre (Mean±SD)	Post (Mean±SD)	t	p value
VIBRATION SENSE	**Radial (sec)**	Right	3.67±1.34	4.68±1.54	-7.41	**0.00**
		Left	3.96±3.74	4.74±1.58	-1.67	0.09
	Ulnar (sec)	Right	3.96±1.64	4.68±1.54	-5.49	**0.00**
		Left	3.86±1.52	4.87±1.67	-6.04	**0.00**

Data expressed as mean± standard deviation, sec: second

According to paired t-test and Wilcoxon test, we found the statistically significant improvements in JPS of wrist joint for all axis (flexion-extension, radial-ulnar deviation) on two sides in the study group (n=60) (p<0.01) (Table 4.7).

Table 4.7. Comparison for Joint Position Sense during Pre and Post Powerball Training in the Study Group

			Pre (Mean±SD)	Post (Mean±SD)	t/Z	p value
JOINT POSITION SENSE (JPS)	**Radial Deviation (10˚)**	Right	2.21±2.37	1.01±1.12	Z=-3.75	**0.00**
		Left	3.36±2.77	1.62±1.67	t= 4.62	**0.00**
	Ulnar Deviation (15˚)	Right	2.92±2.61	0,96±1.31	t= 5.79	**0.00**
		Left	3.61±3.51	1.40±1.36	t= 4.25	**0.00**
	Flexion (30˚)	Right	3.84±2.90	1.63±1.27	t= 7.72	**0.00**
		Left	3.96±2.45	1.22±1.66	t= 7.77	**0.00**
	Extension (30˚)	Right	3.67±2.81	1.36±1.71	t= 5.54	**0.00**
		Left	3.92±3.14	1.57±1.82	t= 5.00	**0.00**

Data expressed as mean± standard deviation

The Wilcoxon test was performed comparing the pre and post Powerball training findings for DASH questionnaire. In the whole group (n=60), the disability level were statistically decreased according to DASH questionnaire ($p<0.01$). The scores from all subtitles of DASH questionnaire were reduced (disability/symptom score and optional modules for work and sport) (Table 4.8).

Table 4.8. Comparison during Pre and Post Powerball Training for DASH in the Study Group

		Pre (Mean±SD)	**Post** (Mean±SD)	**Z**	**p value**
DASH	**Disability/Symptom**	10.01±9.08	7.62±7.36	-4.28	**0.00**
	Optional Modules (Sport)	7.84±11.49	4.11±6.19	-3.09	**0.002**
	Optional Modules (Work)	7.39±13.34	3.64±8.07	-3.45	**0.00**

Data expressed as mean± standard deviation, lbs: pound, DASH; Disability of Arm, Shoulder and Hand

An independent samples t-test and Mann-Whitney U test were used to compare independent variables between dentists and dental students before the Powerball training program. The results showed that hand grip strength for right and tip pinch for left had statistically differences in two groups ($p<0.05$). The mean values of hand grip strength for both side and tip pinch of the left hand were higher in dentists than dental students during pre evaluation. The other variables had no statistically significant (Table 4.9).

Table 4.9. Comparison of Variables between Two Groups before Powerball Training

			Dentists (Mean±SD)	Dental Students (Mean±SD)	t/u	p value
HAND GRIP STRENGTH	Right		39.93±11.72	32.38±10.07	t=0.83	**0.01**
	Left		35.53±13.02	31.21±10.38	t=0.68	0.42
PINCH GRIP STRENGTH	**Lateral Key(lbs)**	Right	17.73±4.42	16.82±5.45	t= 0.70	0.48
		Left	16.50±4.90	15.73±5.68	t=0.56	0.56
	Tip Pinch(lbs)	Right	12.89±3.21	12.34±3.23	t= 1.86	0.06
		Left	12.76±2.68	11.23±3.13	u=-2.46	**0.01**
	Palmar Pinch(lbs)	Right	13.63±3.13	12.78±4.28	u=-1.55	0.11
		Left	13.60±3.16	11.92±4.17	u= -2.70	0.07
VIBRATION SENSE	**Radial Styloid (sec)**	Right	3.17±1.30	3.77±1.40	t= -0.56	0.57
		Left	3.36±1.05	4.56±5.16	t= -1.24	0.21
	Ulnar Styloid (sec)	Right	3.85±1.50	4.07±1.79	t= -0.51	0.60
		Left	3.82±1.39	3.91±1.67	t= -0.97	0.81
JOINT POSITION SENSE	**Radial Deviation (15˚)**	Right	2.63±2.90	1.79±1.64	u=-1.20	0.20
		Left	3.37±2.66	3.36±2.92	t= 0.01	0.98
	Ulnar Deviation (10˚)	Right	3.58±3.14	2.26±1.76	u=-1.61	0.10
		Left	3.25±3.39	3.97±3.65	u= -0.95	0.34
	Flexion (30˚)	Right	3.58±2.77	4.09±3.04	t= -0.68	0.49
		Left	4.04±2.62	3.88±2.30	t= -0.24	0.80
	Extension (30˚)	Right	3.57±2.97	3.77±2.69	t=-0.26	0.78
		Left	3.19±2.72	3.88±2.30	t= -1.81	0.07
DASH	**Disability/Symptom**		8.03±8.01	11.98±9.78	t= -1.71	0.09
	Optional Modules (Sport)		5.92±9.42	9.37±12.9	t= -0.97	0.34
	Optional Modules (Work)		7.08±14.37	7.7±12.46	t= -0.18	0.85

Data expressed as mean± standard deviation, lbs: pound , sec;second, DASH; Disability of Arm, Shoulder and Hand

During post measurements, the findings had statistically significance for right and left hand (p<0.01). Means of hand grip strength for both sides were higher than comparing with pre evaluation for two groups (Table 4.10).

Table 4.10. Intragroup Comparisons of Pre and Post Measurement Findings of Hand Grip Srength

			Dentists Mean ± SD	**p value**	**Dental Students** Mean ± SD	**p value**
HAND GRIP STRENGTH	Right (kg)	Pre	39.93±11.72	**0.00** t:-8.10	32.38±10.07	**0.00** t:-6.79
		Post	47.02±11.83		39.25±11.34	
	Left (kg)	Pre	31.21±10.38	**0.00** t:-6.91	31.21±10.38	**0.00** t=-5.37
		Post	37.34±12.55		37.34±12.55	

Data expressed as mean± standard deviation, kg: Kilogram

The paired t-test and Wilcoxon test were used to determine the differences in regard to pre and post-tests mean scores of pinch grip consisting lateral key, tip pinch, and palmar pinch. According to intragroup variables, there was a significant difference for palmar pinch of both side (p<0.01). While mean values of tip pinch for left were found significantly improvement during pre and post evaluation in dental students group (p<0.01), we didn’t observe any statistical change for tip pinch among dentists. The mean of lateral key for left was significantly increased in two groups, except lateral key for right (p<0.01) (Table 4.11).

Table 4.11. Intragroup Comparisons of Pre and Post Measurement Findings of Pinch Grip Srength

				Dentists Mean ± SD	p value	Dental Students Mean ± SD	p value
PINCH GRIP STRENGTH	Lateral Key (lbs)	Right	Pre	17.73±4.42	0.32	16.82±5.45	0.058
			Post	18.44±5.25	t:-1.01	18.08±5.37	t:-1.97
		Left	Pre	16.50±4.90	**0.00**	15.73±5.68	**0.001**
			Post	18.19±4.60	t:-3.99	17.35±4.80	t=-3,57
	Tip Pinch (lbs)	Right	Pre	12.89±3.21	**0.007**	11.34±3.23	**0.01**
			Post	13.84±2.99	t:-2.90	12.71±3.10	t=-2,57
		Left	Pre	12.76±2.68	0.65	11.23±3.31	**0.02**
			Post	12.93±2.46	t:-0.45	12.11±3.03	t=-2.34
	Palmar Pinch (lbs)	Right	Pre	13.63±3.13	**0.00**	12.78±4.28	**0.00**
			Post	15.40±3.28	Z=-3.63	14.99±5.06	Z=-3.78
		Left	Pre	13.60±3.16	**0.001**	11.92±4.17	**0.00**
			Post	15.43±2.81	t:-3.70	14.77±4.78	t=-4.61

Data expressed as mean± standard deviation, lbs: pound

When comparing vibration sense for intragroups, paired sample t-test was used. The mean values of vibration sense from ulnar styloid region were statistically difference for both side. Except the vibration sense measurement of dental students from radial styloid regions for left side , the measurement for right side indicated significantly increase comparing the first measurement ($p<0.01$) (Table 4.12).

Table 4.12. Intragroup Comparisons of Pre and Post Measurement Findings of Vibration Sense

					Dentists Mean ± SD	p value	Dental Students Mean ± SD	p value
VIBRATION SENSE	Radial Styloid (sec)	Right	Pre	3.57±1.30	**0.00**	3.77±1.40	**0.00**
			Post	4.75±1.64	t:-5.86	4.61±1.45	t:-4.61
		Left	Pre	3.36±1.05	**0.00**	4.45±5.16	0.82
			Post	4.72±1.67	t:-5.96	4.77±1.51	t:-2.30
	Ulnar Styloid (sec)	Right	Pre	3.85±1.50	**0.00**	4.07±1.79	**0.003**
			Post	5.11±2.08	t:-4.43	4.87±1.64	t:-3.29
		Left	Pre	3.82±1.39	**0.00**	3.91±1.67	**0.001**
			Post	4.84±1.62	t:-4.84	4.89±1.74	t:-3.79

Data expressed as mean± standard deviation, sec:Second

As seen in Table 4.13, there were statistically differences in JPS of wrist joint for all axis in both groups ($p<0.05$). During post measurements, the mean of wrist JPS were significantly lower than the pre measurement in dentists and dental students, with outcomes of angles indicated decreasing the amount of proprioception error (Table 4.13).

Table 4.13. Intragroup Comparisons of Pre and Post Measurement Findings of Joint Position Sense (JPS)

				Dentists Mean ± SD	p value	Dental Students Mean ± SD	p value
JOINT POSITION SENSE (JPS)	**Radial Deviation (15˚)**	Right	Pre	2.62±2.90	**0.001**	1.79±1.64	**0.009**
			Post	1.23±1.31	Z:-2.56	1.39±1.69	Z:-2.61
		Left	Pre	3.37±2.66	**0.007**	3.63±2.92	**0.001**
			Post	1.85±1.64	t:2.87	1.39±1.69	t:3.62
	Ulnar Deviation (10˚)	Right	Pre	3.58±3.14	**0.00**	2.26±1.76	**0.001**
			Post	0.91±1.40	Z:-3.98	1.01±1.24	Z:-3.40
		Left	Pre	3.25±3.39	**0.02**	3.97±3.65	**0.001**
			Post	1.51±1.18	t:2.45	1.28±1.53	t:3.51
	Extension (30˚)	Right	Pre	3.57±2.97	**0.00**	3.77±2.69	**0.002**
			Post	1.08±1.11	t:4.43	1.64±2.16	t:3.41
		Left	Pre	3.19±2.72	**0.006**	4.64±4.40	**0.00**
			Post	1.53±1.30	t:2.98	1.61±2.30	t:4.07
	Flexion (30˚)	Right	Pre	3.58±2.77	**0.00**	4.09±3.04	**0.00**
			Post	1.10±1.01	t:5.63	1.44±1.66	t:5.25
		Left	Pre	4.04±2.62	**0.00**	3.88±2.23	**0.00**
			Post	1.03±1.18	t:6.33	1.42±2.03	t:4.65

Data expressed as mean± standard deviatio

The Wilcoxon test was performed comparing intragroup across the pre and post measurements for DASH questionnaire. All subdivision scores of DASH questionnaire were statistically decreased in both groups during the post evaluation (disability/symptom, optional modules for work and sport) (p<0.05) (Table 4.14).

Table 4.14. Intragroup Comparisons of Pre and Post Measurement Findings of DASH

			Dentists Mean ± SD	p value	Dental Students Mean ± SD	p value
DASH	Disability /Symptom	Pre	8.03±8.01	**0.01** Z:-2.82	11.98±9.78	**0.00** Z:-3.51
		Post	6.53±6.89		8.72±7.75	
	Optional Modules (Sport)	Pre	5.92±9.42	**0.04** Z:-2.04	9.37±12.90	**0.01** Z=-2,38
		Post	2.50±4.71		5.46±6.97	
	Optional Modules (Work)	Pre	7.08±14.37	**0.02** Z:-2.20	7.70±12.46	**0.005** Z=-2,83
		Post	4.37±10.40		2.91±4.85	

Data expressed as mean± standard deviation, DASH; Disability of Arm, Shoulder and Hand

Independent t-test were applied to examine differences comparing between the values during pre and post evaluations among two groups. As it was seen in Table 4.15, we observed that the differences between pre and post measurement of JPS for flexion had greater improvement among dentists. Moreover, the differences of disability/symptom scores of dental students have been shown statistically significant decreasing comparing with dentists. (p=0.02). (Table 4.15).

Table 4.15. Comparison of Difference Between Pre and Post Measurements of Intergroup Variables

			Dentists Mean ± SD	Dental Students Mean ± SD	p value
HAND GRIP STRENGTH	∆ Right (kg)		7.08±4.79	6.86±5.53	p= 0.86, t: 0.16
	∆ Left (kg)		5.92±4.69	6.13±6.25	p= 0.88, t: -0.14
PINCH GRIP STRENGTH	**∆ Key Pinch (lbs)**	Right	0.71±3.85	1.26±3.49	p= 0.56, t: -0.58
		Left	1.69±2.31	1.61±2.47	p= 0.90, t: 0.12
	∆ Tip Pinch (lbs)	Right	0.94±1.78	1.37±2.92	p= 0.53, t: -0.62
		Left	0.16±2.01	0.88±2.09	p= 0.17 , t: -1.36
	∆ Palmar Pinch (lbs)	Right	1.77±2.69	2.12±2.71	p= 0.53, t: -0.62
		Left	1.82±2.69	2.84±3.37	p= 0.20, t: -1.29
VIBRATION SENSE	**∆ Radial (sec)**	Right	1.17±1.09	0.84±0.99	p= 0.22, t: 1.23
		Left	1.35±1.24	0.20±4.92	p= 0.22, t: 1.23
	∆ Ulnar (sec)	Right	1.26±1.55	0.79±1.32	p= 0.22, t: 1.24
		Left	1.02±1.16	0.98±1.42	p= 0.89, t: 0.13
JOINT POSITION SENSE	**∆ Radial Deviation (10°)**	Right	-0.30±5.47	-0.51±2.55	p= 0.19, t: 0.85
		Left	-1.32±3.81	-1.77±3.58	p=0.60, t: 0.51
	∆ Ulnar Deviation (15°)	Right	-1.38±5.32	-0.78±3.01	p= 0.59, t: -0.54
		Left	-0.74±6.18	-2.06±5.21	p= 0.36, t: 0.91
	∆ Extension (30°)	Right	-0.14±4.23	1.37±5.27	p= 0.22, t: -1.23
		Left	- 0.27±3,89	-0.91±3.86	p= 0.32 t: -1.46
	∆Flexion (30°)	Right	- 0.06±4.77	-0.09±3.86	p= 0.94, t:-0.86
		Left	-3.01±2.60	-2.46±2,90	p= **0.02,** t:0.97
DASH	**Disability /Symptom**		-1.16±2.41	-3.26±4.24	p= **0.02,** t:2.35
	Optional Modules (Sport)		-3.28±6.70	-3.90±7.09	p= 0.77, t: 0.29
	Optional Modules (Work)		-2.70±6.28	-4.79±8.63	p= 0.29, t: 1.06

Data expressed as mean±standard deviation, ∆:Post variables minus pre variables, kg: Kilogram, lbs: Pound, sec: Seczond, DASH: Disability of Arm, Shoulder and Hand

In the study we constructed linear regression analysis to determine the affecting factors of disability/symptom sores of DASH during pre measurements. Table 4.16 identified the predictors of disability/symptom scores of DASH that hand grip and tip pinch for both hands, palmar pinch for right, vibration sense from radial styloid of left side, ulnar styloid for right, JPS for radial deviation of right hand, ulnar deviation, extension and flexion of both sides, the age, working years, days and hours were statistically significant predictors for disability/symptom of DASH before training among dentists (R^2:0.934, $p<0.05$)

Table 4.16. Predictors of DASH Disability/Symptom Score by Linear Regression Before Training among Dentists

Predictors			*Standardized Coefficient (B)*	Significance
Hand Grip Strength	Right (kg)		5.65	**0.00**
	Left (kg)		-4.97	**0.00**
Pinch Grip Strength	**Tip Pinch (lbs)**	Right	0.67	**0.01**
		Left	-0.59	**0.02**
	Palmar Pinch (lbs)	Left	-0.91	**0.00**
Vibration Sense	**Radial(sec)**	Left	-3.51	**0.00**
	Ulnar(sec)	Right	4.65	**0.00**
Joint Position Sense	**Radial Deviation (10˚)**	Right	-1.78	**0.00**
	Ulnar Deviation (15˚)	Right	3.87	**0.00**
		Left	-4.49	**0.00**
	Extension (30˚)	Right	0.31	**0.06**
		Left	0.57	**0.04**
	Flexion (30˚)	Right	1.62	**0.00**
		Left	-1.51	**0.00**
Age			-2.52	**0.00**
Working Years			2.29	**0.00**
Working Days			-1.42	**0.00**
Working Hours			0.95	**0.00**
Constant				0.00

R=0.967; R^2=0.934; Adjusted R^2=0.809

Data expressed as kg: Kilogram, lbs: Pound, sec: Second, DASH; Disability of Arm, Shoulder and Hand

Hand grip strength for both sides, lateral key for right, palmar pinch for left, vibration sense from radial and ulnar regions for left, JPS for extension of left hand, flexion of both sides, the age and working years were identified as predictors of disability/symptom scores of DASH by linear regression analysis in Table 4.17. These predictors were statistically significant in disability/symptom of DASH after training among dentists (R^2: 0.861, $p<0.05$).

Table 4.17. Predictors of DASH Disability/Symptom Score by Linear Regression After Training among Dentists

Predictors			***Standardized Coefficient (B)***	**Significance**
Hand Grip Strength	Right(kg)		-0.68	0.71
	Left (kg)		0.85	**0.02**
Pinch Grip Strength	**Lateral Key (lbs)**	Right	-0.94	**0.00**
	Palmar Pinch (lbs)	Left	0.69	**0.00**
Vibration sense	**Radial(sec)**	Left	1.17	**0.003**
	Ulnar(sec)	Left	-0.47	0.72
Joint Position Sense	**Extension (30˚)**	Left	0.45	**0.003**
	Flexion (30˚)	Right	0.22	**0.04**
		Left	-0.24	**0.01**
Age			-3.67	**0.02**
Working Years			3.59	**0.02**
Constant				0.006

$R=0.930$; $R^2=0.861$; Adjusted $R^2=0.770$

Data expressed as kg: Kilogram, lbs: Pound, sec: Second, DASH; Disability of Arm, Shoulder and Hand

Table 4.18 demonstrated the predictors of DASH before training among dental students. Hand grip strength for right hand, lateral pinch for both sides, palmar pinch for left, vibration sense from radial and ulnar styloid regions for left, JPS for extension and flexion of the right and the working days were found as independent risk factors for disability/symptom score of DASH questionnaire (R^2=0.857, p<0.05).

Table 4.18 Predictors of DASH Disability/Symptom Score by Linear Regression Before Training among Dental Students

Predictors			***Standardized Coefficient (B)***	**Significance**
Hand Grip Strength	Right		-0.85	**0.001**
Pinch Grip Strength	**Lateral Key (lbs)**	Right	-1.52	**0.00**
		Left	1.78	**0.00**
	Palmar Pinch (lbs)	Left	0.39	**0.03**
Vibration sense	**Radial (sec)**	Left	-4.73	**0.00**
	Ulnar (sec)	Left	2.54	**0.02**
Joint Position Sense	**Extension (30˚)**	Right	3.67	**0.02**
	Flexion (30˚)	Right	0.49	**0.02**
Working Days			0.35	**0.02**
Constant				0.41

R=0.926; R^2=0.857; Adjusted R^2=0.742

Data expressed as kg: Kilogram, lbs: Pound, sec: Second, DASH; Disability of Arm, Shoulder and Hand

Table 4.19. contains the predictors disability/symptom scores of DASH by linear regression analysis as lateral key, tip pinch and palmar pinch for right, vibration sense from radial styloid for left hand, JPS for radial deviation of both sides, the age, working days. These were statistically significant independent affecting factors of disability/symptom scores of DASH after training among dental students (R^2: 0.742, $p<0.05$).

Table 4.19. Predictors of DASH Disability/Symptom Score by Linear Regression After Training among Dental Students

Predictors			***Standardized Coefficient (B)***	**Significance**
Pinch Grip Strength	**Lateral Key (lbs)**	Right	-1.21	**0.003**
	Tip Pinch (lbs)	Right	-0.93	**0.005**
	Palmar Pinch (lbs)	Right	2.42	**0.00**
Vibration sense	**Radial (sec)**	Left	-1.13	**0.007**
Joint Position Sense	**Radial Deviation (10˚)**	Right	-1.05	**0.001**
		Left	0.81	**0.01**
Age			0.96	**0.01**
Working Days			0.50	**0.02**
Constant				**0.001**

R=0.862; R^2=0.742; Adjusted R^2=0.50

Data expressed as kg: Kilogram, lbs: Pound, sec: Second, DASH; Disability of Arm, Shoulder and Hand

5. DISCUSSION

The mostly important results of our study revealed that all measurements were improved through Powerball training program with six weeks in both groups ($p<0.05$). There were not any significantly differences in all parameters except DASH and JPS for flexion comparing two groups. Disability/symptom scores of DASH showed greater improvement in dental students The other important result indicated that our program led more effectiveness on JPS for flexion of left hand among dentists (Table 4.15) ($p<0.05$). These results support H3 because of the differences between groups. Consistent with hypothesis, we found that Powerball training is effective on hand grip strength, pinch grip strength and proprioception among dentists.

According to statistical analysis (Table 4.5.), the mean values of hand grip strength significantly increased in whole group after six weeks of Powerball training program (n=60) ($p<0.05$). Dentists and dental students showed statistically improvements in hand grip strength through the intragroup comparisons (Table 4.9.). Legg [70] compared the effect of Powerball on hand grip strength in healthy participants for four weeks (Group 1; 20F, Group 2; 20M; 3 times/wk). There was an increase on grip strength of whole participants. Balan et al. [18] reported that regular use of Powerball with 4 weeks period increased the endurance of forearm muscle but they did not found development of hand grip and the capacity of maximum contraction of muscles among healthy participants. It is also stated that participants had greater amount of increasing in grip strength over four weeks. According to study of Szymanski et al. [71], resistance training program contained Barbel biceps curl and bench press, standing radial and ulnar deviation, straight bar wrist curl, seated pronation and supination increased grip strength in baseball players (n=42 M; 3d/12 wk). Cima et al. [72] carried out the study included 20 patients; Group 1 taking rehabilitation program contained strengthening exercises of hand muscles (2 d/wk, 2 months). The authors argued that hand grip and pinch grip strength were significantly increased in group 1 participated strength exercises, whereas any differences was not observed in Group 2. The study of Abd-el-Kader et al. [1] investigated the effects of a comprehensive exercise program on pain intensity, hand grip and pinch strength in dentists diagnosed with CTS. The results showed that severity of symptoms and pain decreased, hand grip and pinch strength increased in the study. The study on how to muscles strength increased after resistance training was explained neuromuscular adaptation as physiological perspective. One possible mechanism in the contracted muscles was defined with neuromuscular adaptation which is the more motor unit enrolled to improve the generation of muscle force. There are low and high threshold of fibers in the motor unit which could change with a higher threshold for increasing generation of the force. Another possible reason implied that variation of muscle fibers type in the resistance training which provides more force generation by changing from Type 1 muscle fibers to Type 2 muscle fibers [73]. In the light of these evidences and our results we can conclude that hand grip strength increased after training in the study group. In linear regression analysis, we determined the multiple risk factors for the disability/symptom scores of DASH during pre and post training. Although in dentists, it was found coefficient of the variable as (OR) 5.65 (95% confidence interval (CI): 2.38,5,33) for hand grip measurements of right pre training program, this value was decreased and changed to coefficient of the variable as (OR) -0,68 (95% CI: -0,84, 0,03). According to this results we think that powerball training had mostly effective results on hand grip strength among the dentists. However we could not achieve same powerful results in the dental students. The duration of the training and totally working hours/wk may be possible explanation of this difference between two groups.

In the present study, we found statistically significant improvements in findings of pinch grip strength consisting lateral key, tip pinch and palmar pinch in the study group ($p<0.05$). According to results, lateral key pinch strength for left hand, tip pinch for right hand and palmar pinch for both hands statistically increased in both groups($p<0.05$). The mean values of lateral key strength for right hand showed the rising, but these results were not showed statistically differences among the study group. The findings of tip pinch for right hand changed a little amount during pre and post Powerball training, thus this result had not also a statistical difference among dentists. Dong et al. [74] conducted a similar study participated 6 dentists and 6 dental students by comparing thumb pinch strength. They found that dental students had greater findings of pinch strength than dentists due to increased experience periodontal scaling causes less pinch force utilization to accomplish scaling. To examine the multiple risk factors of the DASH scores we constructed linear regression analysis in the study, lateral key strength for right was important predisposition factor of DASH during post measurements in dentists (OR: -0,94, 95% CI: -1,69,-0,79) and dental students (OR: -

1,21, 95%; 95% CI: -2,84, 0,67). We think these results can be accepted as remarkable point of our study. Thus negative and statistically important relationship between lateral key and disability/symptom score of DASH may be preventive effects of powerball training.

In the present study, measurement of vibration sense with 128 Hz diapason gained a significantly improvements for radial and ulnar styloid region of both hands except the radial styloid of left hand in the whole groups ($p<0.05$). According intragroup comparisons dentists and dental students showed enhancements in vibration sense in all regions. However, only differences of radial styloid region for left hand had not statistically significant degree among dental students. Akseki et al. [75] evaluated in a study that vibration sense can be used as a measurement of proprioception. The joint position sense and duration of vibration sense were measured in the study participated patients with patellofemoral pain syndrome and healthy individuals. Mean values of vibration sense in the symptomatic knee were less than healthy knees. JPS assessment showed that the symptomatic index of proprioception worsen consistent with duration of vibration perception. As far as we know, there aren't any studies evaluate vibration sense during proprioceptive training in upper extremity. Although vibration senses from radial styloid were found important risk factors affecting on disability/symptom scores of DASH during pre measurements for dentist and dental students (respectively, OR: -3.51, -4.73) (95% CI: -15,70, -3,51; -1,42, -0,54 respectively) OR reduced to -1.13 for dental students during post measurement of vibration sense from radial styloid. We did not find same outputs from vibration sense of ulnar region in both groups. That's why we can say our training program did not cause same improvements on reactivation of muscles from radial and ulnar region according to regression analysis results. As conclusion that when we consider the intergroup comparisons all participants gained in higher duration of vibration perception during post training measured by diapason, we believe that the perception of kinesthesia may be significantly affected from Powerball training. Powerball training can be recommended to stimulate reactive muscle activation as unconscious proprioception re-education tools for wrist to hand therapists.

JPS that is one of the major sense of proprioception was assessed and results showed statistically improvement in all axis of wrist joint among overall participants (n=60). Similarly, intragroup comparisons of pre and post measurement findings were also statistically significant (p<0.01). Proprioception deficits in both dentists and dental students decreased so they move their wrist predetermined angle accurately or with less error. The study about effects of robot assisted proprioceptive training aided with vibro-tactile feedback on JPS and motor learning among young adults showed that the matching errors decreased in proprioceptive training and vibrotactile feedback groups. [76]. The review study of Aman et al. [16], indicated that motor control improved in participants with writer's cramp after proprioceptive therapy; their error of target JPS significantly decreased. Also, the other studies on wrist joint position discrimination (with graded difficulty) for stroke patients showed improvements of 57–67% to detect joint angle position in wrist [77]. Özkul et al. [78] carried out a study on evaluation the proprioceptive sense of elbow flexion through a robot assisted rehabilitation system participated 10 physiotherapy (PT) and 10 electrics and electronics engineering students (EEE). They found that PT students has less matching errors than EEE. In regression analysis, we found that JPS of radial deviation for right, ulnar deviation, flexion and extension for both sides were the significant risk factors of DASH as before training among dentists. The results of our regression analysis indicated that coefficient of JPS for flexion which was determined as predictor risk factor for DASH, decreased in right and left side (from OR:1,62, -1,51 to OR: 0,22, -0,24, 95% CI: 3,13, 6,24; -6,21, -3,03 respectively) after training among dentists. Improvements in JPS of wrist joint are important findings in terms of increased neuromuscular control and reduced repetitive trauma. According to this result, Powerball may be recommended as preventive rehabilitation tools for proprioceptive training.

DASH questionnaire outcomes including disability/symptom scores, optional modules for sport and work showed statistically significant improvements in both groups (p<0.05) However, the differences in mean findings between pre and post Powerball training for disability/symptom score had statistically significant reducing among dental students versus dentists (Table 4.15). In the literature, Hayes et al. [79] compared the effects of wearing loupes on upper extremity between dentists and dental students. DASH scores were revealed higher in dental students than dentists. Authors stated that younger dentists had pain and discomfort in the neck, shoulders and headaches to a greater extent than older dentists [80]. In our study, we found that DASH scores of dental students were higher than dentists during pre and post measurements except post measurement of optional module for work scores. The study on determination the WMSD and the related risk factors of dentists with CTD showed that there is a strong association with various cumulative trauma disorders assessed by (neck disability index, DASH and CTS questionnaire) [8]. Dias et al. [81] were trying to find the prevalence of WMSD in dentists by using personal information and DASH questionnaire. That's why in the present study we determine independent variable for examining the risk factors by multiple linear regression analysis.

Using a backward regression analysis, hand grip strength and tip pinch for both sides, palmar pinch for left hand, vibration sense on radial styloid region for left hand and ulnar styloid for right hand, radial deviation for right, ulnar deviation, extension and flexion for both sides, the age, working years, days and hours were identified as the statistically significant independent predictors of DASH before the training program among dentists (Table 4.16). In a like manner, hand grip strength for both hands, lateral key for right, palmar pinch for left hand, vibration sense from radial and ulnar styloid processess of left hand, JPS for extension of left hand, flexion of both hands, the age and working years were determined statistically significant independent predictors of DASH after training among dentists (Table 4.17). Hand grip strength for right hand, lateral key for both hands, palmar pinch for left hand, vibration sense from radial and ulnar styloid regions of left hand, JPS for extension and flexion of right hands and working days were statistically significant predictor of disability/symptom of DASH before Powerball training among dental students (Table 4.18). The predictors of DASH after Powerball training demonstrated as follows; lateral key, tip pinch and palmar pinch for right hands, vibration sense from radial styloid process of left hand, JPS for radial deviation of both hands, the age and working days (Table 4.19).

In the literature, there are a few studies about Powerball training which increases reactive muscle strength of wrist in patients taking hand rehabilitation. Additionally, there are a lot of studies about prevalence and risk factors of MSD and WMSD among dentists. As far as we know, there are not any published studies conducted Powerball training program on hand grip strength, pinch grip strength and proprioception among dentists.

CONCLUSION AND RECOMMENDATION

The aim of the study was to determine the effects of the Powerball training program with six weeks on hand grip strength, pinch grip strength and proprioception among dentists.

The results we obtained; The Powerball training program demonstrated that there were improvements in hand grip strength, pinch grip strength, vibration sense, JPS and DASH in the overall study group. In the other word, Powerball training program can provide to increase in grip strength, decrease the amounts of proprioception deficit and extend the duration vibration sense perception on the wrist joint, reduce the DASH scores among dentists.

In the light of our results; Powerball training may have effects on hand grip strength in both groups and also a remarkable predictor factors of disability/symptom score of DASH. Additionally, there was negative and statistically important relationship between lateral key and disability/symptom score of DASH which may be preventive effects of Powerball training. As these results, Powerball can be used in the hand strengthening exercise program.

Powerball training improved JPS for all axis of movements and vibration sense perception among study group.

Powerball training ensures the reducing the disability score for daily living, sport and work. Hence, we would like to suggest the utility of Powerball especially dental students to prevent wrist complaints or provide strengthening of the muscles.

Musculoskeletal problems are occupational risk factors in dentists which make dentists conscious about this issue and also preventive rehabilitation programs have to be planned for the prevention of activity limitation. We would like to point that Powerball can be endeavoured to use in hand rehabilitation program after any trauma and injury in the wrist region and also it may be useful for proprioceptive training to prevent MSD.

We concluded that using Powerball may be suggested as unconscious proprioceptive training which caused by reactive muscle activation as valid alternative tools to assist the physical therapy interventions.

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APPENDIX 1. ETHICAL COMMITTEE APPROVAL

BAHÇEŞEHİR ÜNİVERSİTESİ
KLİNİK ARAŞTIRMALAR ETİK KURULU

Üniversitemiz Klinik Araştırmalar Etik Kurulu'na ait 07 Aralık 2016 Tarih ve 2016-10/06 Sayılı Karar Örneğidir.

KARAR:2016-10/06

Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Fizyoterapi ve Rehabilitasyon Anabilim Dalı Yüksek Lisans Öğrencisi Sevgi Gamze FELEK'in **"Diş Hekimlerinde Powerball ile Eğitimin Pençe El Kuvveti, Parmak Ucu Kavrama Kuvveti ve Propriyosepsiyon Üzerine Etkilerinin Karşılaştırılması"** isimli çalışmasının başvuru dosyası görüşüldü.

Görüşmeler sonunda; Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Fizyoterapi ve Rehabilitasyon Anabilim Dalı Yüksek Lisans Öğrencisi Sevgi Gamze FELEK'in **"Diş Hekimlerinde Powerball ile Eğitimin Pençe El Kuvveti, Parmak Ucu Kavrama Kuvveti ve Propriyosepsiyon Üzerine Etkilerinin Karşılaştırılması"** isimli çalışmaları gerekçe, amaç, yaklaşım ve yöntemleri dikkate alınarak; incelenmiş ve uygun bulunmuş olup araştırmanın/çalışmanın başvuru dosyasında belirtilen merkezlerde gerçekleştirilmesinde etik ve bilimsel sakınca bulunmadığına karar verildi.

Prof.Dr. Nazire AFŞAR
Etik Kurul Başkanı

APPENDIX 2: INFORMED WRITTEN CONSENT

Katılımcı Onam Formu

Bu anket, Yeditepe Üniversitesi Sağlık Bilimleri Fakültesi, Fizyoterapi ve Rehabilitasyon Anabilim Dalı, Yüksek Lisans Tezi için hazırlanan **"Diş Hekimlerinde Powerball İle Eğitimin Pençe El Kuvveti, Parmak Ucu Kavrama Kuvveti Ve Propriyosepsiyon Üzerine Etkilerinin Karşılaştırılması"**adlı araştırma kapsamında yapılmaktadır. Araştırma kapsamında çalışmaya kabul edilen gönüllü bireylere yaklaşık 10 dakika sürecek olan 1.kısmı 31 sorudan oluşan sosyodemografik anket ve 2.kısmı ise 11 sorudan oluşan; son 6 içinde geçirmiş olduğunuz yaralanmalar, el veya el bileği rahatsızlıklarını sorgulayan bir anket yüz yüze görüşme yöntemi ile uygulanacaktır. Günlük yaşamınızda el, kol, el bileği ve omuz bölgelerinizde karşılaştığınız fiziksel maluliyet ve semptomları değerlendiren kol, omuz ve el sorunları anketi (DASH) ve el ve el bileği ağrınızı değerlendirmek amacıyla Vizüel Analog Skalası doldurulacaktır. El bileğinizde vibrasyon hissi diapazon cihazı kullanılarak ölçülecektir. El kavrama ve parmak ucu kavrama kuvvetleriniz sırasıyla Jamar El Dinamometresi ve pinchmetre cihazları kullanılarak ölçülecektir. Açı değerleri olan bir platform üzerinde el bileğinizi farklı açılarda poziyonlayıp sizin de belirtilen pozisyona getirmeniz istenecektir. Değerlendirmeler çalışma başlangıcında (ilk test) ve 6 hafta sonunda (son test) tekrarlanacaktır. "Powerball'' (el bileği güçlendirme topu) kullanımı öğretilecek ve 6 hafta süre ile 5 dk sağ ve sol eliniz için çalışmanız istenecektir.

Araştırma ile ilgili olarak sizden doldurmanızı istediğimiz formları doğru bir şekilde doldurmanız ve herhangi bir şikayetiniz ya da rahatsızlığınız olduğunda bize bildirmeniz gerekmektedir. İstediğiniz zaman çalışma dışına çıkma hakkınız olduğunu bilmenizi isteriz. Bu araştırma kapsamında uygulanacak olan uygulamalarda herhangi bir risk bulunmamakta ve yapılacak hiçbir uygulama size zarar vermeyecektir.Bu araştırma kapsamında sizden herhangi bir ücret talep edilmemektedir. Bu araştırmada yer almanız nedeniyle size hiçbir ödeme yapılmayacaktır. Kişisel bilgileriniz herhangi bir amaçla, kurum yöneticileri veya üçüncü kişilerle kesinlikle paylaşılmayacaktır. Katılımınız için teşekkür ederiz.

Danışman Öğretim Üyesi : Prof.Doç. Dr. FERYAL SUBAŞI
Sorumlu Araştırmacı: Fzt.Sevgi Gamze FELEK -05425980418 (Araştırma süresince 24 saat ulaşılabilecek kişi)
Diğer Araştırmacı:Yrd.Doç.Dr. Fatih CABBAR

Yukarıda yer alan ve araştırmaya başlanmadan önce gönüllüye verilmesi gereken bilgileri metni okudum ve sözlü olarak dinledim. Aklıma gelen tüm soruları araştırıcıya sordum, yazılı ve sözlü olarak bana yapılan tüm açıklamaları ayrıntılarıyla anlamış bulunmaktayım. Çalışmaya katılmayı isteyip istemediğime karar vermem için bana yeterli zaman tanındı. Bu koşullar altında, bana ait tıbbi bilgilerin gözden geçirilmesi, transfer edilmesi ve işlenmesi konusunda araştırma yürütücüsüne yetki veriyor ve **"Diş Hekimlerinde Powerball İle Eğitimin Pençe El Kuvveti, Parmak Ucu Kavrama Kuvveti Ve Propriyosepsiyon Üzerine Etkilerinin Karşılaştırılması"** konulu araştırmaya ilişkin bana yapılan katılım davetini hiçbir zorlama ve baskı olmaksızın büyük bir gönüllülük içerisinde kabul ediyorum

Gönüllünün Adı / Soyadı / İmzası / Tarih

Açıklamaları Yapan Kişinin Adı / Soyadı / İmzası / Tarih

APPENDIX 3. STRUCTURED QUESTIONNAIRE

Yeditepe Üniversitesi
Sağlık Bilimleri Enstitüsü
Fizyoterapi ve Rehabilitasyon Anabilim Dalı

DİŞ HEKİMLERİNDE POWERBALL İLE EĞİTİMİN PENÇE EL KUVVETİ, PARMAK UCU KAVRAMA KUVVETİ VE PROPRİYOSEPSİYON ÜZERİNE ETKİLERİNİN KARŞILAŞTIRILMASI

DEMOGRAFİK BİLGİLER FORMU
Part I.
Demografik Bilgiler Formu karşılıklı görüşme ve kayıt yöntemi ile doldurulacaktır.

1. Ad-Soyad:
2. Cinsiyet: ☐E ☐K
3. Tel: E-mail:
4. Yaş
5. Boy: Kilo: VKİ:
6. Dominant El: ☐Sağ ☐Sol
7. Kaç Yıldır Çalışıyorsunuz (Diş Hekimleri için):
   Sınıfı (Öğrenciler için):

8. Sigara içiyor musunuz?

   ☐ Hiç içmedim ☐ Sigara içtim ama bıraktım ☐ Halen içiyorum

9. Günde kaç adet sigara içiyorsunuz?

   Adet/gün…………………….

   Paket/yıl……………………..

10. Alkol kullanıyor musunuz?

    ☐ Hiç kullanmam

    ☐ Az miktarda / kısa sureli

    ☐ Orta düzeyde / 10 yıldan az

    ☐ Fazla miktarda / uzun süredir.

Genel Sağlık Bilgileri

11. Doktor tarafından teşhisi konmuş herhangi bir hastalığınız var mı?

☐ Evet ☐ Hayır

12. Cevabınız evet ise teşhis edilen hastalığınız aşağıdakilerden hangisi /hangileridir?

(Birden fazla şıkkı işaretleyebilirsiniz.)

☐ Kalp-damar hastalıkları ☐ Kanser

☐ Şeker hastalığı ☐ Sindirim sistemihastalıkları(karaciğer,mide,vb)

☐Yüksek tansiyon ☐Solunum sistemi hastalıkları(akciğer vb)

☐ Ruhsal sorunlar (depresyon,aşırı yeme,kusma,gece yeme vb)

☐ Kas iskelet sistemi problemleri (osteoporoz,eklem ağrıları)

☐ Endokrin (hormonal) hastalıklar

☐Vitamin ve mineral yetersizlikleri (Demir,B12 vitamini yetersizliği vb.)

☐ Diğer (belirtiniz)……………………………….

13. Düzenli olarak kullandığınız bir ilaç var mı? Evet ise nedir belirtiniz.

☐ Evet ☐ Hayır ☐ Nedir………………..

14. Egzersiz veya spor yapıyor musunuz?

☐ yapmıyorum ☐ yapıyorum Gün / hafta………………

15. Genel olarak egzersiz veya spor yaptıktan sonra ;

☐ Çok hızlı soluk alıp veririm ve çok terlerim.

☐ Orta derecede solunum sıklığım artar ve terlerim.

☐ Solunum sıklığım hafif derecede artar ve çok az terlerim.

☐ Solunum sıklığım artmaz ve terlemem.

☐ Boş zamanlarımda spor veya egzersiz yapmam.

16. (Egzersiz yapanlar için) Yaptığınız egzersiz genel olarak kaç dakika sürer?

☐ 20 dk.dan az ☐ 20-30 dk ☐ 30-60 dk ☐ 60 dk.dan fazla

17. Haftada kaç kez egzersiz veya spor yapıyorsunuz?

☐ Boş zamanlarımda egzersiz veya spor yapmam ☐ Ayda bir kez
☐ Ayda 2 kez ve fazla ☐ Haftada 1 kez ☐ Haftada 3 kezden az
☐ Haftada 3 veya daha fazla ☐ Hergün

Mesleki Bigiler

18. Haftada kaç gün çalışıyosunuz ? ………………… gün/hafta

19. Haftada kaç saat çalışıyosunuz?.............................. saat/hafta

20. Klinikte çalışırken genellikle ne tür duruş içerisindesiniz?

☐ Her zaman ayakta

☐ Çoğunlukla ayakta

☐ Her zaman oturarak

☐ Çoğunlukla oturarak

21. Hasta randevularınız arasında sık sık mola veriyor musunuz?

☐ Evet ☐ Hayır

22. Klinikte çalışırken eğitimli hemşire ya da asistandan yardım alıyor musunuz?

☐ Evet ☐ Hayır

23. Çalışma ortamınız ne kadar stresli?

☐ Stresli değil

☐ Az stresli

☐ Orta stresli

☐ Çok stresli

24. Semptomlarınız genellikle ne zaman meydana geliyor?

☐ Sabah ☐ Çalışırken ☐ Çalıştıktan sonra

☐ Uyurken ☐ Her zaman

25. Hiç kas-iskelet probleminiz sebebiyle tedavi oldunuz mu ?

☐ Hayır ☐ Evet Lütfen belirtin……………..

26. Hiç kas-iskelet probleminiz yüzünden hastanede yattınız mı?

☐ Hayır ☐ Evet

27. Hiç kas-iskelet probleminiz yüzünden çalışamama durumu yada izin almak zorunda kaldınız mı?

☐ Hayır

☐ Evet Son 12 ay sürecince ortalama devamsızlık gün…………

28. Hiç çalışma saatlerinizi azaltmak zorunda kaldınız mı?

☐ Hayır

☐ Evet

DİĞER AKTİVİTELER

29. Ortalama günde yürüme,koşu,aerobik,yüzme,bisiklet sürme gibi fiziksel aktivitelere kaç saat zaman ayırıyorsunuz?

☐ saat/ gün

30. Ortalama günde basketbol,futbol,voleybol,karate yada boks gibi fiziksel temaslı spor aktivitelerine kaç saat zaman ayırıyorsunuz?

☐ saat/ gün

31. Ortalama günde kaç saat bilgisayar kullanıyorsunuz?

☐ saat / gün

32. Ortalama günde kaç saat televizyon izliyorsunuz?

☐ saat/ gün

Part II.

1)Son 6 ay içersinde üst ekstremitenizi içeren bir yaralanma geçirdiniz mi?

EVET □ HAYIR □

2) Son 6 ay içersinde alt ekstremitenizi içeren bir yaralanma geçirdiniz mi?

EVET □ HAYIR □

3)Son 6 ay içersinde bir yaralanma geçirdiniz mi?

EVET □ HAYIR □

4)Son 6 ay içersinde üst nörolojik rahatsızlanma geçirdiniz mi?

EVET □ HAYIR □

5) Son 6 ay içersinde denge ile ilgili problemleri yaşadınız mı?

EVET □ HAYIR □

6) Son 6 ay içersinde görme ile ilgili problemler yaşadınız mı?

EVET □ HAYIR □

7) Son 1 yıl içersinde üst ekstremitenizi içeren bir ameliyat geçirdiniz mi?

EVET □ HAYIR □

8) Son 1 yıl içersinde alt ekstremitenizi içeren bir ameliyat geçirdiniz mi?

EVET □ HAYIR □

9)Dengenizi etkileyecek ilaçlar alıyor musunuz?

EVET □ HAYIR □

10)Daha önce el bileğinizi içeren bir rehabilitasyon aldınız mı?

EVET □ HAYIR □

11) Kronik el bileği rahatsızlığı geçirdiniz mi?

EVET □ HAYIR □

APPENDIX 4. DISABILITY OF ARM, SHOULDER AND HAND QUESTIONNAIRE

KOL, OMUZ VE EL SORUNLARI ANKETİ

DASH-T

AÇIKLAMA

Bu anket bazı bedensel etkinlikleri yerine getirmenizin yanı sıra hastalık belirtilerinizi sormaktadır.

Her soruyu son haftadaki durumunuzu göz önüne alarak uygun numarayı yuvarlak içine almak suretiyle cevaplayınız.

Son hafta içinde bedensel etkinliği yapma fırsatınız olmadıysa,lütfen hangi cevabın en doğru olacağına göre en iyi tahmininizi yapınız.

Hangi el veya kolunuzu kullandığınızı dikkate almadan sadece bedensel etkinliği yapabilme becerinize göre uygun cevabı verin.

KOL, OMUZ VE EL SORUNLARI ANKETİ

Lütfen son hafta içindeki aşağıdaki etkinlikleri yapma yeteneğinizi uygun cevabın altındaki numarayı daire içine alarak sıralayınız.

	Zorluk Yok	hafif derecede zorluk	orta derecede zorluk	aşırı zorluk	hiç yapamama
1-Sıkı kapatılmış yada yeni bir kavanozu açmak	1	2	3	4	5
2-Yazı yazmak	1	2	3	4	5
3-Anahtarı çevirmek	1	2	3	4	5
4-Yemek hazırlamak	1	2	3	4	5
5-Zor açılan bir kapıyı iterek açma	1	2	3	4	5
6-Yukarıdaki bir rafa bir şey yerleştirmek	1	2	3	4	5
7-Ağır ev işleri yapmak (duvar silmek, yer silmek,tamirat yapmak vs.)	1	2	3	4	5
8-Bağ bahçe işleri yapmak,odun kesmek	1	2	3	4	5
9-Yatak yapmak	1	2	3	4	5
10-Alışveriş çantası yada evrak çantası taşımak	1	2	3	4	5
11-Ağır bir cismi taşımak (4.5 kg'den fazla.)	1	2	3	4	5
12-Yukarıdaki bir ampulü değiştirmek.	1	2	3	4	5
13-Saçları yıkamak veya kurulamak.	1	2	3	4	5
14-Sırtını yıkamak.	1	2	3	4	5
15-Kazak giymek	1	2	3	4	5
16-Yiyecekleri kesmek için bıçak kullanmak	1	2	3	4	5
17-Az çaba gerektiren eğlendirici işler (iskambil oynamak, örgü örmek vs.)	1	2	3	4	5
18-Kolunuzdan, omuzunuzdan veya elinizden güç aldığınız veya darbe vurduğunuz eğlenceye yönelik etkinlikler (önünüzde yerde bulunan bir konserve kutusu veya küçük bir taşa iki elinizle kavradığınız bir sopayla yandan vurmak,tenis oynamak,masa tenisi oynamak)	1	2	3	4	5
19-Kolunuzu serbestçe hareket ettirdiğiniz eğlendirici işler (suda taş kaydırmak, meyve taşlama, çelik çomak oynama)	1	2	3	4	5
20-Ulaşım ihtiyaçlarını kendi başına giderebilmek (bir yerden başka bir yere gitmek)	1	2	3	4	5
21-Cinsel faaliyetler	1	2	3	4	5

KOL, OMUZ VE EL SORUNLARI ANKETİ

	Hiç engel yok	Az engel	Orta derecede	Bir hayli	Aşırı
22-Son hafta süresince kol omuz yada el sorununuz aile arkadaşlar, komşular veya gruplarla normal sosyal etkinliklerinize *ne ölçüde* engel oldu	1	2	3	4	5

	Hiç kısıtlanmış Hissetmiyorum	Hafif derecede kısıtlı	Orta derecede kısıtlı	Çok kısıtlı	Bedensel etkinlil yapamıyorum
23-Son hafta süresince kol omuz yada el sorununuz nedeniyle işinizde yada diğer günlük etkinliklerde kısıtlandınız mı?	1	2	3	4	5

	Yok	Hafif	Orta derecede	Bir hayli	Aşırı
24-El, omuz ya da kol ağrınız	1	2	3	4	5
25-Herhangi belirli bir işi yaptığınızda el,omuz ya da kol ağrınız	1	2	3	4	5
26-El,omuz yada kolunuzdaki karıncalanma(iğnelenme)	1	2	3	4	5
27-El,omuz yada kolunuzdaki güçsüzlük	1	2	3	4	5
28-El, omuz yada kolunuzdaki hareket zorluğu	1	2	3	4	5

	Zorluk Yok	hafif derecede zorluk	orta derecede zorluk	aşırı zorluk	O kadar zorluk var ki uyuyamıyorum
29-Geçen hafta içinde el, omuz yada kol ağrınız nedeniyle uyumada ne kadar zorlandınız	1	2	3	4	5

	Kesinlikle Katılmıyorum	Katılmıyorum	Ne katılıyorum ne katılmıyorum	Katılıyorum	Kesinlikle katılıyorum
30-Kol, omuz veya el problemimden dolayı kendimi daha az yeterli, daha az yararlı hissediyor veya kendime daha az güveniyorum.	1	2	3	4	5

YÜKSEK PERFORMANS İSTEYEN SPORLAR-MÜZİSYENLER

Aşağıdaki sorular kol, omuz veya el sorununuzun müzik aleti çalmanıza, spor yapma veya her ikisine olan etkisi ile ilgilidir. Eğer birden çok spor yapıyor, müzik aleti çalıyorsanız (veya her ikisi de) bu etkinliklerden sizin için en önemli olanı göz önüne alarak cevaplayınız.

Lütfen sizin için en önemli olan müzik aleti veya sporu belirtiniz:..

#Bir müzik aleti çalmıyor veya spor yapmıyorum(bu bölümü atlayabilirsiniz)

Lütfen son hafta içinde fiziksel yeteneğinizi en iyi tanımlayan numarayı yuvarlak içine alınız. Zorluğunuz oldu mu?

	zorluk yok	hafif derecede zorluk	orta derecede zorluk	aşırı zorluk	hiç yapamama
1-Spor yaparken veya müzik aleti çalarken her zamanki tekniğinizi kullanmada zorluğunuz oldu mu ?	1	2	3	4	5
2- Kolunuz, omuzunuz ve el ağrınız nedeniyle müzik aletinizi her zamanki gibi çalmada veya spor yapmada zorluğunuz oldu mu?	1	2	3	4	5
3- Müzik aletinizi istediğiniz kadar iyi çalmada, spor yapmada zorluğunuz oldu mu?	1	2	3	4	5
4- Her zamanki süre kadar bir müzik aleti çalarken veya spor yaparken zorluğunuz oldu mu?	1	2	3	4	5

İŞ MODELİ

Aşağıdaki sorunlar kolunuz, omuzunuz veya el sorununuzun işinizi yapma yeteneğiniz üzerindeki etkisini sormaktadır. (eğer ev hanımı iseniz soruları ev işlerini soruları ev işlerini düşünerek cevaplayınız.)

Lütfen işinizin/mesleğinizin ne olduğunu belirtin:...

Çalışmıyorum (bu bölümü atlayabilirsiniz)

Lütfen son hafta içinde fiziksel yeteneğinizi en iyi tanımlayan numarayı yuvarlak içine alınız.

	zorluk yok	hafif derecede zorluk	orta derecede zorluk	aşırı zorluk	hiç yapamama
1-İşinizi yaparken her zamanki tekniğinizi kullanmada zorluğunuz oldu mu?	1	2	3	4	5
2-Kolunuz, omuzunuz veya el ağrınız nedeniyle işinizi her zamanki gibi yapmada zorluğunuz oldu mu ?	1	2	3	4	5
3- İşinizi canınızın istediği ölçüde yapmada zorluğunuz oldu mu?	1	2	3	4	5
4-İşinizi her zaman ki sürede bitirmede	1	2	3	4	5

APPENDIX 5. VISUEL ANALOG SCALE (VAS)

VİZUEL ANALOG SKALA (VAS)

Adınız Soyadınız: ________________________________ Tarih: ________________

Ağrı şiddetinizi aşağıdaki ölçek üzerinde işaretleyin.

APPENDIX 6. Measurements of Hand Grip Strength, Pinch Grip Strength, Vibration Sense and Joint Position Sense (JPS)

Pençe El Kavrama Kuvveti Ölçümleri (Jamar Dinamometresi)

Egzersiz Öncesi	1.Deneme	2.Deneme	3.Deneme	ORTALAMA
Sağ El				
Sol El				

Egzersiz Sonrası	1.Deneme	2.Deneme	3.Deneme	ORTALAMA
Sağ El				
Sol El				

Parmak Ucu Kavrama Kuvveti (Pinchmeter)

Egzersiz Oncesi	Parmak Ucu Kavrama (2 Nokta)			Anahtar (Lateral) Kavrama			Palmar Kavrama (C3-Nokta Ped)			Ortalama		
	1.	2.	3.	1.	2.	3.	1.	2.	3.	1.	2.	3.
Sağ EL												
Sol EL												

Egzersiz Sonrası	Parmak Ucu Kavrama (2Nokta),			Anahtar (Lateral) Kavrama			Palmar Kavrama (C3-Nokta Ped)			Ortalama		
	1.	2.	3.	1.	2.	3.	1.	2.	3.	1.	2.	3.
Sağ EL												
Sol EL												

VİBRASYON ÖLÇÜMLERİ:(Diapazon)

Egzersiz Oncesi	1.Deneme		2.Deneme		3.Deneme		ORTALAMA	
	Radial	Ulnar	Radial	Ulnar	Radial	Ulnar	Radial	Ulnar
Sağ El								
Sol El								

Egzersiz Sonrası	1.Deneme		2.Deneme		3.Deneme		ORTALAMA	
	Radial	Ulnar	Radial	Ulnar	Radial	Ulnar	Radial	Ulnar
Sağ El								
Sol El								

EKLEM POSİZYON HİSSİ ÖLÇÜMLERİ:

Egzersiz Öncesi	10° RADYAL			15° ULNAR			30°EKSTANSIYON			30° FLEKSIYON			ORTALAMA		
	1.	2.	3.	1.	2.	3.	1.	2.	3.	1.	2.	3.	1.	2.	3.
Sağ EL															
Sol EL															

Egzersiz Sonrası	10° RADYAL			15° ULNAR			30°EKSTANSIYON			30° FLEKSIYON			ORTALAMA		
	1.	2.	3.	1.	2.	3.	1.	2.	3.	1.	2.	3.	1.	2.	3.
Sağ EL															
Sol EL															

ÖZGEÇMİŞ

1. Adı Soyadı : Sevgi Gamze FELEK

<u>İletişim Bilgileri</u>

Adres : İnönü Mahallesi Medine mescidi sokak no:8/6 Kayışdağı/Ataşehir/ İSTANBUL

Telefon : 05425980418

Mail sevgigamzefelek@gmail.com

2. Doğum Tarihi **:18.01.1990**

3. Unvanı **:Fizyoterapist**

4. Öğrenim Durumu **:Yüksek Lisans**

Derece	Alan	Öğrenim Yeri	Yıl	Not Ortalaması
Lise	Sayısal Alan	Şanlıurfa Yabancı Dil Ağırlıklı Lise	2008	91,76/ 100
Lisans	Fizyoterapi ve Rehabilitasyon (İngilizce)	Yeditepe Üniversitesi	2015-Ocak	3.38/ 4.00
Yüksek Lisans	Fizyoterapi ve Rehabilitasyon	Yeditepe Üniversitesi	Devam Etmekte	

5.Lisans Tezi

The Immediate Effect of Kinesio™ Taping on Shoulder External Rotation of People with Shoulder

6.Projeler

6.1. Job Coaching Training:Place, Train, Maintain for People with Intellectual Disabilities, Erasmus Plus Yetişkin Eğitimi Projesi.

7.Sertifika ve Katılınan Kurslar
7.1. Duyu Bütünleme ve Ergoterapi Sertifika KURSU, Uzm. Ergoterapis Elennur ERKMEN,22-29 Mart 2015
7.2. Yürüme ve Biyomekaniği Eğitim Kursu, 14 Mart 2015
7.3. APPİ Pilates Seviye 1 (Matwork), Melanie Bryant& Uzm.Fzt. Özlem Üstünkaya, 22-23 Ekim 2016
7.4. Lumbosakral ve Kalça Eklemi Problemlerinde İç Organ Tanı ve Tedavi Kursu, Michel Puylaert,MSc, Osteopath DO, 10-12 Mart 2017

8. Diğer Faaliyetler

8.1. 6.Engelsiz Üniversite Birimleri Çalıştayı, 22-23 Mart 2012 (Çalıştay Sekreteryası)

8.2. Kaynaştırma Eğitimi Seminer ve Çalıştayı, 12-17 Ekim 2015 (Düzenleme Kurulu)

8.3. Job Coaching Training:Place, Train, Maintain for People with Intellectual Disabilities, Erasmus Plus Yetişkin Eğitim Projesi kapsamında düzenlenen workshop 31 Mayıs- 5 Haziran 2015

8.4. Job Coaching Training:Place, Train, Maintain for People with Intellectual Disabilities, Erasmus Plus Yetişkin Eğitim Projesi kapsamında düzenlenen Symposium 14-16 Temmuz 2016

Akademik Eğitim Faaliyetleri

Kod	**Dersin Adı**	**Asistanı (Arş. Gör.)**	**Dönemi**
PTR 314 (Lisans)	Nörolojik Reh il tasyon	Fzt.Sevgi Gamze FELEK Fzt.Güzin KAYA	2015 Bahar
FHS 121 (Lisans)	Anatomi I	Fzt.Sevgi Gamze FELEK	2015 Bahar
PTR 122 (Lisans)	Anatomi II	Fzt.Sevgi Gamze FELEK	2015 Güz
PTR 205 (Lisans)	Elektroterapi I	Fzt.Sevgi Gamze FELEK	2015 Güz
PTR 208 (Lisans)	Elektroterapi II	Fzt.Sevgi Gamze FELEK	2015 Bahar
PTR 205 (Lisans)	Elektroterapi I	Fzt.Sevgi Gamze FELEK	2016 Güz
PTR 208 (Lisans)	Elektroterapi II	Fzt.Sevgi Gamze FELEK	2016 Bahar
PTR 216 (Lisans)	Tedavi Hareketleri Prensipleri	Fzt.Sevgi Gamze FELEK	2016 Bahar

PTR 203 (Lisans)	Manipülatif Terapi	Fzt.Sevgi Gamze FELEK	2016 Bahar
FHS 121 (Lisans)	Anatomi I	Fzt.Sevgi Gamze FELEK	2016 Güz
PTR 205 (Lisans)	Elektroterapi I	Uzm.FztElif ÜSTÜN Fzt.Sevgi Gamze FELEK	2016 Güz

2014-2017 Yeditepe Üniversitesi Engeli olan Öğrenci Danışma ve Koordinasyon (EÖDK) Birim Asistanlığı

Yayınlar:

A.Uluslararası Diğer Hakemli Dergilerde Yayınlanan Makaleler (Index Copernicus International)

B-Uluslararası Hakemli Dergilerde Yayınlanan Makaleler

C. Projeler:

C.1.Uluslararası düzeyde

Job Coaching Training: Place, Train, Maintain. Erasmus Plus, Adult Education Projesinde (014-1-TR01-KA204-013427 / 2014-2016).

Ortaklar:

Yunanistan, Selanik'ten Alexander Technological Educational Institute of Thessaloniki,

Polonya, Varşova'dan Akademia Wychowania Fizycznego Jozefa Pilsudskiego

Down Sendromlular Derneği

Yönetici: H. Serap Inal.

Araştırmacılar ve Eğitmenler: Feryal Subasi, Sule Demirbas, Elif Ustun, Panaogiatis Tsaklis, Bartozs Molik.

Eğitmenler: Rasmi Muammer, Didem Takinacı

Genç Araştırmacılar: Aybüke Ersin, Nilo V. Sayedee, **Sevgi Gamze Felek**, Güzin Kaya

D. Ödüller:

D1. 2014-1-TR01-KA204-013427 Numaralı *"Job Coaching People with Intellectual Disabilities: Place, Train, Maintain"* başlıklı K2 ERASMUS PLUS Projesi, 5.Ulusal Fizyoterapi ve Rehabilitasyon Kongresi, Abant İzzet Baysal Üniversitesi, En iyi poster sunum ödülü.

D2. Oksijen Destek Tedavisi Alan ve Almayan Kronik Obstrüktif Akciğer Hastalığı Olan Hastaların Solunum Parametrelerinin Karşılaştırılması, Solunum 2016 Kongresi, 17-21 Ekim 2016, Çeşme, İzmir. Kongre Katılım Bursu.

E.Ulusal Bilimsel Toplantılarda Sunulan ve Bildiri Kitabında Basılan Bildiriler

E1. Felek S.G., Karlık M, Gök Ş, İnal HS (2014) The Immediate Effect of Kinesio™ Taping on Shoulder External Rotation of People with Shoulder Pain. Orthopeadic Journal of Sports Medicine. 24(2). Doi:10.1177/2325967114S00170

E2. 2014-1-TR01-KA204-013427 Numaralı *"Job Coaching People with Intellectual Disabilities: Place, Train, Maintain"* başlıklı K2 ERASMUS PLUS Projesi, Poster Bildiri. 5.Ulusal Fizyoterapi ve Rehabilitasyon Kongresi, Abant İzzet Baysal Üniversitesi, Bolu.

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E4. İnal,S., Subaşı,F., Subaşı Yurtçu, A.B., **Felek,S.G**., Atadeniz,Ş.N., Burçoğlu Kuran, N. Yeditepe Üniversitesi Engeli Olan Öğrenciler Danışma Ve Koordinasyon Birimi (EÖDK) Çalışmaları, 21-22 Mayıs 2015, İstanbul

E5.Çağla Hacıömeroğlu, Rasmi Muammer, Hakan Günen , Sibel Boğa ,Osman Hacıömeroğlu, **Sevgi Gamze Felek**, Kıymet Muammer, Elif Üstün,EP-386 Oksijen Destek Tedavisi Alan ve Almayan Kronik Obstrüktif Akciğer Hastalığı Olan Hastaların Solunum Parametrelerinin Karşılaştırılması, TÜSAD 38.Ulusal Solunum 2016 Kongresi, 17-21 Ekim 2016, Çeşme, İzmir.

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E10. Hoşbay, Z.,Tanrıverdi,M.,Celbek B., Kaya, G., **Felek, S.G,** THE EVALUATION OF DEMOGRAPHICS, STRENGTH AND SYMPTOMS OF LATERAL EPICONDYLITIS IN ROWER,"XXI Federation of European Societies for Surgery of the Hand (FESSH2016 June 22-25, 2016, Santander, Spain.

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E13. Üstün E, Subaşı F, Demirbaş Ş, **Felek SG**, Kaya G, İnal S.: Zihinsel Engeli Olan Bireyler İçin İş Koçluğu Eğitimi: Yerleştir, Eğit, Sürdür Vaka Çalışması II, 1. Engellilik Araştırmaları Kongresi, 24-25 Kasım 2016, İstanbul Üniversitesi, İstanbul.

E14. Kaya G, Subaşı F, Demirbaş Ş, Üstün E**, Felek SG**, İnal S.: Zihinsel Engeli Olan Bireyler İçin İş Koçluğu Eğitimi: Yerleştir, Eğit, Sürdür Vaka Çalışması III, 1. Engellilik Araştırmaları Kongresi, 24-25 Kasım 2016, İstanbul Üniversitesi, İstanbul.

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