



**UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
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Faculty of Health Sciences
School of Health Care Sciences
Department of Occupational Therapy

**Establishing functional outcomes of tendon transfers and occupational
therapy intervention following radial nerve injury.**

(Protocol number: 721/2018)

**Dissertation for the degree
Masters in Occupational Therapy (Research)**

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ABSTRACT

Upper limb injury, involving radial nerve injury, is a devastating injury, which has significant implications on daily functioning of individuals. Tendon transfers following failed radial nerve regeneration further pose a major challenge for the occupational therapists during rehabilitation. There are various studies globally regarding peripheral nerve injuries and tendon transfers; however, the researcher noted a paucity of literature that described the occupational therapy intervention and measured functional outcomes after completing rehabilitation.

The aim of this study was to establish the functional outcomes of patients who underwent tendon transfers for a radial nerve injury and completed the prescribed eight-week Gauteng Provincial occupational therapy hands treatment programme. This study adopted a quantitative, retrospective, descriptive, cross-sectional design. The study took place in the northern Gauteng region of South Africa at Steve Biko Academic Hospital. There were 23 participants identified based on the orthopaedic upper limb outpatient clinic roster; however, only 15 participants were able to attend the physical evaluation of the hand, eight were unable to attend due to the national COVID 19 pandemic.

Data was collected by all participants completed the demographics questionnaire and the DASH questionnaire. Only 15 participants were physically measured in their range of motion of the wrist extension, metacarpophalangeal joints of finger extension and thumb in extension/abduction was measured with a manual goniometer, and muscle strength of the wrist, fingers and thumb was measured using the Oxford Standard Scale. Hospital records were reviewed for passive range of motion of the wrist and evaluating compliance to treatment.

The results showed that 69.56% of participants were considered independent when performing their activities of daily living and asymptomatic, while 21.73% were also independent, however had limitations with tasks requiring 22-45kg occasionally or 11-22.72 frequently. Participants' range of motion fell within functional ranges of the wrist fell within good to excellent category, fingers and thumb between good to excellent category. Muscle strength was between 3 and 4+ by 86.95% of participants, indicating functional strength to engage in activities of daily living.

There were factors that hindered participant's ability to return to work. Reportedly, the majority of employers did not follow the guidelines as promulgated in the Labour Relations act. This compromised many of employees, some even losing their jobs due their injuries.

Conclusion: Although there was no achieving of this confidence level in any of the measured outcomes, there were satisfactory to good results achieved from the Dash questionnaire, range of motion of the wrist extension, fingers MPJ extension and thumb MCP extension. The results were good with muscle strength of the wrist extension, fingers MPJ extension and thumb extension.

Key words: functional outcome; tendon transfers; radial nerve; activities of daily living

ACKNOWLEDGEMENTS

I would first like to thank my God Almighty for providing, guiding and leading me through this research journey. Through your will God, I managed to complete this research...thank you.

I would like to thank my research supervisors Mrs. Elsje Rudman and Ms. Eileen Du Plooy for your dedication and support throughout this tumultuous journey. A special thanks to you Mrs. Rudman for your assistance and emotional support in the most difficult times through this research. Your guidance and immense support is highly appreciated.

I would like to thank the Steve Biko Academic Hospital for allowing me to conduct this research. A special thanks goes out to Dr. Hlabane Sithebe, orthopaedic surgeon, and the registrars from the Orthopaedics Upper Limb Clinic. The occupational therapy department staff of Steve Biko Academic Hospital, thank you for your assistance. I would also like to thank Mr. B. Nyathi for drawing anatomical images for me for this research.

I would like to extend special thanks and gratitude to my wife, Nolwazi Ncwane, who is my anchor, pillar of strength, and reality checker. My beautiful daughters, Thingolenkosazane and Nqubekowezibusiso Ncwane, for keeping me smiling always and distracting me from the stressors of research on most days. I could not have done this without the Ncwane family, it has been tough years and we survived them.

This research is dedicated to all my fallen family members who lost their lives during the COVID 19 pandemic: Mkhul' Mjiyo Ncwane, Mkhul' Kufakwakhe Ncwane, Mkhul' Khilile Ncwane, Sbongiseni Ncwane, Lungi Ncwane, Zinhle Ncwane and Samkelisiwe Manzi. You will forever be in our hearts and this thesis is dedicated to you all.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
BR	Brachioradialis
ECRL	Extensor carpi radialis longus
EDC	Extensor digitorum communis
FDP	Flexor digitorum profundus
FDS	Flexor digitorum superficialis
IPJ	Interphalangeal joint
MPJ	Metacarpophalangeal joint
PIPJ	Proximal interphalangeal joint
PL	Palmaris longus
PT	Pronator teres
ADL	Activities of daily living
DASH	Disability of Arm, Shoulder and Hand Assessment Tool
CB	Coracobrachialis
FCR	Flexor Carpi Radialis
FCU	Flexor Carpi Ulnaris
FPL	Flexor Pollicis Longus
PQ	Pronator Quadrates
ECRB	Extensor Carpi Radialis Brevis
ECU	Extensor Carpi Ulnaris
ED	Extensor Digitorum
EDM	Extensor Digiti Minimi
APL	Abductor Pollicis Longus
EI	Extensor Indicis
EPL	Extensor Pollicis Longus
EPB	Extensor Pollicis Brevis

LIST OF OPERATIONAL DEFINITIONS

- Activities of daily living – everyday purposeful and meaningful activities that people participate in individually or family structure on a daily basis including basic self care.¹
- Instrumental activities of daily living – activities individuals do every day to take care of themselves, family and their home.¹
- Activity participation – It is the carrying out of a task or accomplishment by an individual to enhance engagement or participation in meaningful task.¹
- Activity limitations - complications a person may have in executing activities.²
- Body functions - biological operations of body's structure, including psychosocial functions.³
- Body structures - are anatomical structures of the body such as organs, limbs and their mechanism⁴
- Compliance – conforming or complying to a specific recommended hand therapy programme until discharged by occupational therapy.⁵
- Engagement – refers to the skill to “actively”, partake in meaningful ADL independently⁶
- Impairments - are restrictions in body functions or structures, such as a major deviation or resultant from an injury⁷
- Injury - penetrating trauma to the upper limb, such as knife, panga, gunshot or closed fractures, that can injure the radial nerve.⁸
- Leisure – a performance area where individuals use their discretionary time to engage in meaningful activities to achieve their targeted subjective experience and outcome.⁹
- Motor function is the ability to move body structure using neurons in the peripheral and central structures of the central nervous system.¹⁰
- Occupational Therapy – a process of applying conservative means of rehabilitation or techniques to enable an injured person to function independently in their areas of occupation.¹¹
- Paralysis – inability of the muscles supplied by the radial nerve in the upper limb to perform their inherent function due to injury of the radial nerve.¹²
- Participation - is an active involvement in daily life tasks.¹³

- Participation restrictions - are limitations a person may experience in active involvement in daily life.¹⁴
- Performance areas are routines, tasks, sub-tasks categorised by individuals to engage in meaningful occupations that are culturally appropriate and meaningful, and fulfil their occupational performance roles.¹⁵
- Performance component – an action or ability of an individual in performing occupational tasks.¹⁶
- Rehabilitation (as used in this study) – is a process whereby the occupational therapist engages in re-training the affected body function to perform daily occupations.¹⁷
- Tendon transfer – a surgical procedure of using functioning muscles to replace the function of non- functioning (affected) muscles to restore function.¹⁸
- Work – is an action involving physical and mental endeavour to achieve a result, giving a sense of identity, purpose and meaning. It is meaningful, fulfilling and provides satisfaction in a form of self-actualisation or financial means.¹⁹
- Orthopaedic hand surgeon - A hand specialist is an orthopedic doctor specializing in diagnosing, treating, and preventing disorders in the hand, wrist, and forearm.²⁰

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Daily function is a term used in occupational therapy to describe the individual's capability to engage in their Activities of daily living (ADL), iADL, work and leisure¹ independently. This entails the ability to participate in ADL's such as bathing, dressing, feeding,¹ as well as leisure and work. This description is also in the findings of Kovacs et al.,²¹ which concluded that quality of life is derived from a realisation of the psychological, physical and functional ability to optimally engage in ADL.²¹

Upper limb function plays an integral role in an individual's capability to perform ADL. Upper limb nerve injuries result in an impaired hand that has functional loss leading to the inability to execute ADL's and instrumental ADL (IADLs). This often results in a financial burden in both the employed and unemployed population.^{22,23} A study conducted in the USA indicated that 30% of an estimated 3.3 million injured⁴ workers impacted with upper limb injuries in the emergency care population to be peripheral nerve injuries, leading to a serious impact on the economy.²⁴ The Industrial Safety and Hygiene News published an article ceding that hand injuries were the number two leading cause of work-related injuries and mostly preventable.²⁵ The United States National Safety Council⁵¹ and the United States Bureau of Labor Statistics²⁵ concluded that the standard hand injury insurance claim has now exceeded \$6000, with each lost time worker's compensation claim reaching nearly \$7 500.²⁵ This leads to prolonged time taken from work to attend intervention and rehabilitation at the hospital. In South Africa it is estimated that that traumatic hand injuries account for approximately one-third of all traumatic injuries treated in government hospitals which accounts for significant time off work, loss of income, change in or loss of occupation and residual functional impairment.²⁶

Hand trauma is not only limited to the biomechanical impact on function, it also has psychological implications, which have an impact on the outcome of surgery and capacity to resume ADL, work and leisure.^{27,28} Jaquet et al.²² noted that 64% of the 67 participants presented with moderate to severe psychological symptoms during the first month following upper limb injury. This may lead to loss of efficacy, control and learned helplessness by the patients.²²

Upper limb injury, involving radial nerve injury, is a devastating injury, which has significant implications on daily functioning of individuals. Tendon transfers following failed radial nerve regeneration further pose a major challenge for the occupational therapists during rehabilitation. There are various studies globally regarding peripheral nerve injuries and tendon transfers; however, the researcher noted a paucity of literature that described the occupational therapy rehabilitation process and measurement of patient outcomes upon completion of tendon transfer surgery. Furthermore, there was limited information found that described whether after completing the recommended rehabilitation participants were able to engage optimally in their ADL, iADL, work and leisure.

Management of peripheral nerve injuries is determined by the orthopaedic surgeon based on the classification of nerve injuries, which dictates whether it should consist of conservative or surgical management.²⁸ Occupational therapists conduct an assessment after receiving referral for patients with upper limb injuries and provide treatment after the patient was stabilised and underwent medical or surgical management as determined by the orthopaedic surgeons.

In Gauteng, South Africa, hospitals that have orthopaedic surgeons specialising in upper limb and hand trauma work together with a multi-disciplinary team to treat these upper limb trauma injuries. A standard 'Gauteng Provincial occupational therapy programme' (Appendix A) follows in acute rehabilitation, as well as after tendon transfer surgery for peripheral radial nerve injury to improve hand function. The question arose if the time and effort spent on the surgery and rehabilitation of these injuries makes a

difference in the functional use of the hand and ability to work. There was a paucity of literature within the South African context exploring the effect of “tendon transfers for a radial nerve injury”, which focused on the significance of occupational therapy rehabilitation and specified functional outcomes.

In South Africa, Gauteng hospitals follow a protocol developed in 2008 by a selected experienced senior occupational therapists in the government hospitals, including lecturers from universities in Gauteng, to guide newly qualified occupational therapists in managing these conditions. Anecdotal evidence suggests that at Steve Biko Academic Hospital the patients with these types of injury took longer to recuperate despite following the protocol. There were multiple factors, such as compliance, socio-economic status, employment and actual support system from the families, which played an integral role in the rehabilitation of these individuals. Therefore, the conducting of this study was to establish the functional outcomes of the individuals who have undergone tendon transfers surgery and rehabilitation.

A retrospective descriptive cross-sectional study took place in the Northern Gauteng region of South Africa, to establish the functionality of the hand with radial nerve injury after tendon transfer surgery and occupational therapy rehabilitation. The study informs whether patients can return to their pre-morbid levels of occupations and independently engage in their ADL, work and leisure.

1.2 PROBLEM STATEMENT

In the Northern Gauteng region of South Africa, patients with traumatic radial nerve injuries are referred to the upper limb specialist clinic at Steve Biko Academic hospital for tendon transfers and further management. This hospital provides the services of orthopaedic surgeons and registrars, specialising in upper limb trauma, as well as occupational therapists and physiotherapists. Whenever social or psychological support is necessary, the social worker and psychologist may also become involved.

The upper limb clinic register indicated that the radial nerve tendon transfers were the highest (49 patients) of all peripheral nerve injuries with tendon transfers done within 12 month period. Tendon transfers formed an integral part of the services provided by Steve Biko Academic Hospital to the population of an extended region since it was only done at the academic hospitals. However, the researcher noted that it has not yet been established whether the patients that have undergone “tendon transfer surgery and occupational therapy intervention” are able to go back to their pre-morbid functioning within all areas of performance, namely ADL, iADL, work and leisure after surgery and therapy based on the recommended ‘Gauteng Provincial occupational therapy programme” (Appendix A).

This programme, formulated by the Task Team of senior occupational therapists from the public sector and universities appointed by the Gauteng Department of Health Deputy Director, has been implemented throughout Gauteng Province since 2008. However, there has been no research done to establish its outcomes, and due to this lack of research, the decision was to conduct this study.

1.3 RESEARCH QUESTION

What are the functional outcomes of patients who underwent “tendon transfers for a radial nerve injury”, and completed the prescribed eight-week Gauteng Provincial Hands Protocol?

1.4 STUDY AIM

To establish the functional outcomes of patients who underwent “tendon transfers for a radial nerve injury” and completed the prescribed eight-week Gauteng Provincial Hands Protocol.

1.5 OBJECTIVES OF THE STUDY

- a) To determine the affected hand's function in ADL, work and leisure “post-radial nerve tendon transfer surgery and occupational therapy intervention”, using the Dash Questionnaire.
- b) To determine the active range of movement of the affected hand's wrist extension, metacarpophalangeal joint (MPJ) extension and thumb (MPJ) extension “post-radial nerve tendon transfer surgery and occupational therapy intervention”, using a goniometer.
- c) To determine muscle strength of wrist extension, metacarpophalangeal (MPJ) joint extension and thumb extension “post-radial nerve tendon transfer surgery and occupational therapy intervention”, using Oxford Standard Scale measurement.

1.6 SIGNIFICANCE OF THE STUDY

This research provided insight into the functional outcomes of radial nerve tendon transfer surgery, within the northern Gauteng region, following the recommended ‘Gauteng Provincial occupational therapy programme’ (Appendix A). It provided information as to whether patients can function independently in their ADL and participate in work and leisure pursuits after surgery and rehabilitation.

1.7 SCOPE AND DELINEATION OF THE STUDY

1.7.1 Scope

The study was restricted to patients with “radial nerve injuries who underwent tendon transfer surgery and rehabilitation” in the northern Gauteng region.

1.7.2 Delineation of the study

The study focused on evaluating active range of movement of wrist extension, muscle strength of wrist extension and engaging in ADL following tendon transfers surgery and

occupational therapy rehabilitation. There was no consideration of dominance, even though it may have an impact on the effectiveness of the performance of activities.

1.8 ASSUMPTIONS AND LIMITATIONS

1.8.1 Assumptions

The assumption is that patients with failed radial nerve regeneration would have referral for tendon transfer surgery. Also assumed, is that patients with radial nerve injuries are referred for occupational therapy rehabilitation pre- and post-surgery, and that they were independent in their activities of daily, work and leisure participation pre-morbidly.

1.9 LAYOUT OF THE DOCUMENT

Chapter 1: Introduction to the research study

Chapter 2: Address the literature review of upper limb anatomical structures including its bones, muscles, nerves arteries and veins. It includes biomechanics of the upper limb and its joints, trauma, healing, rehabilitation and splinting.

Chapter 3: Focus on the research methodology followed in the research process for data collection. The emphasis is on addressing the actual “how” this research was conducted.

Chapter 4: Present the results from the data collected and its analysis.

Chapter 5: Discuss the results of the study, its limitations and recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

To appreciate the impact that “radial nerve injuries” have on the function of the hand, it is imperative to have insight into the anatomy and structure of the upper limb. This chapter will focus on:

- Upper limb and hand function
- Anatomy of the upper limb and brachial plexus
- Causes and prevalence of upper limb injuries
- Functional impact of upper limb injuries
- Occupational Therapy management
- Secondary management of Radial Nerve injuries with the use of tendon transfers.
- Conclusion presented as subsections of the literature review.

There were different databases sourced in literature, including PubMed, Elsevier, Ebsco Host, Google Scholar, Research Gate and Medline Plus. Keywords used for searching these databases were radial nerve injury, hand trauma in adults, anatomy of hand, protocols of hand therapy, occupational therapy, surgery of radial nerve, hand function assessment, adults hand function assessment, activity participation with radial nerve rehabilitation, hand extensor tendon transfer criteria, tendon-healing theories and hand splinting.

2.2 UPPER LIMB AND HAND FUNCTION

Humans interact with the world using their hands. They are both critical in performing daily tasks and interacting socially with the use of gestures. Volpe S²⁹ noted that it is a complex structure that enables performance of multi-faceted movements not only in

grasping, but also in a cognitive role through touching, lifting, rotating and relocating objects held in the hand.²⁹ Study.com website³⁰ referred to function as the skill to “actively” partake in meaningful ADL independently, using your hands to grasp and release objects voluntarily.³⁰ This entails the ability to participate in activities such as bathing, dressing, feeding, leisure and work. Kovacs et al. concluded that quality of life is derived from a realisation of the psychological, physical and functional ability to optimally engage in daily occupations.

Upper limb injuries may diminish a person’s capability to perform their ADL, iADL, work and leisure participation considerably for a variable period, depending on the severity and type of the damage.²⁹ Upper limb injuries are therefore both functionally and psychologically devastating to individuals and have an impact on their ability to return to their occupational duties.^{29,31} Upper limb nerve injuries result in an impaired hand that has functional loss leading to financial burden in both the employed and unemployed population.³²

It is important to assess the extent of the functional sequelae of the nerve injury. Functional outcomes determine the individual’s ability to recuperate from upper limb trauma to engage in pre-morbid ADL, which improves quality of life within physical, psychological and functional ability of the individual. These outcomes may be determined with the use of various assessment methods, which would be unravelled in the sections that follow.

2.3 ANATOMY OF THE NERVES AND RADIAL NERVE STRUCTURE

2.3.1 Nerves of the Upper Limb

The nervous system^{33,34} in the body provides the impulses that the muscles need to function; without these impulses, no function can take place. Most nerves innervating structures in the upper limb are from the brachial plexus^{33,34}. This is a major nerve distribution comprising of the anterior rami of, C5-C8^{42,43} and the first thoracic, T1

nerves^{33,34}. These constitute the roots of the brachial plexus. The roots pass between the anterior and middle Scalene^{42,43} muscles along with Subclavian artery^{33,34}. The posterior rami innervate the para-spinal muscles, provide sensation to the posterior aspect of the neck and are important in localising brachial plexus lesions,^{33,34} brachial plexus and its branches³⁵ (see Figure 2.1)



Figure 2.1 –Brachial plexus and its branches around the neck³⁵

The roots also carry sympathetic fibres from grey rami of the middle and inferior cervical plexus, derived from T2-T8, as they pass between the Scalene muscles. The roots have no dural sheath and can be avulsed from the spinal cord easily.

They are, however, indirectly protected by the connection with the dura, which later becomes epineurium and fibrous connections of the deep cervical fascia with the intervertebral foramen, which are prominent in C5, C6 and C7 but become minimal in the C8, T1 region. This indicates the caudal structure of the plexus (C8, T1) are more likely to avulse, while the cranial structures (C5-& C7) are more likely to stretch or rupture.^{33,34}

At the lower part of the neck, the roots unite to form three trunks, superior, union of C5 and C6 roots, middle, continuation of C7 root, lastly, inferior, union of C8 and T1 roots^{33,34}. The trunks additionally bifurcate into anterior and posterior^{33,34} divisions as

they pass posterior to the clavicle (retro-clavicular portion) in the cervico-axillary canal. The anterior divisions supply the flexor compartments and the posterior divisions supply the extensor compartments^{33,34} of the upper limb. The divisions become cords in the infra-clavicular part of the brachial plexus invested in the axillary sheath, and are named according to their connection to the axillary artery, lateral cord, anterior division of the superior and middle trunks^{33,34}. Middle cord, anterior division of the inferior trunk and posterior cord^{42,43}, are the posterior divisions of all three trunks, as seen in Figure 2.1.^{33,34,35}

The terminal branches arising from the cords, musculocutaneous nerve, C5 to C6,^{33,34} arises from the lateral cord and innervates the following muscles Coracobrachialis, Brachialis and biceps brachii muscles^{33,34}. Median nerve roots C6, C7, C8, and T1^{33,34} arise from lateral and medial cords and innervate all except one and half of the anterior forearm muscles, thenar eminence of the thumb and two lumbricals muscles, the radial two lumbricals are supplied by the median nerve, while the ulnar nerve supplies the two on the ulnar side^{33,34}. Radial nerve roots, C5, C6, C7 and C8^{33,34} arise from the posterior cord and supply the Triceps brachii both long lateral and medial heads, supinator, anconeus, the extensor muscles of the forearm and brachioradialis muscles. The axillary nerve arises from the posterior cord and innervates deltoid and teres minor muscles.^{33,34}

2.4 PREVELANCE OF UPPER LIMB INJURIES

Angermann and Lohmann³⁶ revealed that of 50 200 injured persons in Denmark, 28.6% were attended in emergency unit with hand trauma,³⁶ Tendon lesions with nerve injuries are in second position (29%) after fractures. Even though only 2% of the patients are hospitalised, upper limb trauma, especially tendon and nerve injuries, play a key role in orthopaedic and trauma treatment.³⁶ On average in Europe, upper limb injuries account for 14% to 30%³⁷ of all treated patients in emergency unit. At the Royal Infirmary of Edinburgh, United Kingdom, a pilot study over a period of five years

indicated that 33.9% of 530 000 patients were tendon injuries with nerve injuries, 72.1% were male with an average age of 32.9 compared with 42.0³⁸ in females.

The World Health Organization has marked South Africa a developing country with a unique history characterised by receded political conflict, yet challenged by high levels of interpersonal violence³⁹, fuelled by high levels of urbanisation and ongoing socioeconomic disparities. A survey conducted with hospital medical superintendents⁵² in South Africa publicized that an approximate 1.5 million trauma cases accessible to the country's secondary and tertiary level hospitals in 1999, with violence accounting for more than half of the trauma caseload.³⁹ A retrospective study done in Groote Schuur Hospital, in Cape Town, revealed higher violence prevail toward males (71.3%) younger than 40 years of age (74.6%)⁴⁰. Furthermore, the study revealed high rates of violent interpersonal injury at 71.6% of intentional injury, with the use of sharp objects and gun related incidents and motor vehicle injury accounting for 18.8% of all injuries.⁴⁰

A study by Stewart et al at Chris Hani baragwanath Academic Hospital in Johannesburg revealed that approximately 88.5% of acute traumatic occupational injuries seen in government hospitals were male and 85% were main breadwinners in their homes. The hand injuries were predominally from machine operators, general manual labourers and construction workers. Common injuries sustained were lacerations, cruch injuries and fractures. The Hand Injury Severity Score was used to rate severity of injuries sustained and it revealed that 34% participants presented with moderate, 20% severe and 17% major severity of hand injuries.

2.5 CAUSES OF UPPER LIMB INJURIES

The major cause of upper limb injuries are due to trauma varying from blunt trauma, stab wounds, gunshots, motor vehicle accidents and defence wounds. These injuries can sever tendons, fracture bones as well as injure the blood vessels and nerves. Sometimes what seems like a simple cut upon inspection could, in fact, be more serious, causing damage that requires expert orthopaedic care after evaluation.⁴¹ Upper

limb injuries are considered to be the frequent body injury sustained, the treatment of which is of extended duration and immense expense to the community.⁴¹

Indirect trauma may result from bony malalignment or injury after osteosynthesis. This usually predisposes ruptures, e.g., the Extensor Pollicus Longus tendon after screw insertion from the palmer side.⁴¹

In South Africa, these upper limb injuries are frequent amongst young people and are commonly associated with other complications, such as vascular injuries. Howard⁶ noted that panga or machete attacks⁴² were a widespread motive of major upper limb trauma in South Africa. "Injuries from blows with the long cutting edge of the blade are most frequently seen, and lacerations are often deep enough to transect tendons, nerves, blood vessels and bone..."⁴². A study by Stewart et al concluded that a high incidents of acute traumatic occupational hand injuries seen within public hospitals occurred from machine operators, general manual labourers and construction workers. Eighty per cent of the patients had never received any occupation-specific training.

2.6 CLASSIFICATION OF NERVE INJURIES

The medical management and sequelae of nerve injuries is classified by the severity of the nerve injury³⁴. Therefore, it is imperative to comprehend the classification of nerve injuries. Paralysis occurs when there is an interruption of the integrity in nerve conduction resulting in neurological deficits. Figure 2.5 shows structural anatomy of the nerve fibres conducting stimulation in the axons in the nerves. The Sneddon classification provides in-depth insight into the anatomical correction and recovery prognosis of nerve injury.³⁴

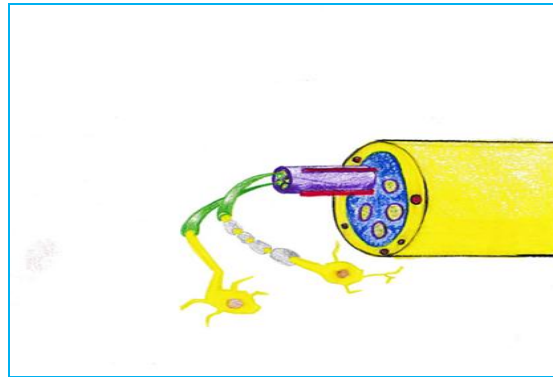


Figure 2.2 – Nerve fibres and their conduction of stimulation through axonal structure⁴³

Levels of nerve injury are graded from one to five, less impact in grade 1 result in preservation of the axon with a better outcome of complete recovery. Conversely, in grade 5, there is no recovery due to neurotmesis, which is the loss of continuity of nerve conduction³⁴ (see Table 2.1) for all grades and their implications to nerve functions.

Table 2.1- Grading of nerve injury, according to the Sunderland's classification.³⁴

Grades	Nerve Impact	Functional Implication on the Nerve
Grade 1	Neuropraxia	Axonal connection preserved and fast and complete recovery
Grade 2	Axonotmesis	Axonal injury but endoneural sheath intact; no fibrosis or structural injury and slow but complete recovery
Grade 3	Axon injury plus endoneural sheath destroyed	Perineurium intact, inconsistent fibrosis and slow and variable recovery
Grade 4	Axonal injury plus fascicular structure of nerve destroyed/perineum destroyed	Axonal injury plus fascicular structure of nerve destroyed/perineum destroyed, complete fibrosis and no recovery
Grade 5	Neurotmesis	Loss of connection of nerve trunk and no recovery

Sunderland's classification³⁴ of nerve injury indicates that paralysis may be temporary in grades 1 and 2, or permanent in grade 4 and 5 nerve injuries³⁴. In grade 1 and 2 injuries, no surgical involvement is needed, and full improvement is expected.³⁴ Muscles that have lost their nerve supply lose their capacity to accept re-ervation or react to low amplitude electrical stimuli after 9-18 months³⁴. Once the muscle has reached a

point where it no longer accepts re-nervation, tendon transfers and assistive devices are required and become an integral part of the individual's life³⁴. Muscles without nerve supply become fibrotic and contracted³⁴, and may have a undesirable impact on the flexibility of the muscle and associated joints. This has a detrimental impact on hand function in the ADL. Hence, these patients receive a referral to an occupational therapist for hand therapy before and after surgery. The main focus of early treatment before tendon transfers include therapy to maintain the supple joints by preventing stiffness on the joints, which is imperative in any tendon transfer surgery.³⁴

2.7 RADIAL NERVE INJURY

The following sections expand on the function of the radial nerve.

2.7.1 Muscles innervated by Radial nerve

Starting from proximal to distal, the muscles possibly affected by a Radial nerve injury and their biomechanical function will now be discussed. As mentioned in the anatomy description in 2.1, the Triceps brachii^{44,45} muscle is at the posterior compartment of the arm adjacent to the humerus and has three heads proximally. Both lateral and medial heads^{44,45} originate from the humerus and the long head from the infra-glenoid tubercle of the scapula^{44,45}, as illustrated in Figure 2.10. All heads combine to form a common tendon that inserts onto the olecranon and the deep ante-brachial fascia^{44,45} on each side of it. Each head receives its own motor branch of nerve supply⁴⁵, understood to originate from the radial nerve⁴⁵. Multiple studies have indicated that the motor branch of the long head of the triceps (LHT)⁴⁵ originates from the axillary nerve or the posterior cord. It concluded that the primary innervation to the LHT⁴⁵ originates from the radial nerve but axillary/posterior cord innervations occur occasionally⁴⁵. Injury to the radial nerve at this level would result in loss of elbow extension of the upper limb⁴⁵, which will have an impact on functional tasks above shoulder level.

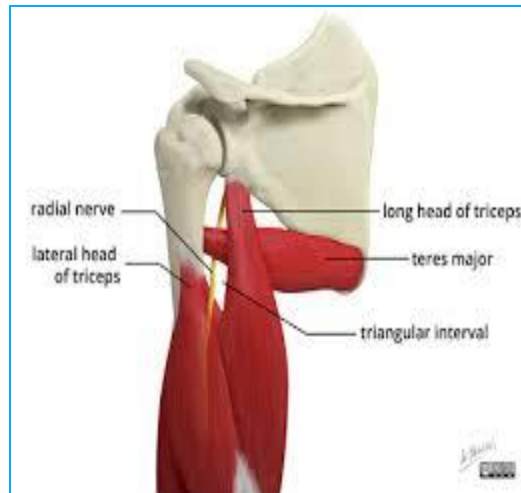


Figure 2.3 – Image of posterior compartment of the arm and radial nerve at the shoulder level⁴⁶

Extensor digitorum communis (EDC) is at the posterior compartment of the forearm⁴⁵, as illustrated in Figure 2.3. It is part of the superficial layer, and muscles arise from a common tendon⁴⁵ attached to the lateral epicondyle of the humerus. EDC is one of the extrinsic muscles of the hand and represents a medial group of superficial extensor muscles⁴⁵, and passes under the extensor retinaculum⁴⁵, which acts as a pulley to direct the force of the muscle then through the fourth extensor compartment of the wrist⁶⁸. Once it passes under the sagittal of the metacarpophalangeal joint⁴⁵, the tendon bifurcates into three 'slips' consisting of two lateral slips and a central slip⁴⁵. The lateral slips⁴⁵ run both sides of the proximal interphalangeal joints⁶⁸ then congregate with the intrinsic muscles of the hand to form a conjoint tendon that inserts at the dorsal aspect of the base of the distal phalanx⁴⁵. The central slip inserts at the dorsal surface of the base of the middle phalanx⁴⁵, and innervated by deep interosseous nerve from the radial nerve⁴⁵. Failed nerve⁶⁸ supply to the EDC would result in an inability to extend the wrist⁶⁸, which would have a significant impact on hand function.⁴⁵

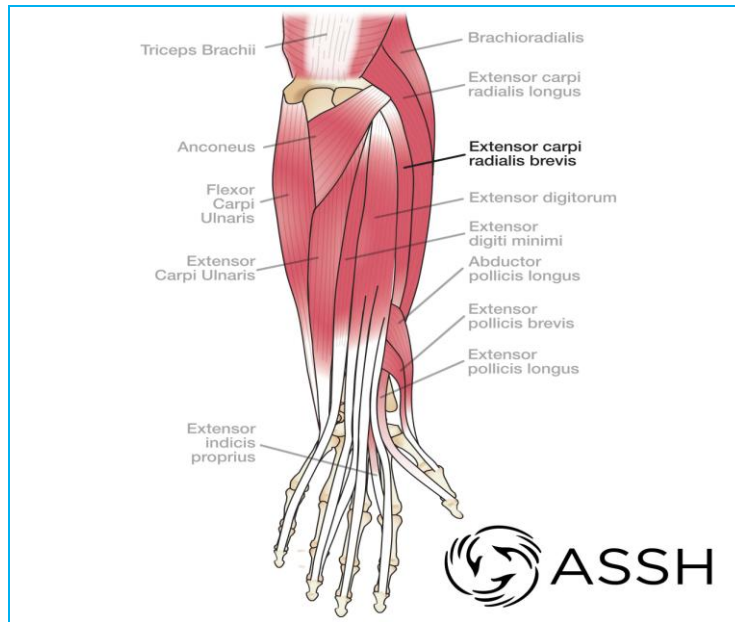


Figure 2.4- Muscles in the posterior forearm innervated by radial nerve on dorsum of hand⁴⁷

Extensor pollicis longus (EPL) is an essential contributor to thumb function, and is an extrinsic thumb muscle^{48,49}, which extends and adducts the thumb metacarpophalangeal (MCP) and interphalangeal (IP) joints^{748,49}. It originates on the dorsal side of the ulna and the interosseous membrane⁷⁰. Passing through the third tendon compartment^{48,49}, it is inserted onto the base of the distal phalanx of the thumb, and innervated by the deep branch of the radial nerve (C7-C8)^{48,49}.

The EPL^{48,49} is the only anatomic structure of the third extensor compartment. As the EPL^{70,71} transverse the wrist, the muscle belly converts into a tendon bounded by a synovial tendon sheath, which forms the medial border of the anatomical snuffbox of the wrist^{70,71}. The tendon divide into two different parts, the proximal and distal tendinous divisions, separated by a fenestra^{70,71}. Three tendons form anatomical snuffbox surface, from medial, to the ulnar to the lateral radial.^{48,49}

Radial nerve injury thus results in motor dysfunction of the hand leading to significant functional loss. Individuals with radial nerve injury have an impaired ability to perform

essential hand movements and functional grasps.^{48,49,50,51} Grip strength is lost because of the inability to stabilise the wrist during power grasps. In functional loss, injuries to the radial nerve that occur above the elbow joint, are classified as a high lesion, while those occurring below the elbow joint are low lesion injuries.^{48,49,50,51}

2.7.2 High lesion Neuropathy

As described in 2.4, there are various possible causes for injury to the radial nerve^{48,49,50,51}. The radial nerve^{74,75} can also be compacted in the axilla in patients using the old type of crutch with a T-type support at the top, or from Saturday night palsy^{48,49,50,51,52,53}, which is falling asleep with the arm hanging over the arm rest of a chair compressing the radial nerve. Hems concluded that it can also be injured at the point where it curls around the humerus, a fracture at this level results in injury or transection of the radial nerve.⁴² High radial nerve^{48,49,50,51,52,53} injury results in lack of ability to extend the wrist and fingers at the metacarpophalangeal joints (MCPJ)^{48,49,50,51}, and incapacity to extend and abduct the thumb^{48,49,50,51,52,53}. The incapacity to extend the fingers and thumb result in the inability of releasing objects and the active ability to place the hand around objects prior to grasps.^{48,49,50,51}



Figure 2.5 – Image of patient's wrist drop no finger extension due to radial nerve palsy⁵⁵

2.7.3 Low Lesion Neuropathy

In low lesion radial nerve palsy^{48,49,50,51,52,53}, patients present with loss of muscle function below the elbow extending to the hand. The extensor carpi radialis longus (ECRL) retains its innervation, however, wrist extension would have significant radial

deviation because of lack of balance from the extensor carpi ulnaris (ECU). Sensation on the dorsum of the thenar web-space^{48,49,50,51,52,53} would become affected and be insensate. Hems⁴² noted that the radial nerve may be injured when intramuscular injections are carelessly given in the lower part of the arm.

2.8 COMPLICATIONS OF RADIAL NERVE INJURY

Damage to the radial nerve around the axilla would lead to loss of sensation of on the lateral aspect of the arm, posterior area of the forearm from dorsum-radial aspect of the hand and wrist.⁵⁵ The patient may develop posterior interosseus nerve syndrome when the radial nerve is damaged below the elbow where it innervates the extensor compartment. This leads to pain in the forearm and wrist. This is followed by weakness of the wrist and fingers, leading to flexion contracture of the wrist and fingers.⁵⁵

Distally to the elbow the patient can develop Waterberg syndrome which is entrapment of the nerve between brachioradialis and surrounding muscles. This could lead to numbness and tingling sensation in the radial half of the dorsum of the radial three and half of the fingers. However, motor function remains intact.⁵⁵

2.8.1 Dislocations

Shoulder girdle injuries are also associated with radial nerve injuries. Proximal radial nerve injuries occurring around the infra-clavicular brachial plexus including axillary level are classified as cord injury.⁵⁶ When it extends distally to the radial nerve they are classified as “cord to nerve” injuries. De Laat et al noted in their study that 22% of the cases from the 101 patients presented with radial nerve injury.⁵⁶ Thereby concluding that shoulder dislocation and humeral neck fractures result in radial nerve injury.⁵⁶

2.8.2 Fractures

Stretch injuries remain the highest cause of posterior cord or proximal radial nerve injuries. Bertelli and Ghizoni reported that 13 patients with proximal radial nerve injuries

resulted from high velocity stretch mechanism. Humeral shaft fractures accounted for 11.8% of the injuries. Wang et al noted that iotrogenic radial nerve palsy in 30 patients from the 707 that were surgically treated with humeral shaft fractures over a 10 year period.⁵⁶

El Madhoun, T et al⁵⁶ noted that several studies indicated that more than 75% of participants with closed humeral shaft fractures with radial nerve injury reported spontaneous recovery after three months. El Madhoun, T et al concluded that majority of the authors recommended four months waiting period and conservative management before explorative surgery.

Pan et al⁵⁶ studies 244 cases of radial nerve grafting to nerve injury at different levels. Radial nerve Forty-four participants had radial nerve injury at the infra-clavicular level. At 21.5 moths, the results indicated that 80% of the participants had recovered wrist extension to Medical Research Council (MRC) grade 3 or 4 regardless of the level of the injury. Thumb and finger extension recovered for patients with injury very distal to the radial nerve at the Posterior Interroseos nerve level. Minority of patients achieve grade 4 or better wrist extension function which is considered clinically useful extension despite graft repair underscores that requires precise follow up and early consideration of tendon transfers to augment wrist extension function.⁵⁶

2.8.3 Penetrating injuries

Gun short wounds or penetrating injuries are uncommon causes of infraclavicular injuries. Radial nerve lacerations due to penetrating or open injuries with no sign of recovery within 3-4 months, surgical exploration is preferred. Surgical exploration includes decompression, neurolysis or nerve grafting. Other authors advocate for distal nerve transfer if radial nerve injury is extensive and very proximal.⁵⁶

2.9 NERVE HEALING AND MANAGEMENT OF RADIAL NERVE INJURY

Optimal management of peripheral nerve injuries^{57,58} dictates whether the type of nerve injury is important in establishing whether surgical exploration technique or conservative management would be adopted. ^{57,58}closed injuries are usually characterised by nerves in continuity and associated with neuropraxia or axonotmesis, where spontaneous recovery is possible. however, in the event where recovery is not apparent within six weeks, the treating medical doctor or orthopaedic surgeon may request electromyogramme (emg) and/or an ultrasound conducted as a baseline evaluation to determine if the nerve is severed; in this, case surgical exploration, must be done. in the event of the nerve not being severed, but with no evidence of recovery after 12 weeks, the patient must repeat the emg. ^{57,58}if electrical signs of re-innervation are present with the presence of motor unit potential (mup's), then spontaneous recovery is anticipated.

^{57,58}

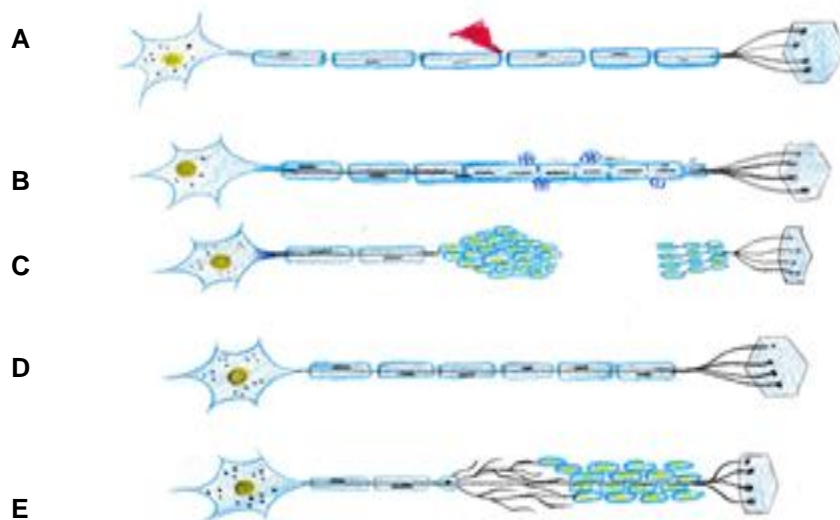


Figure 2.6 – Illustration of nerve injury and regeneration process⁵⁹

A - Normal neuron connected to muscle during injury on the myelin sheath. B – 2 weeks after injury Macrophage formation⁶⁶ around injury site (Wallerian degeneration phase⁶⁶). C - 3 weeks after injury. Proliferation of the Schwann Cells⁶⁶ and Axonal sprout⁶⁶ penetrating bands of Bugner. D - occurs 3 months after injury with successful nerve regeneration. E - occurs several months after injury⁶⁶, and with unsuccessful nerve regeneration. Axonal sprouts become disorganised

Nerve regeneration is the process of the injured nerve repairing itself, called sprouting. Nerves regenerate one inch per month, i.e., 2.54 centimetres per month.^{57,58,60} The nerve produces regenerating nerve units that grow on the nerve to re-innervate the muscle or skin. When the regenerating nerve fibres have sufficient sensory or motor connections, the muscle regains its function and sensation of the skin. The occupational therapists and orthopaedic surgeons must have a comprehensible understanding of the anatomy^{57,58,60} of the nerve and its path in order to test the regeneration process. A Tinel test establishes if the nerve is recovering or not.^{57,58,60} The tester percusses lightly over the course of the nerve from distal part of the hand to proximal aspect, which elicits a sensation of pins and needles or tingling sensation where the new growth is taking place. Some patients report it as an electrical shocking stimulus on the nerve undergoing testing. The nerve regenerates⁸⁰ from proximal moving to distal part of the limb.^{57,58,60}

Where there is no evidence of re-innervation between three to six months post injury^{57,58,60}, the nerve should undergo surgical exploration. With open injuries caused by sharp lacerations, such as knife or razor, primary repair is preferred; if caused by a blast, gunshot or crush injury, then the delay of primary repair is necessary because it may be difficult to establish the zone of injury^{57,58,60}. The inflammatory process of the surrounding structures is thus able to settle.^{57,58,60}

Griffin et al.⁶¹ noted that nerve and tendon injuries are a difficult problem for orthopaedic surgeons due to three reasons. Firstly, tendon and nerve injuries with grade 4 and 5 of Sneddon Classification of the upper limb are a clinical problem because they cannot be restored to health without surgical treatment, as the two ends need bringing together for the healing to occur. Secondly, post-operative management needs careful planning as mobilisation has shown to be indispensable to prevent adhesions and improve soft tissue gliding, but this also increases the risk of rupture. Lastly, despite success following surgery complications, including tendon adhesion and fibrosis formation, tendon rupture and stiffness of the joints⁶¹ are common.

It became clear in the classification of nerve injuries that the extent of the injury determines the management of the healing process. After management by the orthopaedic surgeon, the patient will go for rehabilitation management to the occupational therapist in the early phase of treatment. In order to determine the most applicable treatment plan for each individual there are different processes that the occupational therapist may follow.

2.10. OCCUPATIONAL THERAPY PROCESSES AND ITS PHILOSOPHY

Occupational therapy is “*a process involving assessment and treatment of individuals using purposeful and meaningful activities to rehabilitate individuals regain their independence after injury or trauma.*”⁶² Other definitions indicate that it is engagement of patients in purposeful ADL⁶², such as self-care, education, work, or social interaction, to facilitate or promote participation in these tasks despite impairments or restrictions in physical or mental functioning.

The occupational therapy⁶³ process comprises of different processes developed internationally over time. This process follows a client-centred approach embedded on a collaborative relationship between the client and occupational therapist.⁶³ It is aimed at adopting problem solving strategies to improve every clients’ quality occupational performance independence in their ADL.^{62,63} The occupational therapy process is categorised into three main areas, namely evaluation process, intervention process and outcome,⁸¹ as indicated in Figure 2.7⁶³

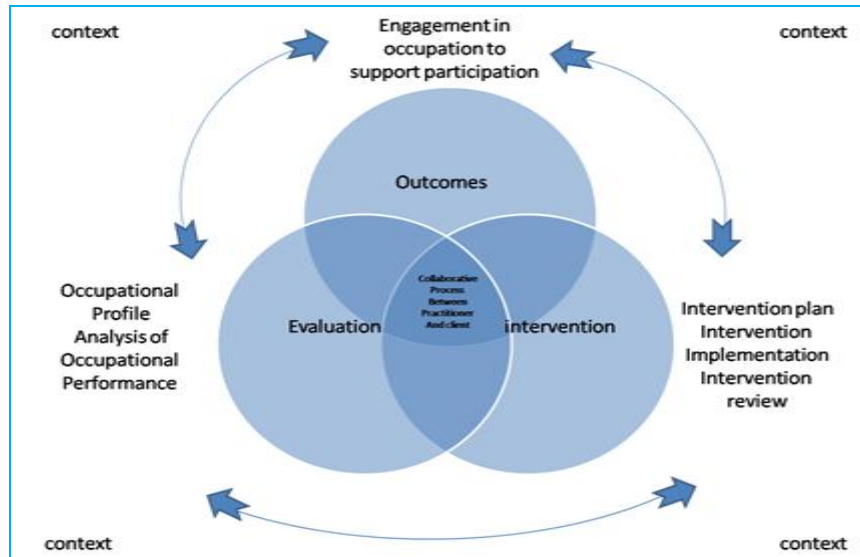


Figure 2.7 illustrating the occupational therapy process⁶³

The evaluation processes focus on referral and assessment of the client to create a holistic profile, including their occupational performance in ADL. Following this is intervention planning, implementation, and regular review of progress. Lastly, the conducting of outcome measurement was to evaluate whether the primary aim formulated was reached, and the clients' occupational independence in their areas of occupation achieved.^{62,63}

A short description follows of the most relevant theories needed for a holistic approach.

- **Philosophy of Occupational Therapy**

The ideas that formulated and defined occupational therapy with its founding philosophy were found within the humanistic psychology school of thought in the 20th century sharing similar views in the concepts of personal freedom, self-determination and creativity.^{63,64} All these facets are integral in individuals to be able to identify them as holistic beings and contributing members of society. Abraham Maslow and Carl Rogers expanded on this concept of treating individuals as holistic beings through a client-centred approach.^{63,64} There are many frames of reference described and often, there may be more than one frame of reference applied together in the treatment of a client.

One of the approaches used regularly in clients with physical injuries is the Biomechanical frame of reference⁶⁴.

- **Biomechanical Frame of Reference**

The Biomechanical Frame of Reference⁶⁵ is a remedial approach with emphasis on improving impairments, which affect independent functioning. This approach elucidates that patients are able to attain motor skills deemed important to perform a required human occupation. It has the view that engagement in work and therapeutic activities have the capacity to remediate the impairments, thus improving independent daily functioning. The fundamental goal of this approach is to prevent deterioration and preserve existing movement patterns, to re-establish movements and/or to compensate or acclimatize for the loss of the affected movement to promote independent functioning in occupational performance. Individuals with limitations in performing their ADL due to impaired movements, poor muscle strength, decreased endurance, loss of sensation or other biomedical conditions are suitable for this frame of reference.⁶⁵

The Model of Occupational Functioning maintains that people strive to achieve sense of self-efficacy and self-esteem throughout their engagements. This is through being independent and in charge of your own life and your own roles that define each individual.⁶⁵

- **International Classification of Functioning, Disability and Health**

The International Classification of Functioning, Disability, and Health (ICF)⁶⁶ is a classification system, which indicates multifaceted connections between a person and their physical, social, and psychological environments and addresses the influence of such systems⁶⁶ on the individuals wellbeing. According to the ICF, components of performance include body functions, body structures, activities⁶⁶, and participation; while components of disability involve impairments, activity limitations, and participation limitations⁶⁶. The ICF model, which has been adopted by the WHO, prioritises independent functioning in ADL within their environment. Studies show that diagnosis

alone⁶⁶ does not envisage service needs, length of hospitalisation, and level of care or performance outcomes; nor is the presence of an illness or disorder an precise predictor of acknowledgment of disability benefits, work performance, return to work potential, or probability of social integration⁶⁶.

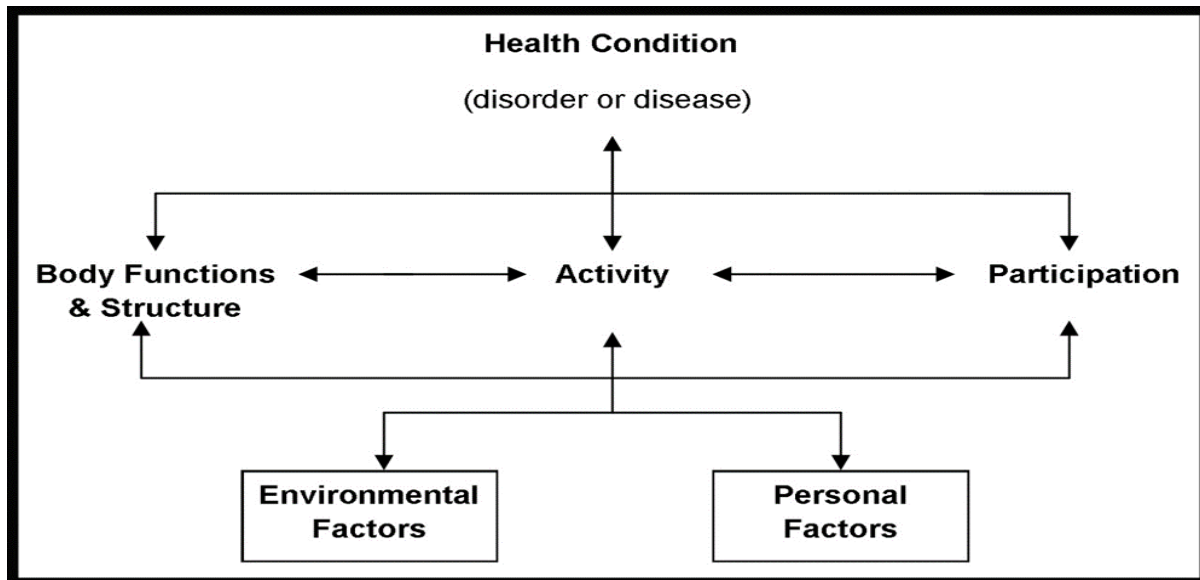


Figure 2.8 – ICF Framework from WHO 2013⁶⁶

- **Model of ICF basis of disability (WHO)**

In ICF, as the diagram illustrates, disability and functioning are interactions between health conditions (injuries) and contextual factors^{66,67}. Contextual factors^{66,67} are within the external environmental, i.e. social attitudes, environmental settings, social structures, as well as climate, terrain and legal systems. Internal individual factors^{66,67} include gender, age, coping mechanisms, background, education, profession, past and current experience, behavioural patterns, character and other factors that influence how the individual experiences disability^{66,67}. Figure 2.8 identifies the three levels of human functioning, classified by ICF functioning^{66,67}, at the level of body or body part, the whole person, and the whole person in a social context. Disability therefore involves^{66,67} the incapability to function at one or more of these levels: impairments, activity restrictions and participation restrictions.

All the above information is considered when the management of the patient is determined. After the initial injury, surgery of the injured nerve and tendon injuries, by an orthopaedic surgeon, is the first step towards the recovery process. The patient needs to undergo rehabilitation of the hand once surgical repair of the injured structures has taken place in theatre. The patient needs treating as a holistic being considering the multi-facets of the patient's psychosocial and environmental factors. Mennen⁶⁸ noted that, "it is important to realize that rehabilitation is not something mystical at the end of the line of treatment, but rather it commences with the first contact with the patient and continues until optimal function is achieved."⁶⁸ It is imperative for the multi-disciplinary team approach when treating the patient, to optimise the outcome or results of the patient. The multi-disciplinary team would comprise of the orthopaedic surgeon, nurse, OT, physiotherapist, social worker and psychologist. The aims of all team members should be the same to prevent confusion to the patient.⁶⁸

The Occupational Therapist helps with mobilising and improving muscle power and coordination, using various ADL. Fabrication of static splints for tendon transfers is an imperative first stage of occupational therapy management for optimal recovery of the injured hand. A splint is an assistive device to facilitate the healing of a pathological condition or at least to delay deterioration.⁶⁸ The purpose of the splint is to prevent deformity, immobilise, mobilise, position, or to protect the wrist and individual finger joints to restore the hand to maximum function.⁶⁸

To ensure optimal recovery, and a consensus between the multi-disciplinary team members, there should be treatment guidelines established. Hand therapy protocols are continuously formulating, and research continues, since the emergence of splinting of patients post-World War II.⁶⁸ Various surgeons have identified protocols to promote effective and optimal hand function after upper limb injury repairs. Anecdotal evidence suggests there is a paucity of literature on tendon transfer physiology and healing compared to flexor or extensor tendon repair.

2.11 OCCUPATIONAL THERAPY PROCEDURES

The use of daily function in occupational therapy is to describe the ability to participate in daily basic tasks such as bathing, dressing, feeding, leisure and work. This narrative is also embedded in the findings by Kovacs et al. which concluded that quality of life is derived from a realisation of the psychological, physical and functional ability to optimally engage in ADL. In Geneva, the World Health Organization⁶⁶, 2001, defined “*Health as being not only the absence of disease and infirmity but also the presence of physical, mental and social well-being*”.⁸⁵ Treatments are no longer viewed within the scope of morbidity and mortality, but rather emphasise its impact on function.^{87,89}

2.12 OCCUPATIONAL THERAPY ASSESSMENT AND INTERVENTION IN ACUTE PHASE

In Gauteng Province, South Africa, a group of senior occupational therapists from all levels of care, i.e. primary healthcare, district hospitals, regional and tertiary hospitals, including representatives from the University of Limpopo, Medunsa Campus and University of Pretoria, elected by the Deputy Director of Provincial Allied Health Services, were to form a task team. The main aim of this task team was to formulate uniform approach in the management of hand conditions that would assist junior occupational therapists and community service therapists to use as a guide when treating these patients at various levels of care. Furthermore, to assist in the development of minimum standard guidelines for the treatment of common hand injuries. This also assisted in identifying mentorship programmes with senior occupational therapists in various catchment areas. These members formulated and released a manual on the Gauteng Hands Protocol⁶⁹ in August of 2009 (unpublished).

As mentioned before, it is standard procedure within Gauteng Health hospitals for the medical doctor to refer the patient to occupational therapy after sustaining an upper limb injury with nerve involvement. After the doctor has established the severity of the hand injury, and managed it from the medical and surgical side, the patient goes for

occupational therapy intervention while still in the ward. The occupational therapist evaluates the patient to establish if they are stable enough to go to the occupational therapy department. The occupational therapist would then execute a subjective and objective assessment with highlighting on the specific client factors, as indicated in Table 2.2.⁶⁹

Before any treatment could commence, the occupational therapist would conduct an interview to obtain biographical data from the patient, focusing on the medical history including the patient's recent surgical report.⁷⁰ The history of the cause of injury is also pertinent in therapy because it guides the therapist's approach and gives insight into other related factors to be integrated into therapy. It is also important to have knowledge on the type of medication that the patient is taking as it may influence the patient's response to therapy. The occupational therapist further needs to obtain the patients social and work history, because pain has a significant impact in this area.⁷⁰

Occupational Therapists use clinical assessment as a process decision regarding future management of the patient. According to the Occupational Therapy Practice Framework III⁹¹ the main goal of evaluation process is to establish the patients' needs and their current ability after an injury.⁷¹ The assessments process is combined with clinical reasoning, and is a fundamental centre of the evaluation process.⁷¹ It allows the OT to use their skills and knowledge obtained from the assessment to establish the ideal evidence-based practice to provide intervention.⁷¹

Table 2.2 – Subjective and objective evaluation by occupational therapists as described in the Gauteng Hands Protocol (Appendix A)

Subjective Evaluation	Objective Evaluation
<ul style="list-style-type: none"> ➤ Observe the posture of the hand. Normal posture is slight extension of the wrist with fingers curled towards scaphoid bone. ➤ Observe the mobility of the hand by requesting the patient to open and close his hand and move the thumb. ➤ Observe any obvious deformities of the hand. ➤ Observe condition of the skin, e.g. skin loss, fragility and scarring because of previous injury, scars across the joint, which may limit ROM. ➤ Observe colour of the skin for signs of inflammation or impaired blood supply. ➤ Ask the patient how the hand feels, e.g. pain, numbness and tingling sensations, dryness versus sweatiness. ➤ Observe for hand oedema. ➤ Ask patient to score their pain using Rating Scale, location of pain and frequency. ➤ Ask the patient which hand is dominant. ➤ Establish if there is family support. ➤ Obtain work and leisure history. 	<ul style="list-style-type: none"> ➤ Use a tape measure to measure circumferential oedema. ➤ Evaluate sensation of the hand for specific nerves (ulnar, median and radial nerve) distribution to the skin.⁹¹ ➤ Passive range of movement of each affected joint after tendon healing has taken place ➤ Muscle strength of the hand after tendon healing has taken place ➤ Grasps and pinches using different modalities (spherical grasp, ball grasp, hook grasp, tripod grasp and key grip) after tendon healing. ➤ Bilateral hand function after tendon healing has occurred.

Based on the information described above, the Gauteng Department of Health decided to have a standardised protocol for the management of tendon transfers for all State Hospitals in Gauteng. Occupational therapists use standardised and non-standardised

methods of assessments to gather data. Standardised assessments comprise of Hand Dynamometer, Smith-Hand Function Evaluation, Jebsen-Taylor Test for Hand Function, Short-Form³⁶ and Patient Rated Wrist Evaluation (PRWE) within the northern Gauteng region. Non-standardised testing involves structured interviews and observations. Dunn⁷² explains there may be circumstances within practice deemed unfavourable for standardised assessments, the therapist may then make use of more informal non-standardised⁷² evaluation methods, such as skilled observations or interviews. According to Corr⁷³, at Stellenbosch University, a measurement tool is standardised if validity, reliability, sensitivity and clinical utility⁷³ have been recognized.

Once the decision is to perform tendon transfer surgery, the occupational therapist will need to provide the team with information obtained with the use of standardised and non-standardised assessments. The patient's sensation would be evaluated using different modalities of light and deep touch following specific nerve distribution on the hand or monofilament test on the table surface with the patient's vision occluded.⁷⁰

To establish a baseline passive range of motion of each affected joint involves placing the affected forearm on the table in mid-position and the goniometer on the radial styloid and measuring axis to wrist motion.⁷⁴ The goniometer is placed on the distal part of upper limb with the stationary arm against the radius bone and movable arm along the metacarpals of the index finger; record the maximum passive range of movement in degrees. The finger goniometer measures passive range of movement of the metacarpophalangeal joint from the dorsal to the joint of each finger with the stationary arm aligned with the metacarpal⁷⁴, while the movable arm is in alignment with the proximal phalanx.

According to the Gauteng Provincial occupational therapy protocol,⁶⁹ the main purpose in the acute phase of occupational therapy is to maintain the mobility and hand function without causing further damage to internal structures by education of sensory loss of the affected muscles depending on the injured nerve. Daily passive movements of all the joints involved are necessary to prevent development of stiffness and deformities. The

patient is educated about this programme to execute 10 repetitions every 2 hours. Usually patients receive education on this programme and continue on their own as a ward programme. Scar tissue massage can be done three times daily for at least 5 minutes if appropriate, starting when the wound is closed.⁶⁹

After the initial injury, surgery of the injured nerve and tendon injuries, by an orthopaedic surgeon, is the first step towards the recovery process. The patient needs to undergo rehabilitation of the hand once surgical repair of the injured structures has taken place in theatre. The Occupational Therapist helps with mobilising and improving muscle power and coordination, using various ADL. Fabrication of static splints for tendon transfers is an imperative first stage of occupational therapy management for optimal recovery of the injured hand. According to the Gauteng Provincial occupational therapy protocol,⁶⁹ the main purpose in the acute phase of occupational therapy is to maintain the mobility and hand function without causing further damage to internal structures by education of sensory loss of the affected muscles depending on the injured nerve.⁶⁹

At week one up to week 4 post-tendon transfer, the patient's hand is placed in a Plaster Of Paris (POP) splint in 30° extension, with Metacarpophalangeal joints (MCP) and Proximal interphalangeal joints (PIP) each in 30° flexion. The Distal Interphalangeal joints (DIP) can move free.²⁴ POP remains for 4 weeks. At week 5-8, the POP is removed, hands are washed thoroughly with disinfectant, stitches carefully removed by the nursing staff. A thorough Occupational Therapy evaluation of the hand takes place.⁶⁹

A static wrist extension splint can protect the tendon for at least another 2-3 weeks depending on the type of work the patient does.⁶⁹ Scar tissue massage is demonstrated to the patient once the skin is closed and must be done three times daily, using the thumb of the unaffected hand to rub in circular movement. Topical agents such as Vaseline, aqueous cream or massage oils.⁶⁹ The patient is advised to remove the splint five to eight times daily to do home exercise by doing MCP extension by flexing the wrist first. Then teach the patient to use the transferred muscle, by actively contracting

the transferred muscle and doing the desired movement 10 times, not the “OLD TRICKS”.⁶⁹

Keeping the thumb mobile doing flexion/extension, abduction and adduction and opposition without resistance.⁶⁹ Do MCP flexion with IPs flexed (20 repetitions). Gradually introduce minimal resistance as recommended by the treating occupational therapist.²⁴ Splints must be washed daily in cold water and soap to remove sweat and odour. Hand is bathed daily in warm soapy water and patient can do the active flexion and extension exercise in the water.⁶⁹ The splint is only removed when exercising. Activities that encourage active extension are recommended. Patients can return to work about 6 weeks later still protecting tendon. Follow-up appointment must be made to evaluate progress. At Week 8 the splint is taken away by the occupational therapist and a full assessment of the hand is done.²⁴ Further management if necessary depending on the findings of the re-assessment; discharge plan if ready.⁶⁹

2.13 PSYCHOSOCIAL IMPLICATIONS OF RADIAL NERVE INJURIES

Upper limb trauma is not only limited to the biomechanical impact on function, it also has psychological implications, which have an influence on the outcome of the surgery and their capability to resume their ADL, work and leisure.⁷⁵ Jaquet et al. noted in their study that 64% of the 67 participants presented with moderate to severe psychological symptoms during the first month following upper limb injury.³ This may lead to loss of worth, control and learned helplessness by the patients. This loss of worth and control is exacerbated further by the deprivation of the individual's ability to participate in skilled or semi-skilled routine tasks and independent functioning in the most private self-care activities.⁷⁵

The altered hand function due to the injury causes humiliation and public exposure of the affected hand, causing people to stare or enquire on the cause of the injury. This causes greater judgment of stigmatisation and social conspicuousness.⁷⁵ Sometimes, in the communities, members may react with indecent remarks regarding the appearance

of the hand, such as looks of horror, disgust and repulsion along with drawn out staring at the injured extremity⁷⁵, resulting in further isolation and ostracising of the individual with hand trauma.⁷⁵ These psychological manifestations of hand trauma have an integral influence on the outcome of the surgery and their ability to return to normal life.⁷⁵

2.14 SOCIO-ECONOMIC IMPLICATIONS FROM RADIAL NERVE INJURIES

Considering the lengthy period of recovery and arduous process for tendon transfers, when needed, substantial time off work is required. Jaquet et al. noted that upper limb trauma involving peripheral nerve injuries could take more than 2 years to recover.³ This lengthy process has significant financial implications due to the patients limited functional capacity, inability to travel long distances to access treatment or rehabilitation and their ability to return to work. It also has additional financial implications to the already overburdened Department of Social Services for temporary disability grant assistance to attend follow up appointments and also sustain patients during recovery.⁷⁶

A study conducted in Australia⁷⁷ revealed complex hand injuries involving Radial nerves are treated in the urban and larger provincial hospitals.⁷⁷ People from the countryside and inaccessible locations are frequently referred to their district hospitals or local clinics to be rehabilitated by local occupational therapists or physiotherapists⁷⁷ after surgical management of their injuries. The high patient numbers managed by the therapists⁷⁷ and shortage of resources to provide a hand therapy service⁷⁷ prove to be the biggest challenge; therefore, follow up appointments have to be organised at the metropolitan or regional facility. This cause's significant financial strain on families required to take time off work to drive patients to appointments. Consequently, patients receive a intermittent hand therapy intervention that fails to address the ongoing hand impairments, which can have an impact on functional outcomes.⁷⁷

Opsteegh et al.⁷⁸ noted in their study that blue-collar workers (unskilled to semi-skilled) took longer to re-enter the job market when compared to white-collar workers (skilled workers). This is attributable to work-site avoidance⁷⁸; the injured workers blame co-

workers or equipment for the sustained injuries and are therefore highly likely to resist returning to former work activities than workers who judge themselves responsible for their accident⁷⁸.

According to the South African Employment Equity Act Number 55 of 1998, *“Reasonable Accommodation refers to necessary and appropriate modification and adjustments not imposing a disproportionate or undue burden, where needed in a particular case, to ensure persons with disabilities the enjoyment or exercise on an equal basis with others of all human rights and fundamental freedoms.”*^{79,80,81} Furthermore, this act protects people with temporary or permanent disability against unfair labour practises in the workplace and encourages employers to implement affirmative action measures to redress discrimination of people with disabilities.^{79,80,81}

It further ensures that employers promote equal opportunities and fair treatment for people with disabilities, as required the Employment Equity Act^{79,80,81}. These policies are in line with the Code of Good Practice¹⁰¹ and Technical assistance guidelines^{79,80,81}, Chapter 23, which ensures that employees should be protected, reasonably accommodated and properly remunerated with a disability or recuperating from an injury or illness.⁸²The purpose of this act is to protect the employees, and becomes more important when extended healing time after an injury is relevant.

2.15 SURGERY: TENDON TRANSFERS OF THE UPPER LIMB

After the conservative management of radial nerve injury and acute occupational therapy, intervention fails for the nerve to regenerate. The orthopaedic surgeons and occupational therapists explore a surgical approach of tendon transfer surgery. A detailed overview of tendon transfers follows.

As mentioned in the classification of nerve injuries, Section 2.6, and as described in Section 2.8, if the muscles reached the point where re-ervation is no longer viable other possible interventions need considering. One of the methods used to restore some upper limb and especially hand function, due to injury or loss of the

neuromuscular-motor unit, is the use of tendon transfers. This surgical technique replaces function of the affected muscles by re-routing and re-attaching functioning muscles, innervated by unaffected nerves. The orthopaedic surgeon harvests these donor muscles to facilitate grasp and release of objects, to improve hand function. Baumeister et al.⁸³ noted that the vision of re-establishing function when transferring a muscle-tendon unit to execute the lost functions is enthusiastically received by the patient and gratifying to the surgeon.

2.15.1 Goals to Achieve in Tendon Transfer Surgery

The goal of tendon transfers is to restore wrist, finger and thumb extension to improve hand function in daily tasks. The orthopaedic surgeon uses PT muscle to achieve wrist extension of the affected hand. Authors are in debate over the tendon transfer that yields best results in finger extension technique. Finger extension can be achieved by taking FCU, FCR or FDS to EDC transfer. Regarding thumb extension and abduction, a PL or one FDS tendon to the re-routed EPL transfer can be performed. When tendon transfer is done on EPL without re-routing it, abduction can be achieved by doing a tendon transfer to APL or an APL tenodesis. Different tendon transfer options are selected by the orthopaedic surgeon, and are discussed with the patients to establish the objectives together. The ideal transfer is selected based on the clinical examination (high or low radial nerve palsy, tendon available for transfer like PL, wrist mobility) and based on the patient's needs and expectations (activities requiring the FCU, finger independence, independence of thumb extension or abduction). The orthopaedic surgeon's used the Brand surgical technique to transfer tendons with radial nerve injury to improve hand function.⁸⁴

2.15.2 Principles of tendon transfers for Radial Nerve injuries

The Orthopaedic Surgeon harvests donor muscles supplied by median and ulnar nerves^{85,86} to restore wrist extension, MP extension and thumb abduction. This facilitates the release of objects, which improves hand function. According to literature, principles

followed by the orthopaedic surgeon to ensure that best outcome is achieved following surgery are as follows:^{85,86}

- Donor muscle function must be dispensable so that its removal would not result in significant loss of function, and its neuro-motor unit should be intact^{85,86}. Literature supports this principle in that the transferred muscle tendon unit excursion must be adequate to achieve the required hand movement^{85,86}. The transferred tendon must have a similar excursion to the tendon that it is replacing. In situations where there is no donor muscle tendon unit available for the required excursion, a tenodesis effect is used to replace the excursion of the replaced tendon.^{85,86}
- The strength of the donor muscle must be normal or near normal. The surgeon needs to select a muscle tendon unit with sufficient strength to achieve the desired movement. It is preferred to have a muscle of the same or greater strength as the donor. A weak donor muscle will compromise the movement, thus having an impact on function. A donor that is too strong would lead to imbalanced movements and asymmetrical posture of the hand in resting position.^{85,86}

The excursion or glide of the donor tendon must be sufficient to restore lost function. A single tendon must be utilised to restore a single function; transferring a single tendon to perform function of numerous functions leads to compromised muscle strength and pattern of movement.^{85,86}

- The course of pull of a recipient tendon must be in line with the donor muscle, and transfer should only cross one joint. Tendon transfer procedures are more successful when there is a straight line of pull. A change in direction of 40 degrees or more results in significant loss of force. Change in course reduces the strength that the transferred Muscle tendon Unit (MTU) is able to apply on its insertion. Ideally, an end-to-end transfer results in better function and force transfer than end-to-side transfer, i.e. pronator teres (PT) transferred to extensor

carpi radialis brevis (ECRB) is common in restoring wrist extension because the line is straighter. Tendon transfer procedures where course change is unavoidable, the tendon could be passed around structures that can act as pulleys.^{85,86}

- Transfer should not be on scarred tissue that may limit excursion. Literature also refers to this principle as soft tissue equilibrium. The focus of this principle is that tendon transfer glides over healthy soft tissue free of scars, irritation and swelling. This enables the tendon to glide freely, minimises adhesions and fibrosis. If there is soft tissue injury on the muscle bed, the surgeon must allow time for the inflammation and swelling to subside before attempting tendon transfer procedure.^{85,86}
- Before surgery, the affected hand's joints should be supple and have full passive range of movement. Tendon transfer surgery fails when the joints are stiff. Forceful therapy is frequently required to reach and preserve supple joints before tendon transfer surgery^{105,106}. In certain cases, surgery to release contractures and hand therapy is recommended prior to tendon transfer surgery.^{85,86}

Transfers should use tendons with similar functions. The synergistic action of donor muscle for the transfer and recipient muscle can facilitate muscle-retraining efforts.¹⁰⁷ Muscles work in groups to perform specific functions or movements¹⁰⁷, e.g. wrist flexion and finger extension have synergistic movements that occur concurrently when performing a certain movement function in daily occupations

2.15.3 Tendon healing

When tendon transfers are done, there should be sufficient information regarding the healing process of these transferred tendons in place. Tendon healing is an area still under research in many countries; this is because there is still no one answer to the complexities of this process. The following section discusses two of these theories.

In the extrinsic healing theory, recuperation takes place through cells extrinsic to the tendon through fibroblastic⁸⁷ reaction from surrounding tissues. It accepts the requirement of surrounding peri-tendinous adhesions to allow inclusive healing of tendons. This immobilisation occurs after the transfer of the tendon transfer. During the immobilisation phase, the inflammatory phase occurs between 0 – 4 days, followed by proliferation or fibroplasia phase lasting between 4 – 21 days, thereafter more than 21 days' scar remodelling or maturation phase.⁸⁷

Intrinsic healing, recovery is probable in absence of cells and tissue extrinsic to the tendon¹⁰⁸. Clinical evidence supports this theory, including round end plates of unrepaired tendons, tendon healing in the absence of adhesions and in vitro healing of tendons in isolated, cell free environments⁸⁷. Controlled mobilisation of repaired tendons allows healing, but prevents peri-tendinous adhesions that were stated as an advantage. At 0-3 days – proliferation and thickening of epitenon cell layers¹⁰⁸ takes place; 5-7 days – collagen and vascular¹⁰⁸ ingrowth ensue; 10 days – fibrous callus noted; 2-3 weeks – proliferation in growth of endotenon tenocytes.⁸⁷

Lastly, due to the exceptional anatomy of the tendons operating through the tendon, sheath function needs considering. Surgeons need to plan surgery properly to prevent tendon adhesion and fibrosis from occurring.⁸⁷

2.16 OCCUPATIONAL THERAPY INTERVENTION DURING TENDON TRANSFER SURGERY

Before tendon transfer surgery takes place, the occupational therapist should have a comprehensive understanding of the anatomy of the muscles, biomechanics and kinesiology of the muscles and functional implications. As described below, the selection of the donor muscles are very important to obtain optimal function.

2.16.1 Biomechanical Functions of Relevant Muscles in the Upper Limb

Brand et al.⁵² noted that the mechanical balance of the hand requires equally strong muscles on opposite sides of the joint. Balancing torque in a sequential manner on the joints is imperative as the force exerted by the hand on an external object needs to be controlled.⁵² The muscles listed in Table 2.2 are imperative for upper limb function in ADL, work and leisure⁵². They work in synergy with other muscles innervated by different peripheral nerves to ensure that there is maintenance of mechanical balance in the upper limb. Co-contraction of the upper limb muscles ensure the prehensile and non-prehensile movements are well coordinated in order for the specific function or grasp to occur.⁵²

There should be assessment and strengthening of possible donor muscles in occupational therapy before surgery. The following muscles are the most frequently used donor muscles.

2.16.2 Donor Muscles for Tendon Transfer surgery

- PT is a spindle shaped muscle found at the antero-lateral compartment of the forearm. It belongs to the superficial flexors group of the forearm muscles. It is composed of two heads, which originate respectively from the distal aspect of the humerus and the coronoid process of the ulna. Its main function is pronation of the forearm. It also aids forearm flexion at the elbow. This muscles' nerve supply is the median nerve.⁸⁸ Figure 2.19 shows anatomical structure of pronator teres muscle.⁸⁹



Figure 2.9 – Image of pronator teres muscle insertion and origin⁸⁹

- The flexor carpi radialis (FCR) is a thin muscle situated on the anterior part of the forearm⁹⁰ in the superficial compartment. It originates from the medial humerus epicondyle and inserts at the base of the metacarpal of the index finger⁹⁰ (IF). It is visible when the wrist comes into flexion against minimal resistance. The muscle's situation is superficial to the flexor digitorum superficialis (FDS)⁹⁰. The median nerve provides the motor innervation, and it receives its blood supply through the radial artery⁹⁰. Its function is to provide flexion of the wrist and assists in abduction of the hand and wrist⁹⁰. Figure 2.10 illustrates origin and insertion of FCR muscle on the forearm.⁹¹



Figure 2.10 - Image of Flexor Carpi Radialis muscle⁹¹

- The palmaris longus (PL)⁹² muscle is a long thin muscle, which is sometimes present in the flexor compartment of the forearm. It is sandwiched between the FCU and FCR muscles and accepted as a vestigial muscle, and almost 30%⁹² of the population could be lacking this muscle in one forearm (unilateral) or both (bilateral), but the percentage varies. The uniqueness of this muscle in its presence, or absence, is that it does not have an impact on grip strength. The absence of PL in terms of its prevalence is more common in women than men.⁹²

PL originates from the medial epicondyle of the humerus with the common flexor tendons⁹². It inserts at the Palmar Aponeurosis (PA)⁹² and Flexor Retinaculum (FR) over the wrist joint. The median nerve innervates it, and its main function is to flex the wrist and small joints; it also assists with tightening and tensing of the palmar aponeurosis.⁹² Figure 2.11 shows an image of the Palmaris longus muscle origin and insertion.⁹³

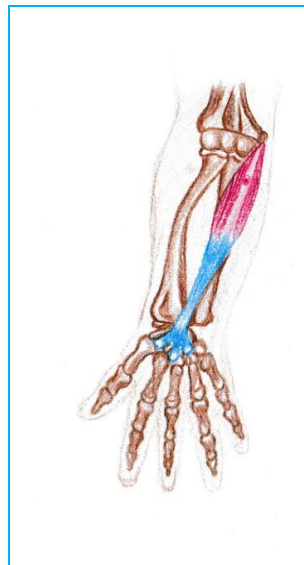


Figure 2.11 - Image of Palmaris Longus muscle⁹³

- Flexor digitorum superficialis (FDS)⁹⁴ is another muscle that can be used to connect to EPL when the patient does not have PL. The FDS is the primary flexor of the proximal interphalangeal (PIP) joints of the middle phalanges¹¹⁶, but it also assists in flexion of the MCP joints. Based on its origin sites, FDS is divided into two heads; a humero-ulnar head and radial head⁹⁴. It has a large muscular

belly that progresses distally towards the wrist, where it bifurcates into four tendons and attaches to the middle phalanges of the second through fifth digits of the hand⁹⁴. Due to their superficial location, these tendons can be easily palpated on the distal part of the forearm⁹⁴. The main action of this muscle is flexion of the digits index, middle, ring and little fingers at both the metacarpophalangeal (MCP) joint and PIP. It is supplied by the median nerve⁹⁴. Figure 2.12 illustrates drawn image of FDS origin and insertion on the forearm.⁹⁵

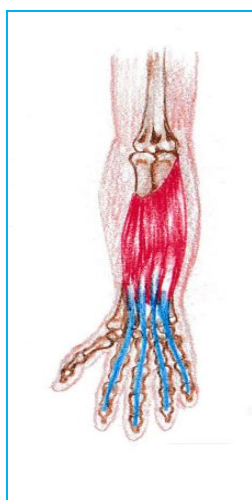


Figure 2.12 – image of Flexor Digitorum Superficialis on the forearm⁹⁵

2.16.3 Functional Outcomes Expected After Tendon Transfer

The occupational therapists and orthopaedic surgeon note that regeneration of the nerve occurs after 4-6 months, despite acute occupational therapy intervention. Therefore, the occupational therapists and orthopaedic surgeons conduct a second round of assessment before exploring tendon transfer surgery. The assessment is below.

- **Joint Range of movement Norms**

Range of movement measurement is an imperative part of hand joint assess to establish impairment, as well as to evaluate the effects of therapeutic interventions⁹⁶. Loss of range of movement leads to a reduction in grip strength, grasp competence, fine motor coordination, and thus hand function. A goniometer measures the passive range of movement;⁹⁶ this is a standardised instrument used to measure flexibility of the joint in various angles of movement.⁹⁶ Figure 2.13 illustrates the image of a goniometer when measuring range of movement on the hand.⁹⁷



Figure 2.13– Image of wrist extension evaluation using Goniometer⁹⁷



Figure 2.14– Image of MPJ extension evaluation using Goniometer⁹⁸

Based on the evidence/findings, research supports the continued use of goniometry in clinical settings. There are three different techniques for goniometric measurement. These methods should not be interchangeable due to inconsistent results. The dorsal-volar technique⁹⁶ demonstrates the highest levels of inter-rater reliability for measuring wrist flexion and extension.⁹⁶ The generalisability theory accounts for standard errors, such as testing conditions, time of day, positioning of subject, and poor visualisation of bony landmarks. This technique has proven to be a non-invasive and economical method of measurement, and considered a precise method to evaluate movement capability⁹⁶.

A study conducted in Europe was to establish an objective assessment of post-operative function of 11 triple transfers for high radial palsies⁹⁹, using PT for wrist extension, FCU for finger extension and PL for thumb extension.⁹⁹ Assessment was done by noting the active ranges of wrist, grip strength, wrist and finger strength and work simulation⁹⁹. The mean follow-up was 3.3 years. The sum strength and range of wrist extension were 42% and 86%, respectively, of the contra lateral wrist. Other calculated movements were within the functional range and work simulation confirmed good restoration of function.⁹⁹

A study conducted in India aimed to evaluate the results of a split flexor carpi ulnaris (FCU) as a single transfer in such patients, and compare our results with other transfers from the available literature.¹⁰⁰ This study revealed that 44% of the patients had good wrist extension of more than 29°, 56% of the patients had fair wrist extension between 0° and 29° with mean extension of 26° (15°–40°). The majority of their patients showed first web opening >39° (76%), 24% of the patients showed first web space opening <39° with mean of 44° (36°–56°). Nearly 68% of patients had good-to-excellent satisfaction, in rest 32% of patient's satisfaction level was fair.¹⁰⁰

Brigstocke et al.¹⁰¹ examined 40 normal subjects, 20 males and 20 females, to determine the ideal range of movement required to perform ADL¹²², ranging from personal care and hygiene, diet and food preparation and miscellaneous ADL¹²². They

concluded that 40° extension, 40° flexion and a combined 40° radial-ulnar deviation permitted a minimal functional range of movement in the normal population¹⁰¹.

- **Muscle Strength**

Muscle strength is determined by means of manual muscle testing of a single muscle or group of muscles to evaluate the ability to perform movement against resistance manually applied against the direction of movement. The scoring is done using Oxford Standard Scale, which views muscle strength in a grading from 0 to 5. Cuthbert and Goodheart^{102,103} demonstrated good external and internal validity in their observational cohort studies.^{102,103} The levels of agreement attained high inter-rater reliability and 96% to 98% for test-retest reliability.^{102, 103}

In Europe, there were other studies of hand injuries, which used Oxford Standard Scales to assess patients with radial nerve injury. These indicated there is controversy with optimal management of persistent radial nerve injuries.¹⁰⁴ The majority of authors concur that tendon transfers lead to acceptable results in most patients.¹⁰⁴ A long-term outcome of muscle strength study in peripheral nerve injuries, conducted by Schreuders et al.¹⁰³ contrasting manual muscle strength testing, grip and pinch strength¹²⁵, over a two-year period revealed manual muscle strength testing muscle recovery to grade 3 or 4. The study concluded that manual muscle strength testing and grip strength measurements show a logical to good recovery¹⁰³.

Muscle strength of the flexors would undergo evaluation using the Modified Oxford Scale, as they could be donors for the tendon transfer surgery.^{104,105}

- PL muscle: the patient brings the tips of their fingers together then flexes the wrist against opposition, while the forearm is in mid-position on the table.
- BR: Place the elbow against the trunk (abdomen) keeping the forearm in neutral mid-position. The participant should bend the elbow with the forearm in neutral position. Apply resistance against the distal aspect of the forearm in direction of extension.

- FCR by requesting the patient to bend the wrist towards radial deviation and resistance applied over the thenar eminence.
- FCU by the patient flexing the wrist in the direction of ulnar deviation and resistance applied against the hypothenar while radially deviating.

- **Disabilities of the Arm, Shoulder and Hand (DASH)**

The DASH questionnaire is a self-directed evaluation tool designed to calculate the outcomes of self-reported upper limb disability and symptoms, work and leisure participation.^{106,107} Participants completed the DASH questionnaire, which was then scored by the researcher. The scoring guideline of the DASH stipulates that lower scores reflect low disability, and high scores reflect further impairments or permanent limitations. Each question consists of a five-point Likert Scale leading to total score from best performance score to the worst functional outcome^{106,107}. The reliability of the DASH Cronbach's alpha score for this assessment tool for test-retest consistency is 0.94.^{106,107} The DASH questionnaire cannot specifically indicate that a particular score, which type of disability, or objectively determine whether an individual patient is able or unable to work.^{106,107}

Other studies have proven the DASH questionnaire to be a reliable tool to extrapolate data with patients with upper limb injuries. Such a study in India, to establish functional outcomes of tendon transfer for radial nerve paralysis, used the DASH Questionnaire.¹⁰⁸ Forty-one patients participated in the study from 2005 until 2009. The surgery involved used PT to be transferred for wrist extension, FCU =18; FCR = 10; FDS=13 were used to achieve extension of the fingers. The use of PL was to achieve abduction and extension of the thumb.¹⁰⁸ There was a record of the range of movement, hand ability and return to work. The patients completed the DASH questionnaire. The results indicated that hand ability and return to work, including the DASH score, showed satisfaction with the surgery. Range of movement was not statistically considerable ($P>0.05$)¹³⁰. All participants had experienced improvement in their daily function, with an overall satisfaction rate of 95%.¹⁰⁸

A retrospective tendon transfer study¹⁰⁹ for “radial nerve palsy” conducted in Malaysia was with 20 participants presenting with radial nerve injury who underwent ‘tendon transfer surgery’ between January 2008 and December 2012. The outcome measures included muscle strength of wrist extension, finger extension, grip strength and DASH scores¹⁰⁹. Results indicated significant progress of muscle strength of wrist and finger extension between pre-operative period and three months post-operatively ($p=0.0005$). Grip strength enhanced considerably as well between pre-operative, three and six months postoperatively¹³¹ ($p = 0.0005$). DASH scores reflecting patient fulfilment at six months postoperatively showed only mild or moderate difficulty of function¹⁰⁹.

A study conducted in Europe¹⁰⁴ was to establish an objective evaluation of post-operative function of 11 “triple transfers for high radial palsies”¹²⁰, using PT for wrist extension, FCU for finger extension and PL for thumb extension¹²⁰. Evaluation was done by noting the active range of wrist motion, grip strength, wrist and finger strength and work simulation¹⁰⁴. The mean strength and range of wrist extension were 42% and 86%¹²⁰, respectively, of the contra lateral wrist¹²⁰. Other calculated movements were within the functional range, and work simulation confirmed good return of function¹²⁰. The mean DASH score was 3.45¹⁰⁴, with no functional complaints from patients¹²⁰. This study shows that even though the range of wrist motion and the strength of the wrist and fingers¹⁰⁴ are a reduced amount of than normal, hand function remains good.

In the United States of America, between 1995 and 2006, 77 patients were involved in a modified Brooks and d'Aubigne¹¹⁰ surgical technique study for “radial nerve palsy”. In 19 cases, the FCR muscle was the donor instead of the FCU muscle. There was a comparison between the movement of the wrist and finger joints and pinch-grip power¹³² with the unaffected side.¹¹⁰ They also evaluated the restriction in pursuing daily activities using the DASH score. The findings revealed wrist extension equalled 73% of the contra-lateral side, whereas the value for movement pattern of digital extension was 32%¹³² and for thumb abduction in the palmar direction¹³², it was 80%.¹¹⁰ The power grip was decreased to 49% and the pinch grip to 28%. The mean DASH score was 15 +/- 9, the symptom score mean was 15 +/- 7¹³², and the working score

mean was 12 +/- 10. The mean total DASH score was 16 +/- 10¹³². The percentage of patients who remained employed after surgical treatment was 89%. They concluded that functional results, adequate patient satisfaction, and with adequate professional and social reintegration is achievable after modified Brooks and d'Aubigne tendon transfer.¹¹⁰

Nalbantoglu et al.¹¹¹ conducted a study in Turkey to assess the results of “tendon transfers in patients with irreversible radial nerve palsy”. The study included 29 patients who underwent “tendon transfers due to radial nerve palsy”, which included low and high radial nerve lesions. Clinical evaluation involved range of movement and muscle strength. Functional evaluation used Tajima criteria and a mean follow-up was 56.9 months. The mean for wrist range of movement was 67.4° (10 - 70 degrees)¹¹¹, extension was 48.3° (10 – 70 degrees) and flexion was 21.5° (10 - 55 degrees)¹¹¹. MCP joint extension mean was 1.7 (0 - 12 degrees)¹³³, thumb abduction 45.6 (34 - 56 degrees)¹³³. Based on the Tajima criteria, muscle strength was measured as 3 (n=3), 4 (n=10) and 5 (n=12) for wrist extensor muscles, finger extension muscles scored at 3 (n=7), 4 (n=10) and 5 (n=12), thumb extension was scored at 3 (n=6), 4 (n=13) and 5 (n=10)¹³³. The results indicated that treatment of irreversible radial nerve palsy with tendon transfers yields victorious results¹¹¹.

The researcher could not find literature in the South African perspective that commented on the functional outcomes of tendon transfers following radial nerve injuries. Considering the statistics of upper limb trauma in South Africa, the implications and consequences of nerve injury and possible tendon transfer surgery have an enormous effect on resources, including surgery and rehabilitation, and have an impact on the employment sector.¹¹² When such injuries are not properly managed within a well-equipped medical care facility with experienced and knowledgeable staff members, the patients could possibly have significant short-term or long-term impairments to their independent functioning within their daily occupations.¹¹³

- **Gauteng Hands protocol management principles post tendon transfers**

According to the Gauteng Hands treatment protocol for occupational therapists, in post-tendon transfer surgery the surgeon places the patient in a Plaster of Paris (POP) slab for four weeks with the wrist in 30° extension, MPs and PIPs each in 30° flexion and the DIPs moving freely. At week five, the occupational therapist removes the Plaster of Paris and replaces it with a removable dorsal forearm-based static wrist extension-blocking splint to protect tendons for another two to three weeks.

During this period, the occupational therapist focuses on scar tissue massage, once the skin is closed, engaging the patient in activities requiring active MP extension, such as tenodesis movements, nuts and bolts board, working on cones and keeping the thumb mobile without resistance. Activities that encourage wrist extension with no resistance are also encouraged during this phase. Patients return to work at week six, depending on the type of work they perform. However, they are still encouraged to wear the splint to protect the transferred tendons. At week eight, the prescription is for the removal of the splint, and a full hand assessment conducted. After this process, patients are discharged should they be ready or further treatment provided if it is required.⁶⁹

The occupational therapist would fabricate a static forearm-based wrist extension splint to support the hand in a functional position, as described in the provincial Gauteng Hands Protocol. Rehabilitation focuses on encouraging the patient to engage in as many guided ADL to improve and maintain the range of the joints of the affected hand. The patient is also educated on compensatory techniques that can be utilised when engaging in daily chores to prevent further injury.⁶⁹

2.17 CONCLUSION

Restoration of finger function after upper limb injury remains a challenge after tendon transfer surgery. Advancements in tendon anatomy biomechanics, nutrition, and adhesion due to scar formation and tendon repair procedures have led to improved results after tendon transfer. Despite these advancements, hand surgeons and occupational therapists still face challenges of stiffness, scarring and functional impairments. Although there was no injury to the tendons in the initial incident, the

interruption of the radial nerve affected their ability to function. Thus, muscles that remain with intact innervations are re-routed to perform altered functions through the transfer of their tendons. Therefore, it is imperative to consider the tendon healing theories during the rehabilitation.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

Walliman and Williman¹¹⁴ asserted that “Research can be defined as an *activity involving finding things that the researcher didn't know in a more or less systematic way*”.¹³⁶ Methodology can be defined as “the philosophical framework within which the research is carried out or the basis on which the research is based”.¹¹⁵ Therefore, a research methodology refers to precise procedures or techniques for identifying, selecting, processing and analysing the topic in a sequence. Research methods involve the exact plans or recipe for which a study is to be conducted, including various components such as the population, research context, data collection techniques and analysis.¹¹⁵

The researcher used a quantitative, retrospective, descriptive, cross-sectional process in establishing the functional outcomes of tendon transfers following radial nerve injury and occupational therapy intervention 24 months after tendon transfer surgery was performed to understand the complex elements and analysis in this study. Assessment was completed at once and there was no follow up of the participants since the study was descriptive.

Gunderson¹¹⁶ states that quantitative research is “explaining phenomena by collecting numerical data that are analysed using mathematically based methods (in particular statistics)”.¹¹⁶ Quantitative studies, according to Leedy and Ormrod¹¹⁷ indicate that it involves the researcher investigating and measuring variables by using generally accepted processes or methods in reality.¹¹⁷ Quantitative hypothesis is regarded as an enquiry into humanitarian or societal challenges by testing a theory composed of variables, calculated with statistics, and scrutinized with statistical measures in order to conclude whether the analytical generalisation of the theory valid.¹¹⁸

3.2 RESEARCH QUESTION, AIM AND OBJECTIVES

3.2.1 Objectives

- a) To determine the affected hand's functional ability in ADL, work and leisure post-radial nerve "tendon transfer surgery and occupational therapy intervention" using the DASH questionnaire.
- b) To determine the active range of movement of the wrist, metacarpophalangeal joint (MPJ) and thumb of the affected hand post-radial nerve tendon transfer surgery and occupational therapy.
- c) To determine muscle strength of wrist extension of the affected hand post-radial nerve tendon transfer surgery and occupational therapy.

3.3 RESEARCH DESIGN

It is a process of selecting all the steps necessary to be undertaken by the researcher to achieve the objectives.¹¹⁸ The rationale of the research design is to ensure that obtained data enables the investigator to answer the initial question as explicitly as possible.¹¹⁹ This strategic approach involves analysis of independent variables and purposive selection of participants.¹²⁰

A quantitative, retrospective, descriptive, cross-sectional design was adopted for this study.¹¹⁶ This design enabled the researcher to evaluate outcomes of participants that underwent tendon transfers after a radial nerve injury, and completed the 'Gauteng Provincial occupational therapy programme' as used by the occupational therapists at Steve Biko Academic Hospital.

3.4 RESEARCH SETTING

The study was at the occupational therapy departments of Steve Biko Academic Hospital in the northern Gauteng region. The occupational therapy hand unit is a familiar setting for patients who received rehabilitation before and after their tendon

transfer surgery. This would reduce any anxiety from participants. It is also a quiet place with individualized workstations for patient' privacy and confidentiality.

3.5 RESEARCH POPULATION

All patients with a radial nerve injury referred to the upper limb clinics at Steve Biko Academic Hospitals that have undergone tendon transfer surgery and completed the prescribed Gauteng Provincial Hands Protocol. Inclusion criteria are in 3.5.2.

3.5.1 Sample size

According to Leedy and Ormrod¹²⁰, the more homogenous the sample is, the smaller the sample can be. In this study, the researchers used a small purposive sample, as the group is homogenous in the sense that they all received tendon transfers for radial nerve injuries as well as participated in the hand rehabilitation programme post-surgery in the same occupational therapy department. The statistician estimated a sample size as a minimum of 20 participants by the statistician. This consisted of participants who have undergone tendon transfer surgery following a radial nerve injury, completed the prescribed Gauteng Provincial Hands Protocol and who also met the requirements of stipulated in the inclusion criteria of the study.

The sample size population was 23 patients who had undergone tendon transfers following a radial nerve injury, and completed the occupational therapy intervention.

3.5.2 Inclusion/Exclusion criteria

a) Inclusion criteria

- Adults, 18 to 65 years of existence, sustained radial nerve injuries, who are employable adults as stated by the Department of Labour
- Patients who had a radial nerve injury and underwent tendon transfer surgery based on the criteria as seen in Appendix B
- Patients that understand IsiTswana, English, or Afrikaans

- Patients who have followed the recommended 'Gauteng Provincial occupational therapy programme' after radial nerve tendon transfer surgery
- Patients who have access to Steve Biko Academic Hospital for radial nerve tendon transfer surgery and occupational therapy rehabilitation

b) Exclusion criteria

- Patients that are minors and pensioners i.e. 18 years and above 65 years
- Patients with spinal cord or other peripheral nerve injuries
- Patients with neurological and rheumatological conditions
- Patients with other pre-morbid conditions resulting in functional impairment of the upper limb or hand prior to the radial nerve injury
- Patients with extensive soft tissue damage

3.5.3 Sampling method

Monette et al¹²¹ stated that purposive sampling is a method of drawing representation of a fraction of a population so that each member has an equal chance of being selected.¹²¹

Due to the limited number of patients that sustained pure radial nerve injury, who have undergone tendon transfer surgery and completed occupational therapy rehabilitation programme purposive sampling was applied. All patients from Steve Biko Academic Hospital that complied with the inclusion criteria were recruited telephonically to participate in the study.

3.5.4 Access to participants

Participant selection was conducted using the Orthopaedic Upper Limb clinic outpatient register on patients that sustained radial nerve injury, underwent tendon transfer surgery and recorded as discharged from the Upper Limb Clinic and occupational therapy. The researcher found 47 participants on the register that were discharged from the upper limb clinic and occupational therapy, only 23 were willing to participate in the

study. The researcher contacted the patients telephonically to provide them with information concerning the research study and requested verbal telephonic consent to participate in the study. Once patients agreed telephonically, the occupational therapy technician made an appointment scheduled for them to come to the occupational therapy department at Steve Biko Academic hospital to receive information letter, sign written informed consent and have an assessment of their rehabilitated hand conducted. Before any patient was included in the study, patients gave their information and written consent.

Only 15 participants were able to come to the hospital for physical evaluation of the hand due to national lockdown and COVID regulations in place at the time. The eight participants were unable to attend the hospital for physical hand evaluation due to COVID regulations, work commitments and fear of being in contact with hospital employees. Telephonic appointments were made by the occupational therapy technicians to access participants at their home and in the time convenient for them. Researcher and occupational therapy technician remained in the vehicle and sealed envelope was issued to the participant, which contained information sheet, consent form, demographics form and Dash questionnaire.

3.5.5 Sampling procedures

Information letter (Appendix C) was made available to each of the patients to clarify the research process, followed by signing the consent form and completion of the demographic information form (Appendix D). The occupational therapy technician, available in the occupational therapy department, was trained by the researcher to assist illiterate patients by reading the informed consent and assisting in the completion of the demographics form where needed. Instructions were standardised for all participants in the hospital. The occupational therapy technicians verbally provided clarification of the rationale for the study and its benefits for future patients through their participation, in English, Afrikaans or isiTswana. All occupational therapy technicians in

Steve Biko Academic hospital are fluent in IsiTswana, English, Afrikaans and IsiZulu, which made it easier to translate the information for participants.

There was anonymity and confidentiality maintained for all participants involved in the study. All information provided would remain highly confidential. After the researcher examined the information, number-coding system was allocated to all participants to conceal their identifying information. The occupational therapist will keep details of participants involved in the study anonymous. The researcher used the allocated codes when recording the findings on the data spreadsheet to maintain the anonymity of the patient's biographical information. The Occupational Therapy technicians signed a confidentiality agreement not to reveal to the assessing OT's the participants involved in the study (Appendix E).

3.6 RESEARCH INSTRUMENTS AND METHODS

Four instruments for data capturing were utilised.

3.6.1 Demographics questionnaire

The researcher formulated a demographics questionnaire to obtain pertinent information about the participants that had an indirect influence on their outcomes. The form was to cover the residential area, employment, type of employment, mechanism of injury, dominant hand, injured hand, support system at home and whether there was reasonable accommodation provided while they were recovering from their injuries.

The researcher trained the occupational therapy technician in Steve Biko Academic Hospital to collect this information and complete the form for the participants unable to read and write. Participants could read and write completed the forms on their own. The researcher populated this information on an electronic spreadsheet, and analysed it to extrapolate variables that directly or indirectly influenced the outcomes of the study.

3.6.2 The DASH Questionnaire

The researcher used the DASH Questionnaire (Disabilities of the Arm, Shoulder and Hand) which concentrates on functional status and symptoms. As described in Chapter 2, it is used to determine physical limitations of the upper limbs in a diverse or harmonized population, i.e. males and females with mild, moderate and severe impairments and with a wide variety of upper extremity disorders. This assessment tool was specifically formulated to measure physical function and symptoms in persons with musculoskeletal disorders of the upper limb. This is a self-administered questionnaire completed by the participant focusing on disability and symptoms, work participation and leisure/sports participation. The reliability of the DASH Assessment tool scores at Cronbach's alpha is 0.94 and test-retest consistency of 0.94. The original DASH was translated and standardised into South African English and Afrikaans by the Oxford Outcomes Limited in 2006.^{128,129} The standardised South African version of the DASH was used for this study. The researcher obtained permission from the author (Appendix F) to use the original DASH, and they recommended the use of the South African English and Afrikaans version (Appendix G)

3.6.3 Goniometer

A goniometer measured the movement patterns of the wrist extension and thumb extension of participants. It is a standardised tool used to calculate the range of movement of joints.¹¹⁸ Based on the evidence/findings reported in chapter 2, research supports the continued use of goniometry in clinical settings. There are three different methods described. The techniques for goniometric measurement should not be interchangeable due to the risk of inconsistent results. Dorsal/volar showed the most reliable results for both inter- and intra-rater results for measurements of passive wrist flexion/extension.^{118,119} Having high ROM measurement reliability is useful because it can determine the success/failure of a given treatment.

3.6.4 Muscle strength

Muscle strength capacity was by means of manual muscle evaluation of a single muscle or group of muscles to evaluate the ability to perform movement against resistance

manually applied against the direction of movement. The scoring used the Oxford Standard Scale, which grades muscle strength scoring between 0 to 5. (refer to Appendix H)

3.7 MEASUREMENT METHODS

The researcher assessed the participants after completion of the eight-week rehabilitation programme. These measurements took place in the occupational therapy department splinting room using the evaluation table. The participant sat on a chair while the assessment took place. The demographics and outcome measure data was recorded on the demographics form (Appendix D) and Occupational Therapy Evaluation Form (Appendix I) and completed at the occupational therapy department.

Measurements were in the following manner:

- a) Participants were required to complete the DASH questionnaire (+/-15 minutes). If a participant was unable to read or write, an occupational therapy technician acted as reader and scribe to assist the patient in completing the questionnaire.
- b) Active extension of the wrist, fingers MPJ and thumb MCP: The researcher used a goniometer to take PM measurements of the fingers and thumb (15 minutes). Positioning was according to the prescribed method as described in Appendix J.
- c) Manual evaluation of muscle strength of wrist extension, metacarpo-phalangeal joint (MPJ) and thumb (10 minutes) was done and recorded by the researcher using the Oxford Standard Scale (refer to Appendix J for the procedure and Appendix H for the Oxford Standard scale).

3.8 DATA COLLECTION METHODS

3.8.1 Range of movement assessment for wrist, thumb and fingers

- The assessment for each participant was conducted as described in Appendix J
- The data for active range of movement of wrist extension, finger MPJ joint extension and thumb MCP extension was recorded on the hand evaluation form in Appendix D for specified joints. Active range of motion would give true

reflection of what the transferred muscles can achieve when opposing muscles contract and relax.

- Passive range of motion of wrist extension from the patients file before tendon transfer was recorded on the evaluation form in Appendix D.
- This numeric data reading from the goniometer was recorded in degrees on the form from zero to the actual degree reached actively. Passive range of motion was not measured on participants.
- Passive range of motion of wrist extension recorded from the patients file before tendon transfer would be compared to active range of motion recordings after tendon transfers and occupational therapy intervention.
- The data was transferred into Excel spreadsheet based on the readings of each joint for analysis
- Coding system was allocated to each participant for anonymity purposes.

3.8.2 Muscle strength testing

- The collection of muscle strength assessment method was as described in Appendix J
- The collected data findings for wrist extension, finger extension and thumb extension were recorded on the hand evaluation form in Appendix I
- The collected data was recorded using Oxford Standard Scale method as indicated in Appendix H
- Data for each movement of the joint was transferred onto an Excel spreadsheet, recording findings of wrist extension, finger extension and thumb extension for analysis.

3.8.3 DASH Questionnaire

- Participants completed the DASH questionnaire (Appendix G) and the occupational therapy technician assisted those unable to read or write to complete the form.

- Each question consisted of a five-point Linkert Scale leading to total score from most excellent performance score to the most unpleasant performance outcome.
- Participants selected one option, which best described their disability or symptom in each question.
- The scores were calculated for each section of the DASH questionnaire, i.e. disability and symptoms, work module and leisure/sports participation.
- For disability and symptoms score: the totalling and equating of the assigned values for all finished responses produced a score out of five. This value was then altered to a score out of 100 by subtracting 1 and multiplying by 25.^{128,129}
- For the work module and leisure/sports module, all four questions needed answering to calculate the score. To get a score out of 100, the assigned values for each response were added up, divided by 4 (number of items), had 1 subtracted and then multiplied by 25.^{128,129}

3.8.4 Patient records

- The researcher reviewed medical files of the participant's involved in the study at the occupational therapy department.
- The researcher submitted a request using patient names and hospital numbers through the file clerk in occupational therapy department for patient files.
- Files were read and occupational therapy notes on patients attendance to appointments scheduled. A date was recorded by the treating occupational therapists on patient files when patient missed previously scheduled appointment date.
- Passive range of motion before tendon transfer surgery was also recorded on patients file and transferred unto the assessment form.

3.9 DATA ANALYSIS

The data analysis included mean, median, minimum, maximum and the standard deviation given for continuous variables. There were incidence counts and magnitude,

together with their connected standard error and 95% confidence intervals, given for categorical variables. The descriptive statistics described the distribution of the sample in terms of the area of interest for the study. To determine the passive range of movement of the affected wrist before tendon transfer and active range of motion after tendon transfer and occupational therapy rehabilitation analysed using descriptive statistics. The demographic questionnaire formulated the nominal data, diversity characteristics of the participants and this was analysed through frequencies and percentages. All analysis was with STATA 15 and evaluated at 5% level. This is based on the 95% confidence levels of patients who had experienced functional improvement and a 5% difference.

Below is the criteria for interpreting the DASH questionnaire findings that would be used.

Table 2.3: The criteria for interpreting scores on the DASH

4	0-29	Total independence in participating in all occupations
3	30-49	Some limitations in participating in occupations (bilateral hand function, unilateral manipulation requiring fine motor skills and lifting or carrying slightly heavy objects)
2	50-79	Participate in occupations with moderate physical support (in tasks that required bilateral hand function, unilateral manipulation and lifting or carrying heavy objects)
1	80-100	Total disability in participating in occupations

Table 2.4: The criteria for interpreting wrist, fingers and thumb extension ROM

	Excellent	Good	Fair	Poor
Wrist extension	0-50	0-39	0-29	0 - 19
Fingers extension MPJ	0-45	35 - 44	25 - 34	0-24
Thumb extension MCP	18 - 20	16 - 18	14 - 16	0-14

3.9.1 Variables

The business dictionary defined a variable as a trait, numeral, or amount that increases or decreases over time, or adopts changed values in different circumstances.¹⁴⁶ A variable represents a quantifiable trait that changes across the research journey. In this research study there were dependent and independent variables when the affected body functions after tendon transfer surgery and completing their rehabilitation occupational therapy programme were measured.^{122,123}

a) Independent Variable

An independent variable is constant and unaltered by other variables being measured. It refers to the form of the research being scientifically manipulated by the investigator.^{122,123}

The variable that the researcher manipulates is the independent or grouping variable. The independent variable in this research is that all participants presented with radial nerve palsy and have received the tendon transfer surgery for radial nerve palsy. The other independent variable in this study were that all these patients had to complete the same Gauteng Provincial Hands Protocol.^{124,125}

Independent: Tendon transfer surgery for radial nerve palsy, Gauteng Provincial Hands Protocol.

b) Dependent Variable

This variable is reliant on other measured factors. The expectation is these variables will change due to manoeuvring of the independent variable or variables; it is the supposed effect.^{124,125}

Dependent: Range of movement, muscle strength, hand function.

3.9.2 Statistical analysis

This process involves accurately organising data and interpreting it in a systematic mathematical manner by following procedures or rules. It involves a methodological system of analysis of numeric data to draw conclusions to narrate its findings.¹⁵¹ Literature indicated that a coding system is necessary to convert raw data collected into numeric codes for the computerised analysis.¹²⁶ Descriptive analysis included frequencies, median, and percentages percentages. Frequency distribution tables and a scatter gram method displayed the results in a graph format after analysis from STATA 15, as reflected in Chapter 4.

3.10 ETHICAL CONSIDERATIONS

a) Do no harm: All measures to prevent harm to the participants were put in place, such as working on a padded table surface, sterilising the goniometer before use and the use of surgical gloves by the therapist, and informing participants to report any discomfort or pain.^{127,128}

b) Beneficence: Maintaining the participant's wellbeing occurred at all times. The participant's beneficence was in knowing they were contributing to the body of knowledge by being part of the research study that would inform Occupational Therapists within the South African context on effectiveness of rehabilitation, and identify possible gaps that would necessitate amendment of the provincial protocol for future patients.^{127,128}

c) Autonomy and control: Ensuring self-determination and autonomy was by explaining verbally, and in the printed informed consent forms, that participation was

voluntary. Questions were answered and participants can choose not to partake or withdraw from the research study if they so wished.

d) Confidentiality: All information would be highly confidential. Participants would not be identified due to number coding system. Research reports and articles in scientific journals would not contain any information that may recognize participants in the study. Records and findings are to be stored in a safe place (Appendix K).^{127,128}

e) Veracity: Considered important was truth telling, to maintain the intrinsic values of the research by conducting accurate measurements and reporting them truthfully. There would be no tampering of the findings by the researcher, and a true reflection maintained at all times. This principle also informed the procedure of the research, whereby there was nothing hidden from the participants, regarding the purpose and procedure of the study being carefully explained to all prior to its commencement.^{127,128}

f) Transferability: The results of this research transferability is limited to similar settings in which there is tendon transfer surgery conducted, if, the same rehabilitation and protocols applied in this study are used.

g) Ethical clearance: The University of Pretoria Ethics Research Committee granted ethical clearance (721/2018) (Appendix L). After asking, the Chief Executive Officer gave permission to conduct research at Steve Biko Academic Hospital (Appendices M). There was no compensation for participants.

h) Bias: The researcher avoided bias by selecting patients from the Orthopaedic Upper Limb Clinic register instead of requesting treating Occupational Therapists to allocate patients to the researcher from their occupational therapy outpatient register. This ensured the Occupational Therapists did not select patients who achieved good results from rehabilitation only. The researcher treated all participants equally and fairly without special favours or privileges. The researcher reported the findings, truthfully and honestly; however, if bias occurred, there would be a report made.

3.11. CONCLUSION

This chapter elaborated on the details of the research process involved in this study. It focused on the research design, research procedures followed, research instruments

and techniques applied to collecting the data. The following chapter will reflect on the results of the research study.

CHAPTER 4

RESULTS

4.1. INTRODUCTION

As indicated in Chapter 1, the research question was ‘What are the functional outcomes of patients that underwent tendon transfers for a radial nerve injury, and completed the prescribed eight-week Gauteng Provincial occupational therapy programme?’

The purpose of the research study was to establish the functional outcomes of patients who underwent tendon transfers for a radial nerve injury and completed the prescribed eight-week Gauteng Provincial Hands Protocol.

The researcher identified and recruited 23 patients from the Steve Biko Academic Hospital (SBAH) Orthopaedics Upper limb register. Of the 23, only 15 were able to come to the hospital and participate in the physical evaluation of the hand, due to national disaster of COVID -19 pandemic and country lockdown. These participants had undergone tendon transfer surgery 24 months prior and completed the Gauteng Health occupational therapy rehabilitation programme.

The researcher and an occupational therapy technician made telephonic appointments with participants who were not able to come to the hospital. They visited the eight participants at their homes, at their convenience, to complete consent forms, demographic information and the DASH questionnaire (English version). Participants completed the forms independently inside their homes while researchers remained outside, in their vehicle, observing COVID-19 safety protocols to minimise human interactions.

The data was analysed using STATA 15 software. Due to the small sample size of 23, a one-sample t-test determined the categories of the joint range of movement and muscle strength, after the completion of rehabilitation post tendon transfer. Correlation of the dependent variables of hand function, joint range of movement and muscle strength was also determined.

The categorisation of this chapter is according to the objectives of the study. Firstly, to determine the affected hand's function in ADL, work and leisure post-radial nerve tendon transfer surgery and occupational therapy treatment using the DASH Questionnaire. Secondly, to determine the active range of movement of the injured hand's wrist, metacarpophalangeal joint (MPJ) and thumb post-radial nerve tendon transfer surgery and occupational therapy using a goniometer. Thirdly, to determine muscle strength of wrist extension, metacarpophalangeal joint (MPJ) and thumb extension post-radial nerve tendon transfer surgery and occupational therapy using the Oxford Standard Scale measurement.

Also explored and analysed were the demographics of the participants, where variables directly or indirectly have an influence on functional outcomes.

This chapter will address the research study's results based on the following:

- a) Demographics of participants in the study.
- b) Employment status following tendon transfer surgery and rehabilitation.
- c) Functional outcomes of tendon transfers following radial nerve injury.

4.2. DEMOGRAPHICS OF THE PARTICIPANTS

Demographics of the participants were considered a variable that may have an influence on the compliance with follow up appointment for rehabilitation, and thus the outcomes measured in this study. Ethnicity, hand dominance, injured hand, age, gender, area of residence, mechanism if injury were determined and unpacked below.

4.2.1. Personal information

The research study consisted of 23 participants. All participants in the study were above 18 years and under the age of 65 years (see Figure 4.1 for age distribution).

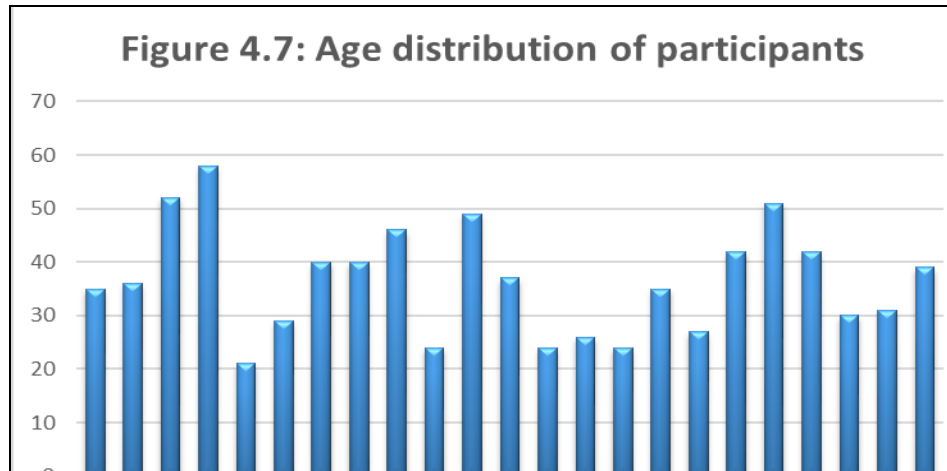


Figure 4.1: Age distribution of participants

Table 4.1 indicates there were 82.61% (n=19) Africans and 17.39% Whites involved in the study. Of the total participants, 91.30% (n=21) were right hand dominant and only 8.70% (n=2) left-handed. It was discovered that 52.17% (n=12) were injured in their dominant hand and 47.83% (n=11) in their non-dominant hand.

Table 4.1: Personal Demographics of the Participants		
Ethnicity	Frequency	Percentage
African	19	82.61%
White	4	17.39%
Hand Dominance		
Right-handed	21	91.30%
Left-handed	2	8.70%
Injured Hand		
Right hand	12	52.17%
Left hand	11	47.83%

4.2.2 Gender and area of residence of the participants

Three of the participants were female and 20 were male (Figure 4.2). The majority of the participants were from Gauteng Province (n= 15), followed by Mpumalanga (n= 4), Limpopo with (n = 3) and a single participant was from North-West (n= 1).

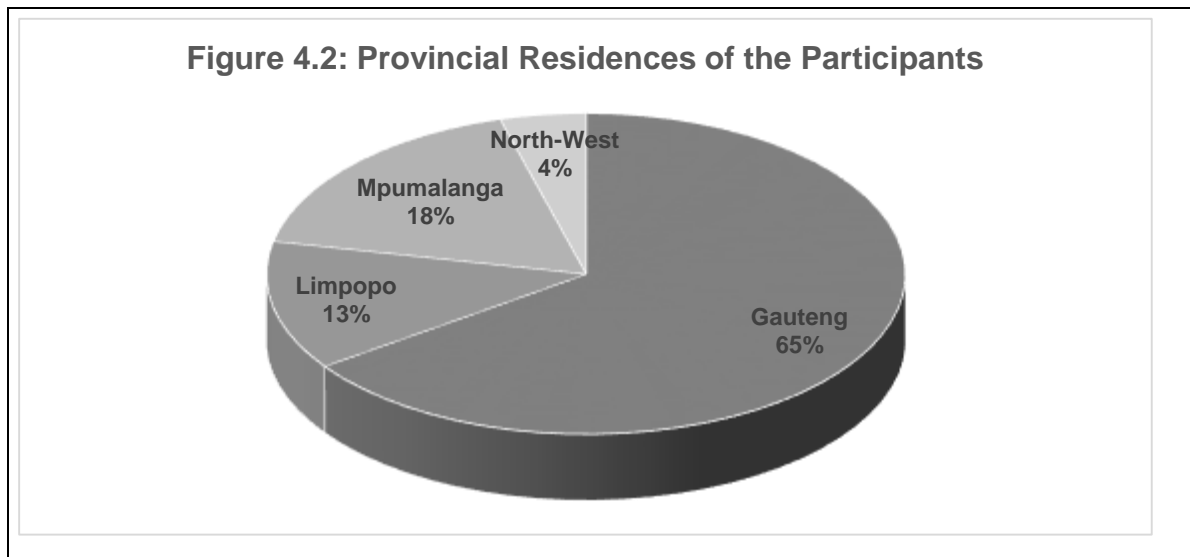


Figure 4.2: Pie chart showing provincial residence of participants

Participants in the study were from Gauteng Province and its neighbouring provinces. Figure 4.2 illustrates the participant distribution in the study. These participants travelled long distances to access treatment and rehabilitation services at Steve Biko Academic Hospital.

Male participants represented 86.96% (n=20) of the sample, which was significantly higher than the female participants at 13% (n=3). Table 4.9 presents the gender of participants involved in the study

Gender	Frequency	Percentage
Female	3	13.04%
Male	20	86.96%

4.2.3 Mechanism of Injury

Figure 4.3 presents the different mechanisms of injuries sustained by the participants. Highest-ranking mechanism of injury was from Motor Vehicle Accidents (MVA) (n= 11), followed by Injury on Duty (IOD), while at work (n= 5), violence related from gunshot (n= 3) and stabbing (n= 3), with the lowest number from falling without any underlying pathology (n= 1).

Figure 4.3 also illustrates the percentages of mechanism of injury. Motor vehicle accidents were in the lead with just over 47.83% (n=11), followed by injury on duty 21.74 % (n=5), gunshot and stabbing incidents tied at 13.04% (n=3) each, and other was 4.35% (n=1).

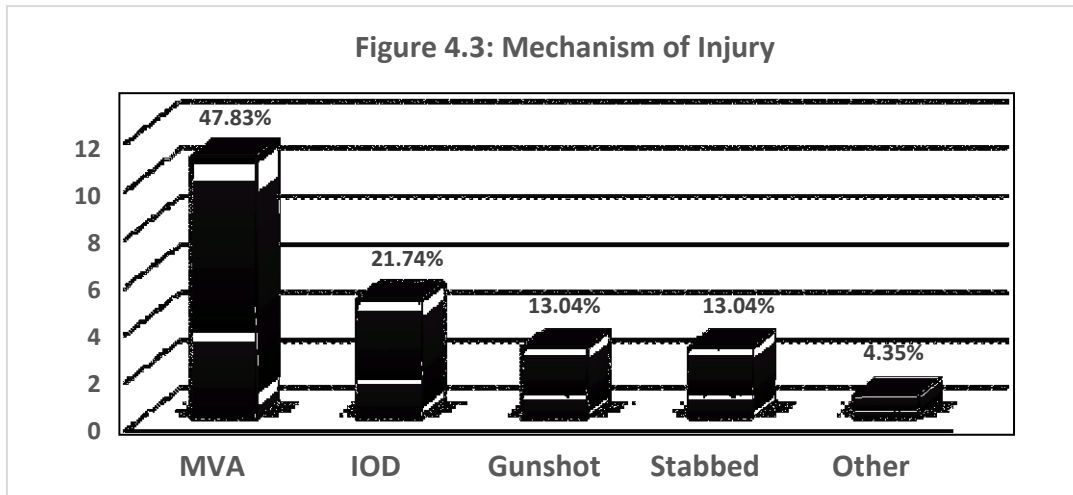


Figure 4.3: Mechanism of injury and percentages

4.2.4 Compliance with rehabilitation

Compliance was a crucial factor regarding patient related factors that may promote healing, yielding positive results. Therefore, it was imperative to measure compliance to the rehabilitation programme using hospital cards to determine whether participants attended the scheduled appointments. Figure 4.4 shows results of compliance to rehabilitation in occupational therapy measured through attendance of all prescribed

and scheduled therapy sessions by the treating occupational therapist, according to the clinical presentation of the patient. Hospital records indicated 30% were non-compliant.

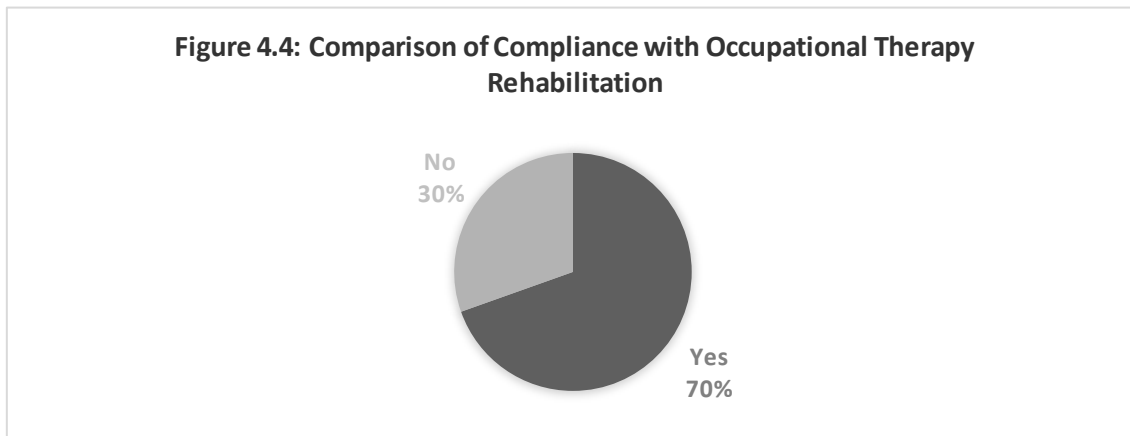


Figure 4.4: Showing results of compliance to rehabilitation

From the initial 23 participants identified, only 15 could physically attend the hospital for the physical evaluation of the hand. Table 4.3 reflect reasons and numbers for those who could not participate in the research study.

Table 4.3: Participants reasons for not being physically evaluated hand	
Number of Declined Individuals	Reasons
17.39% (n=4)	<ul style="list-style-type: none"> • Fear of COVID -19 • Not willing to interact with hospital staff directly during COVID 19 National Disaster • Work obligations
17.39 (n=4)	<ul style="list-style-type: none"> • Lost their employment • No funds or means of getting to the hospital

4.2.5 Employment Status Following Tendon Transfer Surgery and Rehabilitation

Employment status of participants is another factor that may intrinsically motivate individuals to recover fully so that they can financially support their families. Employment status could also play a role in functional outcomes where participants

received reasonable accommodation from their employers while undergoing rehabilitation, and afforded time off work to attend rehabilitation appointments.

Figure 4.5 indicates the number of participants' employment status prior to their injury; the three categories included, unemployed (n=4), employed (n=18) and being a student (n=1).

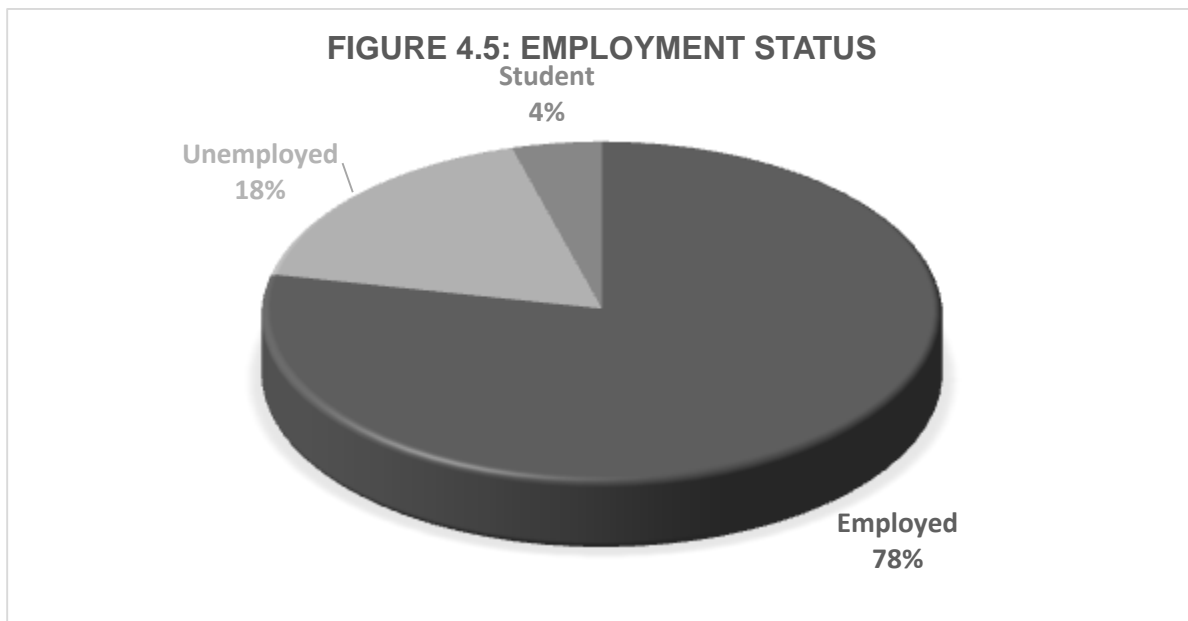


Figure 4.5: Participants employment status

Eight of the participants were able to return to their inherent duties after completing their rehabilitation. Eight participants received reasonable accommodation in other positions after completing their rehabilitation. There were three dismissed from their employment due to the sequelae of their injury and lack of reasonable accommodation within their workplace; of the three dismissed, one participant was among those with surgical implant complication that required further interventions. The other four participants were unemployed, and this group included one student who opted to take a gap year to recover from his injuries.

Forty-eight percent of participants (n=11) were reasonably accommodated while undergoing rehabilitation, while over 52% (n=12) were not reasonably accommodated or re-aligned into light duties by their employers (see Figure 4.6).

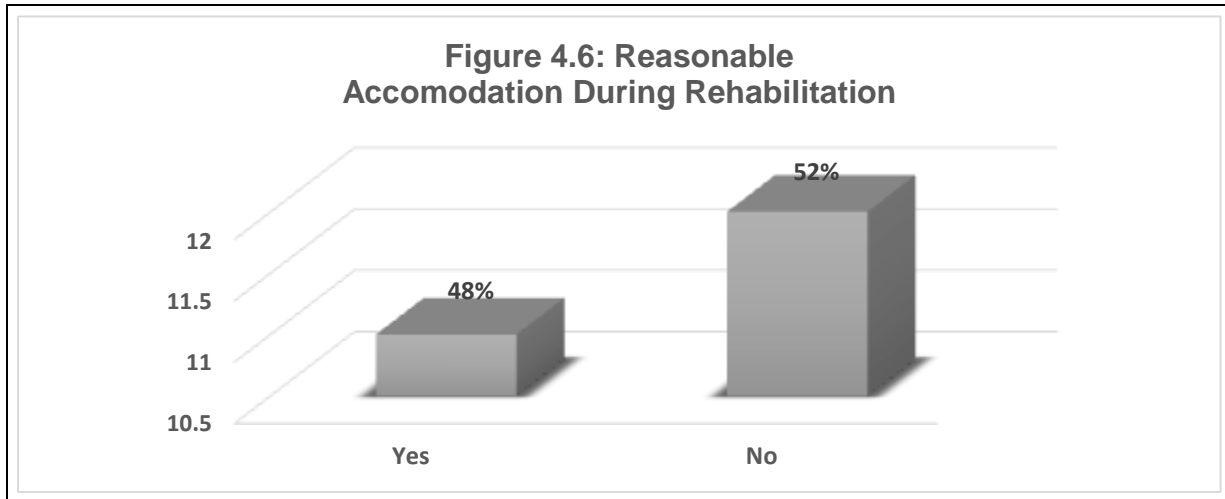


Figure 4.6: Reasonable accommodation during rehabilitation

Eight (30%) of the participants returned to their inherent duties after tendon transfer surgery and completing the Gauteng occupational therapy rehabilitation programme, as reflected in Figure 4.7

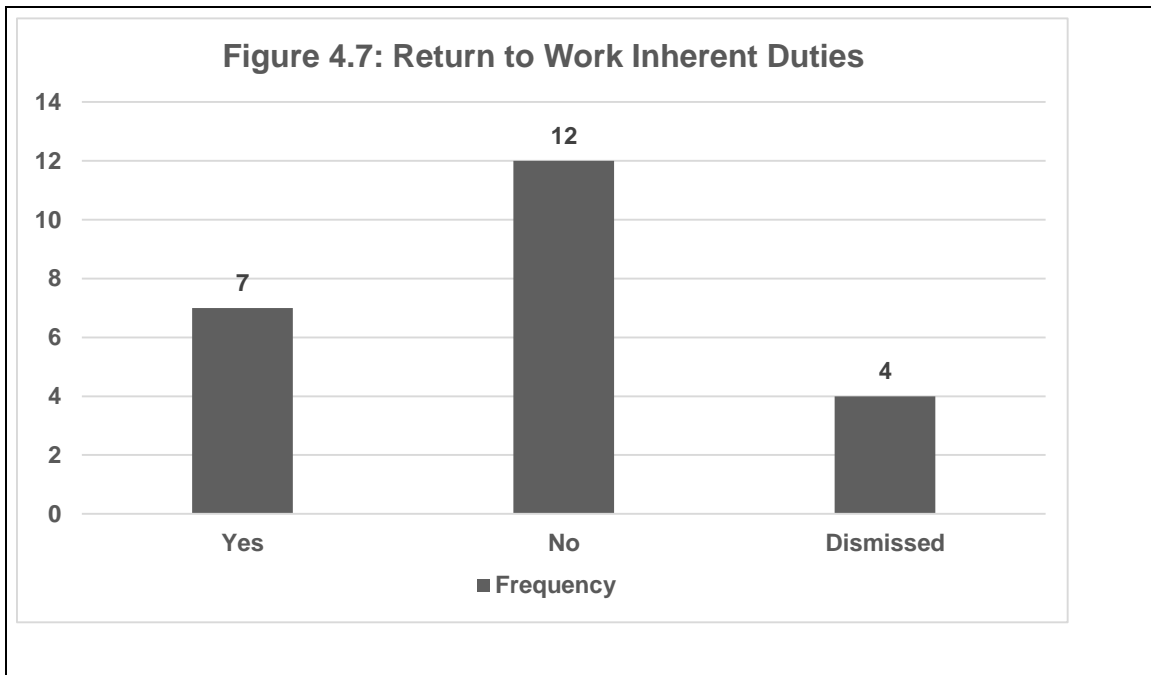


Figure 4.7: Return to pre-injury occupation

Figure 4.7. Illustrates that 52% (n=12) of the participants were not able to return to their pre-morbid normal work duties and 17% (n=4) were dismissed from their work because they were unable to meet the demands of their inherent occupations.

Table 4.4: Job profile of participants

Job Title	Number of participants (n=23)	Percentage (%)
Porter	1	4.34%
Domestic worker	2	8.69%
Farmer	1	4.34%
Information Technology	1	4.34%
Security guard	1	4.34%
General labourers (construction)	2	8.69%
Salesperson	1	4.34%
Packer	1	4.34%
Hairdresser	1	4.34%
Artisans	3	13.04
Call centre agent	1	4.34%
Drivers	2	8.69%
Butcher	1	4.34%
Car mechanic	1	4.34%
Unemployed	4	17.39%

4. 3 FUNCTIONAL OUTCOMES OF TENDON TRANSFERS FOLLOWING RADIAL NERVE INJURY

The DASH Questionnaire evaluated the functional outcomes of tendon transfers and occupational therapy intervention following radial nerve injury, and range of movement and muscle strength of the injured hand. The following sections elaborate these results.

4.3.1. OUTCOMES OF AFFECTED HAND'S FUNCTION IN ADL, WORK AND LEISURE USING DASH QUESTIONNAIRE

All 23 participants completed the DASH questionnaire function and symptoms section. Only 22 participants completed the work module; one participant, who was a student studying towards a computer technician diploma, did not complete indicating that he deregistered a semester to focus on rehabilitation. Only 14 participants completed the leisure/sports module. The DASH questionnaire is in three sub-sections, which are function and symptoms, work modules and leisure/sport module. All scoring was according to the criteria stipulated by the DASH studies.

Table 4.5: Frequency table for the DASH scores

	No. Of Participants	Rating	Description
Disability and symptoms	16	0-29	No disability
	5	30-49	Minimal disability
	2	50-79	Moderate disability
	0	80-100	Severe disability
Work module	12	0-29	No disability
	3	30-49	Minimal disability
	3	50-79	Moderate disability
	5	80-100	Severe disability
Leisure module	11	0-29	No disability
	2	30-49	Minimal disability
	0	50-79	Moderate disability
	7	80-100	Severe disability

According to the score interpretation and a published article by Dash et al.¹⁴⁷ that validated the interpretation, a score between 0-29 is considered to be fully functional with no disability.¹²⁹ The score of the 69.56% (n=16) participants was within 0-29 score on symptoms and function module.¹²⁹ Based on summated responses from the DASH

Questionnaire, 21.73% (n=5) participants who scored between 30-49, were still considered to be functional with the majority of their ADLs with minimal disability. Some limitations in tasks that require bilateral hand function, unilateral manipulation requiring fine motor skills and lifting or carrying slightly heavy objects, by occasionally applying force of 22kg to 45kg, or 11.36kg to 22.72kg frequently or 4.5kg to 9.09kg of force repetitively to move objects for lengthy periods. There were 8.69% (n=2) of participants who scored within the 50-79 category indicating moderate disability.

The work module results indicated that 54.54% (n=12) of participants scored within the category of 0-29. There were 13.63% (n=3) of participants who scored within 30-49 category. Three participants (9.09%) scored within the 50-79 category, which falls within the moderate disability range, indicating they can perform some of their inherent duties but require moderate physical assistance with some aspects of their duties or reasonable accommodation. There were 22.72% (n=5) of participants who obtained the highest score in the 80-100 category, and considered disabled or their hand function severely affected

Only 20 participants involved in the study completed the leisure module, also referred to as sports participation module. The results indicated that 47.82% (n=11) of participants were within the 0-29 category. This was followed by the group scoring 8.69% (n=2), which fell within the 30-49 category group. The last group, 30.43% (n=7) of participants, scored at the highest score, between 80-100 category. This indicated total disability in performing their leisure or sporting activities.

The scores on the function and symptoms module have a minimum score of 3.3, maximum score of 55, and mean score of 21.62 with Standard Deviation (SD) of 12.34. Work module had a lowest score of 0, highest score of 100, mean score of 38.06, SD of 38.28. Leisure module had a lowest score of 25, maximum of 100, and mean score of 69.19 and SD of 31.81.

Figure 4.8 shows results of DASH Questionnaire score in relation to function and symptoms, work and sports/leisure participation with a mean, minimum, maximum and SD scores based on its modules.

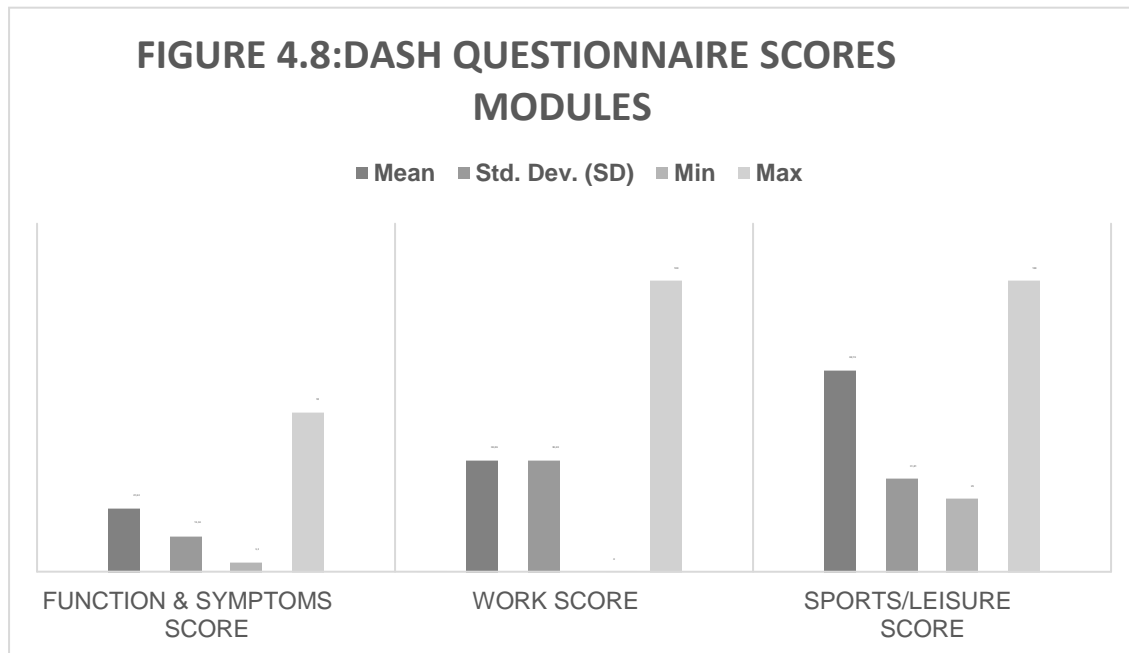


Figure 4.8: DASH Questionnaire score modules

4.3.1.1. DASH Scores Components or Subcategories

A detailed description of the DASH questionnaire sub-component results of function, symptoms and recovery module, work module and leisure/sports module.

a) Function Symptom and Recovery Mean

Twenty-three (n=23) participants' results were analysed using confidence interval of 95% and confidence level of 5%.

Table 4.6 indicates the mean and standard error on function symptom and recovery.

Table 4.6: Mean Score Estimation on Function Symptom and Recovery			
Variable	Mean	Standard Error	Confidence Interval [95%]
Function Symptom and Recovery	21.62	2.57	16.28 - 26.96

Interpretation - based on the mean of 21.62 (22) it is within normal ranges and this category is considered a fully functional hand without any disabilities.

b) Work module mean

Twenty-two (n=22) participants were assessed on the work module, Table 4.7 indicates the mean estimation and standard error for work, when applied at confidence interval of 95% and confidence level of 5%.

Table 4.7: Mean Score Estimation on Work Module			
Variable	Mean	Standard Error	Confidence Interval [95%]
Work Module	38.06	8.16	21.09 - 55.03

Interpretation - based on the mean of 38.06 (38) it is considered to be good function with minimal limitations in some tasks that require manual handling or fine motor hand function.

c) Leisure/ Sport Participation Mean

Fourteen (n=14) participants completed the leisure or sport activities participation module. Nine (n=9) participants reported they do not engage in sports or leisure activities, five (n=5) reported they fear injury due to high contact sporting activities they participated in prior to the accident, the other four (n=4) reported they were not involved in any sporting or leisure activities before the injury.

Table 4.8 indicates the mean and standard error within the confidence interval of 95% and confidence level of 5% for leisure and sport.

Table 4.8: Mean Score Estimation on Leisure or Sport Module			
Variable	Mean	Standard Error	Confidence Interval [95%]
Leisure/ Sport Module	69.19	8.50	50.82 - 87.56

Interpretation - based on the mean of 69.19 (69) it is functional with moderate physical assistance required to execute the task.

4.3.2. OUTCOMES OF ACTIVE RANGE OF MOVEMENT OF THE AFFECTED HAND'S WRIST, METACARPOPHALANGEAL JOINTS (MPJ) OF ALL FINGERS AND THUMB EXTENSION JOINT (MCP)

A goniometer measured the range of movement according to the method described in Chapter 3. There was a comparison of the results with the functional range findings of Brigstocke et al.¹⁰¹

Table 4.9 shows the results of Active Range of movement (AROM) measured on the 15 participants able to undergo physical assessment.

Table 4.9: Active Joint Range of movement of Injured Hand				
Variable	Mean	Standard Deviation (SD)	Minimum	Maximum
Wrist extension	36.66	7.83	26	50
Thumb MCP* extension	17.60	5.03	0	20
Index finger MPJ* extension	47.26	17.66	30	82
Middle finger MPJ* extension	47.66	17.30	30	80
Ring finger MPJ* extension	45.73	18.36	24	80
Little finger MPJ* extension	44.86	17.92	24	80

MPJ: Metacarpal Phalangeal Joint

In Figure 4.9, the table stipulates the mean of the active range of movement of wrist, fingers and thumb extension. The basis of the active range of movement of the thumb's Metacarpo-phalangeal Joint (MCPJ) and fingers of the hand that underwent tendon

transfers with mean, minimum, maximum and standard deviations (SD) scores was on the findings recorded during the evaluation using a goniometer.

Table 4.10 shows the inferential results of the participant's range of motion in active wrist extension, MPJ extension of all fingers and MCP thumb extension of the injured hand. This analysis is based on the 15 participants that were able to attend the hand physical evaluation.

Table 4.10: Inferential results of the wrist, fingers and thumb extension ROM

	Excellent	Good	Fair	Poor
Wrist extension	0-50	0-39	0-29	0 - 19
Fingers MPJ extension	0-45	35 - 44	25 - 34	0-24
Thumb MCP extension	18 - 20	16 - 18	14 - 16	0-14

The results indicate that with active wrist extension, 40% (n=6) of participants scored within excellent results. Five participants (33.33%) scored within good results of active wrist extension and four participants (26.66) scored within fair range of motion.

Finger MPJ active extension is also depicted on table 4.6 for all fingers of the affected hand. Six (40%) participants index finger MPJ extension scored within excellent, six (40%) was good category, three (20%) was fair category. Middle finger MPJ extension scores were six participants (40%) excellent, seven (46.66%) was good and two (13.33) was within fair range. Ring finger MPJ extension scores were four (26.66%) participants fell within excellent category, while seven (46.66%) was within good category and four (26.66%) fell within fair category. Small finger MPJ range of motion was scored with four (26.66%) participants within excellent category, six (40%) within good category and five (33.33) scored within fair category.

Thumb MCP extension range of motion was scored with 80% (n-12) within excellent category, two participants scored (13.33%) good category and one (6.66) scored within poor category.

a) Metacarpo-phalangeal Joints Active Range of movement for Four Fingers

Table 4.11 indicates the active joint range of movement in the four fingers of the injured hand.

Variables	Mean	Standard Error	Confidence Interval [95%]
Index Finger Extension	47.26	4.56	37.48 - 57.04
Middle Finger Extension	47.66	4.46	38.08 - 57.25
Ring Finger Extension	45.73	4.74	35.56 - 55.90
Small Finger Extension	44.86	4.62	34.94 - 54.79

Interpretation - based on the means of 44.68 (45) to 47.66 (48), the above results indicate good outcomes of finger extension of the fingers.

b) Comparison between PROM before tendon transfer and AROM after tendon transfers for wrist extension

Figure 4.3 shows comparisons of the passive range of motion recorded on the evaluation by occupational therapist before tendon transfers and active range of motion after tendon transfers. The comparison was conducted for 15 participants that attended hand physical evaluation.



Figure 4.9: Comparison between PROM before tendon transfer and AROM after tendon transfers

Interpretation – The measurement of all participants’ baseline evaluation of passive range of movement of the wrist was lower in degrees when equated to the active range of movement after tendon transfers and rehabilitation. The results in the graph show that there was improvement of the range of motion in wrist extension when compared with ranges before tendon transfer. Six participants (40%) achieved range of motion of wrist extension between 40° - 50°. Five participants (33.33%) achieved wrist extension range of motion between 30° - 39°. Four participants (26.66%) achieved range of motion between 26°-29°. Pain and hypersensitivity were factors recorded by occupational therapists in the files to be limiting factor when evaluating passive range of movement on patients’ records.

4.3.3 OUTCOMES OF MUSCLE STRENGTH OF WRIST EXTENSION, FINGER EXTENSION MPJ JOINT AND THUMB MCP JOINT

Table 4.12 below are the results criteria of active wrist extension, finger extension and thumb extension or abduction.

Table 4.12: Criteria for wrist, fingers and thumb extension muscle strength

	Excellent	Good	Fair	Poor
Wrist extension	5	4- to 4+	3- to 3+	0 – 2+
Fingers extension MPJ	5	4- to 4+	3- to 3+	0 – 2+
Thumb extension MCP	5	4- to 4+	3- to 3+	0 – 2+

a) Wrist Extension Muscle Strength

The manual Oxford Standard Scale measured the muscle strength of the wrist. Muscle strength measured, was of the wrist extension, which facilitates the release and placing of objects. Figure 4.5 presents the findings of the scores for wrist extension, finger extension and thumb extension muscle strength. There was no baseline for muscle strength of wrist extension. It is inherent that severed radial nerve results in no active wrist extension, thus muscle strength baseline for wrist extension would be 0 (zero) in all participants.

TABLE 4.13: Oxford Standard Scale score of the wrist extension muscle strength

MUSCLE STRENGTH OF WRIST EXTENSION	FREQUENCY	PERCENTAGE (%)
3⁻	1	6.67%
3	1	6.67%
3⁺	5	33.33%
4	6	40.00%
4⁺	2	13.33%

None of the 15 assessed participants had muscle strength below 3 minus (3⁻) after tendon transfer surgery. Figure 4.4 indicates the mean of 3⁺, minimum of 3⁻ and

maximum 4⁺ of wrist muscle strength on the 15 participants who underwent physical evaluation of the hand.

Muscle strength of the wrist extension showed that eight participants (53.33%) scored within results. Seven participants (46.67%) scored within fair muscle strength of wrist extension.

b) Fingers Extension Muscle Strength in MPJ

The muscle strength was measured in each finger in the direction of extension within the metacarpal phalangeal joint (MCPJ), following the guidelines of Oxford Standard Scale. The ranges measured in the 15 participants were: 13 participants had muscle strength between 3 to 4 on the Oxford Standard Scale, one participant (n=1) had a muscle strength of 3 minus (3⁻) and one participant had muscle of 4 plus (4⁺) on the Oxford Standard Scale (refer to appendices F for description).

TABLE 4:14 Oxford Standard Scale finger extension at the MPJ muscle strength

MUSCLE STRENGTH OF FINGER EXTENSION (MCPJ)	FREQUENCY (N)	PERCENTAGE (%)
3⁻	1	6.67%
3	4	26.67%
3⁺	4	26.67%
4	5	33.33%
4⁺	1	6.67%

Figure 4.14 indicates mean (4), minimum (3⁻) and maximum (4⁺) of wrist muscle strength on the 15 participants who underwent physical evaluation of the hand. Oxford Standard Scale grade 4 was noted to be the highest at 33.33% (n=5), followed by a tie of 3⁺ at 26.67% (n=4) and 3 at 26.67% (n=4). The lowest Oxford Standard Scales were 4⁺ at 6.67% (n=1) and 3⁻ at 6.67% (n=1).

The results of MPJ finger extension muscle strength showed that six participants (40%) scored within good category. Nine participants (60%) scored within fair category.

c) Thumb Extension Muscle Strength at MCP

One of the 15 participants had a muscle strength of zero (n=1), and other participants' muscles strength ranged between 3 minus (3⁻) and 4 plus (4⁺). Mean was 3 plus (3⁺), minimum was zero (0) and maximum was 4 plus (4⁺).

TABLE 4.15: Oxford Standard Scale thumb MCP extension

MUSCLE STRENGTH OF THUMB ABDUCTION	FREQUENCY (N)	PERCENTAGE (%)
0	1	6.67
3 ⁻	4	26.67%
3	3	20.00%
3 ⁺	3	20.00%
4 ⁻	1	6.67%
4	2	13.33%
4 ⁺	1	6.67%

Thumb extension on the MCP showed that four participants (26.67%) were within good category. There were 10 participants (66.67%) results which was within fair category on thumb extension. One participant (6.67%) scored within poor category

4.4 CONCLUSION

Personal demographics had multiple components: -

Ethnicity: African and White

Dominance: right and left-handed, there were no ambidextrous participants. The injured hand was either the dominant or the non-dominant hand.

Gender: the majority of participants were male (n=23).

Employment status: four of the 23 participants were dismissed and thus unemployed, one participant was a student, and the other 18 had full-time employment. Employers only allowed reasonable accommodation to 11 of the participants, the other 12 returned to their normal work duties during rehabilitation and after completing rehabilitation.

Participants were from four provinces, Gauteng, Limpopo, North-West and Mpumalanga, with the largest group n=15 from Gauteng Province.

Mechanism of injury had five categories, which were MVA (n=11), IOD (n=4), Stabbing and Gunshot, each with (n=4), and other cause was least with (n=1) where participant fell and sustained fractured humerus resulting in radial nerve palsy. Rehabilitation compliance, 16 of the 23 participants were compliant with rehabilitation before and after tendon transfer surgery. Seven of the participants were not compliant to attending scheduled occupational therapy rehabilitation sessions as required or stipulated by their treating therapists.

The DASH questionnaire results in function and symptoms were from all 23 participants. Twenty-two participants completed the work module and 14 participants only completed leisure and sport participation module. The mean scores ranged between, 21.62 for function and symptom, 38.06 in work module and 69.19 for leisure participation.

Assessment results of active range of movement in the injured hand's wrist and thumb extension had different ranges; wrist extension had a mean of 36.66, thumb extension was 17.60, index to small fingers metacarpal phalangeal joint (MPJ) mean ranged between 4.86 and 47.66. Physical assessment was only possible on 15 of the participants who were able to come to the hospital.

The Oxford Standard Scales measured the outcomes of the muscle strength of the wrist, thumb and fingers extension. For the wrist it ranged between 3 minus (3⁻) to 4 plus (4⁺), Metacarpo-phalangeal joint also ranges between 3 minus (3⁻) to 4 plus (4⁺) and the thumb abduction was the only component which ranged between zero (0) and 4 plus (4⁺) in the 15 participants physically assessed.

Active range of movement wrist flexion and DASH scores, confidence interval was set at 95% and 5% for confidence level. Wrist extension had mean of 36.66 good and thumb extension mean of 17.60 good. The four fingers MCPJ extension had range of means of 44.68 to 47.66 good. DASH components mean scores differed, functional and symptoms had mean of 21.62 indicating good function. Work module had a mean of 38.06 functional with some limitations and leisure or sport participation had a mean of 69.19 requiring physical assistance.

This chapter indicated results of the research demographics of participants, functional outcomes from the affected hand after the tendon transfer surgery and occupational therapy rehabilitation. It further elaborated on results of the DASH questionnaire, range of movement of the wrist and fingers and muscle strength of the wrist. There was a comparison of the mean scores for each component of the DASH with the norms, and DASH means were compared to the hand joint range of movement in the three areas of the hand, wrist, thumb and fingers. The following chapter will elaborate on the interpretation of these results and the factors that may have influenced or led to these findings.

CHAPTER 5

DISCUSSION

5.1 INTRODUCTION

In this chapter, the researcher elaborates the findings more in-depth. In the Northern Gauteng region of South Africa, patients with radial nerve injuries receive a referral to the upper limb specialist units at Steve Biko Academic Hospital for possible tendon transfers and management. The hospital provides the services of orthopaedic surgeons specialising in upper limb trauma and reconstruction, as well as occupational therapists and physiotherapists.

5.2 DEMOGRAPHICS OUTCOMES

The aim of this study was establishing functional outcomes of tendon transfers following radial nerve injury and occupational therapy rehabilitation programme. The study further revealed more data which proved to be pertinent in this study. The researcher noted, other variables, which were identified to have an influence on the outcomes of the study. In the section the demographics are elaborated based on participant's details, employment status, compliance with rehabilitation and complications developed.

5.3 DEMOGRAPHIC FACTORS

The purpose of this study was to establish functional outcomes of tendon transfers following radial nerve injury and occupational therapy rehabilitation programme. The study revealed demographic variables, which proved to be pertinent to the compliance of participants to treatment. This section presents in detail the compliance based on demographics.

5.3.1 Compliance with rehabilitation

Compliance was a crucial factor in patient-related factors that could promote healing, yielding positive results. Therefore, it was imperative to measure compliance to the Gauteng Provincial Hands Protocol using hospital records to establish whether participants, as indicated by the treating occupational therapists, attended all appointments. It is imperative to note that the Gauteng Provincial Hands Protocol rehabilitation programme does not prescribe the number of sessions but rather weeks for rehabilitation post-tendon transfer surgery. Therefore, the treating occupational therapist had the autonomy of deciding the number of sessions the patient would need on a weekly basis, based on the clinical presentation of each patient and severity of the injury. On average, attendance for rehabilitation to the hospital was 10.2 sessions for the entire group following discharge from occupational therapy.

Table 4.4 shows the results of compliance to rehabilitation in occupational therapy, measured through attendance of all prescribed and scheduled therapy sessions by the treating Occupational Therapist, based on the severity of the injury and the patient's clinical presentation, socio-economic status and area of residence. Results revealed that 69.57% (n=16) were compliant and attended all scheduled rehabilitation appointments; only 30.43% (n=7) were not compliant with their scheduled treatment sessions due to various reasons.

Identified in the demographics of the participants were variables that may have had an impact on compliance.

For four participants, there was no reasonable accommodation in their work while undergoing rehabilitation, and they had to return to their normal duties despite their clinical presentation, having a splint on their hand and recommendations by the treating occupational therapist to the employer. There was reasonable accommodation for three participants, but they did not attend all scheduled appointments possibly due to work commitments or fear of dismissal.

5.3.2. Personal information

The researcher noted, based on the results illustrated in Table 4.1, the ethnicity of the participants was limited to African and White participants; there were no other racial groups represented on the attendance register. The results depicted that 82.61% (n=19) of the participants were African and 17.39% (n=7) White who had sustained radial nerve injury and underwent tendon transfer and rehabilitation from occupational therapy. There is no scientific evidence that could provide rationale for the findings of two racial groups mainly involved with this type of injury. The statistics department at Steve Biko Academic Hospital indicated that the demographics within the South African context consult at this facility for medical and surgical services; this also includes foreign national patients.

A large proportion of Africans in Northern Gauteng region and its neighbouring provinces still reside in impoverished townships, semi-rural and rural residential areas stricken by high crime rates, lack of resources and high usage of public transport, mainly taxis, whereas most of the White population reside in more affluent suburban areas closer to all amenities and mainly rely on private transportation. This had an influence on accessibility to hospitals, and severely affected patients attending rehabilitation from other provinces, townships and rural communities. Patients reported financial constraints in frequently accessing the hospital in the city for intervention; compounding this is the lack of financial support from employers. The majority of the participants had to depend on a temporary social grant or family members for financial assistance to enable them to access treatment at Steve Biko Academic Hospital.¹³⁰

5.3.3 Hand Dominance and Injured Hand of Participants

Hand dominance results also proved to be a variable that has an influence on hand function post-tendon transfers. Results indicated that 91.30% (n=21) of participants in the study were right hand dominant, and there were 52.17% (n=12) who had injured their right dominant hand. This implies a severe compromise in their functional independence in ADL. A study conducted by Yancosek¹³¹ noted that upper limb trauma

frequently occurs on the dominant limb, thus producing a “double-impact injury,” whereby individuals are left with single-handedness function and have to rely on the non-dominant hand, which is less effective in some tasks.¹³¹

The participants who sustained injury to their dominant hand (52.17%) relied on their families for support and physical assistance in performing their ADL, iADL, leisure, or work while undergoing rehabilitation. This coincided with findings in Chapter 2, Section 2.11 by Jaquet et al.²² who noted loss of efficacy, control and learned helplessness by the patients. This loss of efficacy and control reinforces “helplessness” and autonomy of the individual’s ability to participate in familiar related habitual tasks and independent functioning in the most private self-care activities using techniques learned through rehabilitation. In contrast, 47.83% (n=11) of the participants were injured on their left non-dominant hand. This group could still perform some ADL, iADL, leisure and work because their dominant hand was not injured. They required minimal assistance with tasks requiring bilateral hand function because their dominant hand was still able to perform the majority of their tasks.

5.3.4 Age, gender, area of residence and mechanism of injury

The participants’ age, gender and area of residence were factors considered to have an influence on the outcomes of rehabilitation. Below is a detailed discussion of their influence or impact in this research.

- **Age**

Research participants involved were between the ages of 18 and 65 years, which is important because at this age most people are working and contributing towards the Gross Domestic Product (GDP) of the country. This group is economically viable, because the majority of them are working and supporting their families. These injuries would have significant implications to a larger population should they not be managed properly in hospital settings, because this would lead to higher levels of employable individuals unable to work due to deformities, which could lead to permanent disability

and become a burden to the state that is already in economic turmoil. This group also concurred with the inclusion criteria of the study.

- **Gender**

There were 20 males (86.96%; n=20) and three females (13.04%; n=3) who presented with injuries that resulted in radial nerve injury necessitating tendon transfer surgery and rehabilitation. This shows a huge discrepancy, indicating that males are more prone to sustaining these types of injuries compared to females. This correlated with the findings of a retrospective study in Groote Schuur Hospital in Cape Town, discussed in Section 2.2 in Chapter 2, which revealed high levels of violence towards males (73.3%) and those younger than 40 years (74.6%).⁷ This further correlated with the findings made in traumatic occupational hand injuries treated public hospitals at Chris hani Baragwaneth Hospital. Multiple international studies also noted that males sustained high rates of radial nerve injuries when compared to females.

- **Area of Residence**

The results also depicted that Gauteng had the highest number (65.22%; n=15) of participants who sustained traumatic injuries to the radial nerve and underwent tendon transfer surgery and rehabilitation. The second highest province in this study was Mpumalanga with 17.39% (n=4) of participants, third was Limpopo with 13.04% (n=3) participants and lastly, North West with 4.35% (n=1) in the study. The majority of these participants returned to their homes so that family members could care for them. They required assistance with the performance of their ADL, work and leisure involvement. This conclusion correlated with those illustrated by Ataguba et al.¹³² who concluded that the high population in Gauteng is because it is the centre of the country's trade and industry. It caters for about 30% of South Africa's (SA) total population¹⁵⁹, and its age distribution shows that 73%¹³² of these residents is of employable age. This provides rationale for higher numbers of these types of traumatic injuries within the province.

The participants that reside outside of Gauteng travelled long distances and spent hours on the road, using public transport to go for rehabilitation, which indicated time off work

and money spent on travel to Steve Biko Academic Hospital. Some of the provinces do not provide hospital transport for outpatients attending their therapy appointments. This resulted in these participants having to spend their own money to use public transportation to access scheduled rehabilitation appointments at the hospital.

- **Mechanism of injury**

Mechanism of injury had five categories, which were MVA (n=11), IOD (n=4), Stabbing and Gunshot, each with four (n=4) and unknown cause was least with one (n=1). This was slightly different from other countries, which indicated their injuries mainly resulted from work related injuries and motor vehicle accidents. The findings from this research coincide with the research conducted by Norman et al.¹³³ as well as Nicol et al. in Section 2.4 in Chapter 2.

5.3.5 Employment Status

In the entire cohort of the study, there were 18 employed participants, four unemployed and one full time student. Of the 18 employed, 13 received reasonable accommodation into unspecified light duties while undergoing rehabilitation, while five were forced to return to their inherent work duties. Reportedly the employer adopted “no work, no pay” principles for their employees. This was noted to be in contravention of the South African Employment Equity Act Number 55 of 1998, Code of Good Practice and Technical assistance guidelines, Chapter 23, which promotes reasonable accommodation¹⁰² in the work place as discussed in Chapter 2, Section 2.12 on socioeconomic implications of hand injuries.^{79,80,81,82}

Eight participants were able to return to their normal pre-morbid occupations and six never returned to work because they alleged their employer informed them there were no light duties or reasonable accommodation available in their companies. Four participants reported they were dismissed because their employer required them to be on duty performing normal duties while undergoing rehabilitation, despite

communication from the hospital and wearing a static splint on their hand. Allegedly, when they were unable to meet the physical demands of their occupations, the employer dismissed them. The student reported he was unable to meet the physical demands of his practical's, despite reasonable accommodation, therefore he deregistered the academic year and resumed with his studies the following year.

The majority of patients attending occupational therapy at Steve Biko Academic Hospital after traumatic injuries, which included peripheral nerve injuries, report they are somewhat prejudiced against by their employers. Their employers mostly ignore their rights, mainly due to lack of knowledge of the policies by employees and their rights. Most patients report that, "*salaries have been stopped*" and their employer is instituting a "*no work, no pay*" system thus putting employees under pressure to return to work prematurely, which may further complicate their injuries. Others must be encouraged by occupational therapists to apply for a temporary disability grant while they undergo therapy to ensure they have transport money to come for therapy and their families are able to have basic needs. Those coming from other provinces receive a referral to their local hospital, which transports them to academic or tertiary hospitals for treatment, at great expense to the state.

5.2 OUTCOMES POST-TENDON TRANSFERS AND REHABILITATION

As mentioned, the main purpose of this research was to establish functional outcomes of "tendon transfers for a radial nerve injury" and completed on of the recommended Gauteng provincial occupational therapy eight-week rehabilitation programme.

5.2.1. OBJECTIVE ONE: TO DETERMINE THE FUNCTION OF THE AFFECTED HAND IN ADL, WORK AND LEISURE POST-RADIAL NERVE TENDON TRANSFER SURGERY AND OCCUPATIONAL THERAPY

The DASH questionnaire is a self-directed evaluation tool designed to calculate the outcomes of self-reported upper limb disability and symptoms, work and leisure

participation.^{101,104} Participants completed the DASH questionnaire, which was then scored by the researcher. The scoring guideline of the DASH stipulates that lower scores reflect low disability, and high scores reflect further impairments or permanent limitations. The DASH questionnaire cannot specifically indicate that a particular score, which type of disability, or objectively determine whether an individual patient is able or unable to work.^{101,104,133} However, according to the score interpretation, and a published article by DASH et al. that validated the interpretation, a score between 0-29 is considered to be fully functional.¹³³ Therefore, the researcher objectively grouped the participants responses' on the selection of answers chosen. A discussion of the three aspects measured by the DASH follows.

a) Symptoms and Function

Participants completed the DASH questions of the standardised tests to establish whether they are functional in their ADL, iADL, work and leisure post-tendon transfer and following the occupational therapy rehabilitation programme. According to the DASH questionnaire scoring system, the higher the score the higher the limitation in daily functioning. As indicated, the scores were calculated and interpreted based on the prescribed categories of the DASH test instrument.

Twenty- three participants involved in the study completed the DASH questionnaire. The results indicated 69.56% (n=16) of the participants were competent to actively participate in their ADL independently. This group of participants is deemed capable of returning to their pre-morbid occupations or be gainfully employed in the work sector. The score of 16 participants were within the 0-29 range, which indicated total independence in engaging in ADL that necessitate upper limb function; thus, considering them to be within normal function.

It was found that 21.73% (n=5) of participants scored in the 30-49 category. Based on the responses, they are functional in the majority of their ADL, IADL, work and leisure; however, there were some limitations in tasks that require bilateral hand function, unilateral manipulation requiring fine motor skills and lifting or carrying slightly heavy

objects, by occasionally applying force of 22kg to 45kg , or 11.36kg to 22.72kg frequently or 4.5kg to 9.09kg of force repetitively to move objects for lengthy periods.¹⁴⁸ Three participants (n=3) from this group presented with ulnar nerve neuropraxia, which was discussed with the orthopaedic surgery upper limb consultant. These participants were contacted for follow up at the upper limb clinic for detailed evaluation by the orthopaedic consultants and registrars; they had to have x-rays and further detailed assessment. After review of their most recent x-rays, the conclusion was that the participants experienced plate failure complications and bone swelling over a year post-tendon transfer surgery, and these related to bone healing and positioning of the plate from their initial surgery before the tendon transfer surgery.

There were 8.69% (n=2) of participants who scored within the 50-79 category. This group reported they were able to engage in their ADL, iADL, work and leisure with moderate physical support in tasks that required bilateral hand function, unilateral manipulation and lifting or carrying heavy objects. A study in India, by Moussavi et al.¹⁰⁸ had similar findings, as they found participants experienced an improvement in their daily function.

This study's findings correlate with the findings of the studies conducted in India, America, Europe and Turkey on Dash scores, indicating independent function in their ADL,^{108,109,110,111} as indicated in Chapter 2, Section 2.16.3. This study found that 69.56% (n=16) of participants were able to engage with their ADL, iADL, work and leisure independently and considered their injured hand to be functioning normally. It further discovered that 21.73% (n=5) of participants could also be classified as independent in engaging in their ADL with mild difficulty of function in certain tasks requiring heavy bilateral hand function, unilateral manipulation that requires fine motor function and lifting or carrying slightly heavy objects. This coincided with the results stipulated in Chapter 4, Section 4.2.1.1, indicating a mean of 21.62 on the symptoms and function module indicating good results.

b) Work Module

Twenty-two participants completed the work module on the DASH questionnaire. The results indicated that 54.54% (n=12) of participants scored within the category of 0-29, which is functional in their ability to work independently without reasonable accommodation or physical assistance.¹³³ They have no limitations in their abilities to perform their occupational demands or be gainfully employed in the open labour market. However only 34.78% (n=8) was able to return to work and be gainfully employed after completing tendon transfer surgery and occupational therapy rehabilitation.

There were eight participants (34.78%) deemed capable to return to their normal pre-morbid occupations after completing the rehabilitation programme. Six (26.08%) never returned to work because they reported their employer informed them there were no light duties or reasonable accommodation available in their companies. Two participants were still attending treatment due to plating complications and they are currently receiving a disability grant. Four participants reported their employer dismissed them because he required them to be on duty performing normal duties while undergoing rehabilitation, despite communication from the hospital and wearing a static splint on their hand. They reported they are now financially dependent on their families since the cancelling of their disability grant after they had recovered from their injuries.

There were 13.63% (n=3) of participants who scored within 30-49 category. This indicated they were able to return to work or have gainful employment in the open labour market with mild limitations in tasks requiring heavy bilateral hand function, unilateral manipulation or moderately heavy occupations, such as occasionally apply 9kg to 22kg of force and/or repeated force 4.45kg to 11.36kg, and/or constantly moving objects up to 4.4kg of force.¹³³

There were 9.09% (n=3) of participants who scored within the 50-79 category, which falls within the moderate disability range, indicating they can perform some of their inherent duties but require moderate physical assistance with some aspects of their duties or reasonable accommodation. There were 22.72% (n=5) of participants who

obtained the highest score in the 80-100 category, and considered disabled or their hand function severely affected. These five participants did not return to work and fully dependent on the disability grant and financial and social support from their families. This indicates that these participants are now on social disability grant, which is already strained in the country due to high levels of disability and impairment, lack of compliance, and following labour laws to reasonably accommodate people with disabilities.^{79,80,81,82} The work module had a mean of 38.06 as indicated in Chapter 4, Section 4.2.1, which falls within functional level of performance.

The findings on work ability were observed to be consistent with the findings observed by the American Hand Journals' published article of DASH Score analysis of long-term results post-tendon transfer for radial nerve palsy, conducted whereby 89% of the participants remained employed. In this study, 78% (n=18) were employed and 4% (n=1) a student before they underwent tendon transfers surgery and rehabilitation; 18% (n=4) were unemployed before undergoing tendon transfer surgery and rehabilitation; 68.17% (n=15) of the participants were employable in their pre-morbid occupations or in the open labour market after tendon transfer surgery and rehabilitation.

According to the findings of this research, 9.09% (n=3) of the participants would require alternative placement or reasonable accommodation from their inherent occupation performed prior to the injury. An additional 22.72% (n=5) were considered totally disabled and unable to return to their occupations..Skoll et al.¹³⁴ found that 13 of 17 participants returned to their employment after radial nerve tendon transfer and only one of seven heavy physical workers returned and was able perform his inherent duties.

Majority of participants were unable to return to work were unskilled manual labourers; few were semi-skilled to skilled employees. These findings correlated with the findings stipulated by Opsteegh et al.,⁷⁸ that the majority of unskilled to semi-skilled (blue collar) employees have higher rates of not returning to work for multifaceted reasons, as stipulated in Chapter 2. The five participant's occupations entailed manual, heavy and physical demanding occupations which prevented them from returning to their previous

employment. These five participants correlated with findings by Skoll et al and Opsteegh et al

A study in India reported in Chapter 2, Section 2.7, conducted to establish outcomes of tendon transfer for radial nerve paralysis between 2005 to 2009, agreed with the findings of this research that hand ability and return to work in the DASH score showed satisfaction following surgery.

c) Leisure/Sports Participation

Only 14 participants involved in the study completed the leisure module, also referred to as sports participation module. The results indicated that 47.82% (n=11) of participants were within the 0-29 category.¹⁴⁷ This implied they are considered fully functional in their leisure or participation in sport activities without limitations. This was followed by the group scoring 8.69% (n=2), which fell within the 30-49 category group. This group was able to participate in leisure or sporting activities with mild limitations; the observation was that their leisure and sports tasks required fine motor coordination, eye-hand-foot and foot-eye-foot coordination.

Another group at 8.69% (n=2) scored the same, falling within the 50-79 category. This group had difficulties in executing leisure or sporting activities and required assistance and guidance to perform their leisure activities independently.

The last group, 30.43% (n=7) of participants, scored at the highest score, between 80-100 category. This indicated total disability in performing their leisure or sporting activities. This severely affected their leisure profile, and they indicated they also experienced anxiety performing their activities despite not involving the affected limb. They reported having trouble with balancing, especially with high contact sports activities. Other studies related to this injury did not identify this. The researcher notes this could be due to the reaction of the body to the changed biomechanical function of the injured hand.

The researcher noted a paucity of literature with specific measures of leisure participation following tendon transfers. However, an article in the United Kingdom

stipulated that a discussion was necessary with the hand surgeon and hand therapist before patients engage in leisure participation. It further elaborated that after tendon transfer and rehabilitation, patients can sometimes take up to six months before they return to the leisure activities they previously engaged in before the tendon transfers.^{135,136} This was noted to be consistent with this study, because 65.20% (n=15) participants were able to return to their leisure participation after completing the rehabilitation following radial nerve palsy; however, this was noted to be after a prolonged period of more than eight months. The other 30.43% (n=7) indicated they were unable to engage in leisure activities and were limited by fear of another injury to the upper limb.

5.2.2. OBJECTIVE TWO: TO DETERMINE THE ACTIVE RANGE OF MOVEMENT OF THE AFFECTED HAND'S WRIST EXTENSION, MPJ EXTENSION OF ALL FINGER JOINTS AND THUMB MCP EXTENSION POST-RADIAL NERVE TENDON TRANSFER SURGERY AND OCCUPATIONAL THERAPY

As discussed in Chapter 2, range of movement is a worldwide indicator for successful surgical and non-surgical management of upper limb trauma. Brigstocke et al.¹⁰¹ evaluated 40 normal subjects, 20 males and 20 females, to establish their ideal range of movement necessary to engage in ADL, iADL, work and leisure. They deduced that 40° extension, 40° flexion and a combined 40° radial-ulnar deviation allowed a minimal purposeful range of movement in the normal population.¹⁰¹

These findings are consistent with the measurements obtained from the participants in this study. However, most of the participants range of movement of the wrist in this study fell slightly below 40° extension of the wrist, which is considered to be the ideal range of movement by Brigstocke et al.¹⁰¹ Four participant's wrist range of movement was measured to be below 30°, these were participants recorded to be non-compliant in attending their scheduled appointments for rehabilitation by their treating occupational therapists.

The results indicate that with active wrist extension, 40% (n=6) of participants scored within excellent results. Five participants (33.33%) scored within good results of active wrist extension and four participants (26.66) scored within fair range of motion.

Finger MPJ active extension results showed that six (40%) participants index finger MPJ extension scored within excellent, six (40%) was good category, three (20%) was fair category. Middle finger MPJ extension scores were six participants (40%) excellent, seven (46.66%) was good and two (13.33) was within fair range. Ring finger MPJ extension scores were four (26.66%) participants fell within excellent category, while seven (46.66%) was within good category and four (26.66%) fell within fair category. Small finger MPJ range of motion was scored with four (26.66%) participants within excellent category, six (40%) within good category and five (33.33) scored within fair category.

Thumb MCP extension range of motion was scored with 80% (n-12) within excellent category, two participants scored (13.33%) good category and one (6.66) scored within poor category. The comparative analysis of the passive range of motion before tendon transfer surgery and active range of motion after tendon transfer and occupational therapy rehabilitation results show that there was improvement of the range of motion in wrist extension when compared with ranges before tendon transfer. Six participants (40%) achieved range of motion of wrist extension between 40° - 50°. Five participants (33.33%) achieved wrist extension range of motion between 30° - 39°. Four participants (26.66%) achieved range of motion between 26°-29°. Pain and hypersensitivity were factors recorded by occupational therapists in the files to be limiting factor when evaluating passive range of movement on patients' records.. These findings indicate that there is improvement in range of motion after tendon transfer surgery and occupational therapy rehabilitation.

Latheef et al.⁹⁹ study in Europe had an expected value of 3.3 years follow-up which revealed range of wrist extension as 42% and 86%, pertaining to the other unaffected wrist. Other measured of movement patterns fell within the functional range and work

trial confirmed good return of function. A prospective study by Sharma et al.¹⁰⁰ in India revealed that 44% of the patients had good wrist extension of more than 29°, 56% of the patients had fair wrist extension between 0° and 29° with mean extension of 26° (15°–40°).¹¹⁶ Based on these criteria, Moussavi et al.¹⁰⁸ also found that participants had fair (10.33%) results and other groups had 89.6% excellent results with their wrist extension, finger extension was within fair (23.6%), good (74.9) and excellent (5.6%), and thumb abduction or extension was measured to be fair (42.36%), good (19.93%) and excellent (5.6%).¹⁰⁸

Results of this study also correlates with extension of the wrist, fingers and thumb extension. Participants' range of movement was within similar ranges and their hands were functional. This enabled them to engage actively in their ADL, work and leisure independently and others with minimal to moderate limitations. Findings of this study shows similar results with wrist and finger range of motion.

The mean follow up for this study was 1.4 years for the participants. Mean for wrist extension mean was 36.66, thumb abduction 17.6, index finger extension 47.26, middle finger extension 47.66 and ring finger extension 45.73

5.2.3. OBJECTIVE THREE: TO DETERMINE MUSCLE STRENGTH OF WRIST EXTENSION POST-RADIAL NERVE TENDON TRANSFER SURGERY AND OCCUPATIONAL THERAPY

Measuring muscle strength of the wrist, fingers and thumb extension used the Oxford Standard Scale, as discussed in Chapter 2. The Chartered Society of Physiotherapy states that the Oxford Scale is a 0-5 scale and recorded as 0/5 or 5/5, sometimes with a + or - symbol reflecting more or less power but not enough to decrease or amplify the number. The Oxford Standard Scale for Muscle strength testing is available in Appendix F.

Muscle strength of the wrist extension showed that eight participants (53.33%) scored within results. Seven participants (46.67%) scored within fair muscle strength of wrist extension. The results of MPJ finger extension muscle strength showed that six participants (40%) scored within good category. Nine participants (60%) scored within fair category. Thumb extension on the MCP showed that four participants (26.67%) were within good category. There were 10 participants (66.67%) results which was within fair category on thumb extension. One participant (6.67%) scored within poor category

A Malaysian study showed considerable advancement between each three-month follow up time frame. There was a significant improvement in muscle strength between the pre-operative phase and 3 months post-operatively, between the pre-operative phase and 6 months post-operatively, and between 3 to 6 months post-operatively. The results showed noticeable improvement at 3 months post-operatively to 15.5 kg and an additional increase of 32.0 kg¹²⁶ at six months post-operatively.

In the United States of America, from 1995 until 2006, 77 patients were involved in a modified Brooks and d'Aubigne surgical technique study for radial nerve palsy, which revealed that the grip strength reduced to 49% and the pinch grip to 28%. They concluded that the results were functional, and there was sufficient professional and social reintegration after the aforementioned techniques.

Patient-reported outcome measures on a single patient study in America, including the DASH questionnaire, was to observe the return of functional independence, and the numeric pain-rating scale assessed the pain. Upon discharge, the patient's hand grip strength was 4.5 kg, her key pinch strength was 4.1 kg, and her 3-jaw pinch strength was 2.3 kg. Manual muscle strength testing grades were, 2/5 for wrist extension, 3/5 for extension from digits 2 through 4, 3+/5 for thumb extension.

A study by Nalbantoglu U et al conducted in Turkey on tendon transfers after irreparable radial nerve. The study had a duration of 19.7 months after tendon transfers were done with a mean follow up of 56.9 months. Twenty-nine participants had muscle strength

measurements involved muscle strength of wrist extensor muscles, finger extensors and thumb extensor muscle¹⁵¹. Muscle strength results showed wrist extension grade 3 (n=3), grade 4 (n=10) and grade 5 (n=12). Fingers extensor muscle strength was scored as grade 3 (n=7), grade 4 (n=10) and grade 5 (n=12). Thumb extensor muscle strength scored grade 3 (n=6), grade 4 (n=13) and grade 5 (n=10). Range of motion was also measured and results showed excellent category in 15 patients (51.7%), good in nine patients (31%) and moderate in five patients (17.2%)

Muscle strength results in this study were consistent with the conclusions in studies listed above, and reported in detail in Chapter 2, Section 2.16. In total, 86.95% (n=20) of the participants in this study had muscle strength of the wrist, MPJ and thumb in ranges of 3 to 4+. Only 8.69% (n=3) of participants' muscle strength of the thumb fell within -3 muscle strength; these were participants discovered to be non-compliant with rehabilitation programme in the study.

5.3. LIMITATIONS OF THE STUDY

Various factors, including national disaster regulations regarding the international COVID-19 pandemic, resulted in multiple limitations in the physical execution of this study. It affected the targeted number of participants to undergo physical evaluation on the range of movement and muscle strength of the affected hand. From the initial 23 participants identified, only 15 were able to attend for the physical assessment of the hand; the other eight participants were unable to report to the hospital due to reasons stipulated in Table 4.3.5 in Chapter 4. The limited number of participants had an impact on the generalisability of the findings, thus a larger follow up study would be advisable to confirm these findings. The follow up period of participants was also limited and it would add value to any further studies to follow up on these participants to identify any changes in their functionality, as found in other studies referred to in this document.

The researcher noted there was no establishing of whether the patients who had undergone tendon transfer surgery and occupational therapy treatment were able to go back to their pre-morbid functioning within all areas of occupations, namely ADLs,

iADLs, work and leisure after following the recommended 'Gauteng Provincial Hands Protocol.'

5.4. CONCLUSIONS

This chapter presented the results reported on the functional outcomes from the affected hand of participants after radial nerve tendon transfer surgery and occupational therapy rehabilitation programme. It elaborated on results of the DASH questionnaire, range of movement of the wrist and fingers and muscle strength of the wrist. Although there was no achieving of this confidence level in any of the measured outcomes, there were satisfactory to good results achieved from the Dash questionnaire, range of motion of the wrist extension, fingers MPJ extension and thumb MCP extension. The results were good with muscle strength of the wrist extension, fingers MPJ extension and thumb extension. Compliance to the rehabilitation was important to the outcomes of the study, and the demographics of the participants could have been an influencing factor. Employers were not following the guidelines of injury on duty and majority of employees returned to work pre-maturly due to fear of being dismissed or not receiving their salaries. Reasonable accommodation for majority of employees remains a challenge and they are compelled to work in their inherent duties with the injuries sustained. There was an exploration into and discussion of these factors.

5.4.1. Relationship of the Current Study to other Research

DASH modules assessment on participants differed in function and symptom; all 23 participants underwent assessment. Only 22 participants completed the work module and 14 participants the leisure module. Active range of movement in the affected hand, wrist and thumb extension had different ranges. The findings of the study correlate with various studies done with tendon transfers for radial nerve injuries. Most of the participants (69.5%) were able to return to their ADL, leisure and work. Only three participants developed complications related to surgical plating failure, which developed after tendon transfer surgery and completion of occupational therapy rehabilitation programme.

Active range of movement wrist extension and DASH scores were set at 95% and 5% for confidence level. Although there was no achieving of this confidence level in any of the measured outcomes, there were satisfactory results achieved. Wrist extension had a mean score of 36.66, which indicated a good prerequisite to function in daily occupations. The thumb extension mean of 17.60 and the four fingers MCPJ extension had a range of means from 44.68 to 47.66, indicating good results for the participants to engage in their ADL independently. DASH module mean scores differed, functional and symptoms had a mean of 21.62, which was within the good category, indicating the injured hand is fully functional and asymptomatic. The work module had a mean score of 38.06, which translated to good results with mild limitations with some tasks requiring heavy physical lifting, bilateral or unilateral hand function. Leisure or sport participation had a mean score of 69.19, which indicated poor function. This research study noted that the majority of participants never returned to their leisure or sport participation; they reported fear of another injury due to high contact sports they engaged in.

Outcomes of the muscle strength of the wrist, thumb and fingers extension used the Oxford standard scales. For the wrist it ranged between 3 minus (3⁻) to 4 plus (4⁺), the Metacarpal phalangeal joint also ranged between 3 minus (3⁻) to 4 plus (4⁺), and the Thumb abduction was the only component that ranged between zero (0) and 4 plus (4⁺) in the 15 participants who received physical hand assessment. There is a strong correlation with the muscle strength studies globally and this research. The findings of muscle strength for this cohort group also fell within 3 to 4+ except for one participant, whose muscle strength was 3-. This participant was among those that were not compliant with rehabilitation.

5.4.2. Explanation of Unanticipated Findings

Employment status, four of the 23 were dismissed and unemployed, one participant was a student, and the other 18 had full or part - time employment. Eleven participants received reasonable accommodation placement, while the other 12 returned to the same work inherent duties. Other studies revealed that the majority of their participants were able to return to their employment. However, the researcher noted that with this

cohort, some employers did not follow the recommended guidelines and labour regulations prescribed by the government.

The employees were left “helpless” due to the system of “no work, no pay” and forced to prematurely return to their employment despite still wearing a static splint and their treating occupational therapist advising they should not work at the time. There is a gap between employer compliance to Labour Relations Act and Code, Code of Good Practice and Technical assistance Guidelines. The treating occupational therapists recommend “light duties” or alternate placement while patients are undergoing rehabilitation. However, employers do not follow their recommendations, forcing employees to return to work before time to secure their jobs and provide for their families.

During the course or period of data collection, there were 19 of the 43 identified participants excluded due to four reasons. Eight had work obligation, fear of COVID-19 and interacting with hospital staff during the pandemic; five lost their source of income and were unable to afford transport to come for the study assessment; six changed their contact details. Sixteen of the 23 participants were attending rehabilitation, and seven of did not attend occupational therapy sessions as required or stipulated in the programme. High number of patients were able to return to their pre-injury occupations despite not being compliant with all the recommended sessions by the treating occupational therapist, but only 30% could return to work.

5.5. IMPLICATION FOR THE PRACTICE IN OCCUPATIONAL THERAPY

Compliance with rehabilitation and occupational therapy interventions has proved to be a challenge. The majority of patients in this setting travelled far from their homes to attend rehabilitation services. They had to pay for their own transport because there are limited hospital transports for patients who are medically stable. Many patients had challenges with their employers and returned to work prematurely despite advice from treating occupational therapists. Stormbroek et al.²⁷ noted similar findings with

compliance in hand therapy and concluded that it needs to be a collaborative approach, appreciating both internal and external factors that influence compliance to rehabilitation.²⁷

Psychosocial and emotional support during tendon transfer was not a prioritised in occupational therapy intervention. The emphasis was on addressing the affected physical client factors and returning the patients back to their communities. There was no recommendation of psychosocial evaluation or interventions with these patients. Hand injuries are disfiguring and psychologically traumatic to patients, and more needs doing to address them to enable seamless reintegration into the community.

The eight-week occupational therapy rehabilitation programme prescribed by the Gauteng Department of Health proved to be effective with participants in this study. Of note was that all the participants continued to receive rehabilitation for more than the recommended eight weeks. The programme recommended a splinting regime and positioning, which worked for the majority of the participants. Most of them removed their splints to return to work and perform their duties due to obligations to support their families. There was no addressing of psychosocial components by the recommended programme, which contravenes the occupational therapy ethos of viewing a person holistically. The programme also was not prescriptive on the number of sessions required weekly for the patients, and failed to cater for deviations that surgeons could make.

5.6. RECOMMENDATIONS FOR FURTHER RESEARCH

- There should be a repeating of the study on a larger scale within the South African context, including all the academic or tertiary hospitals in the country, to formulate a precise and inclusive programme to incorporate all areas of occupation.
- Investigations of the changes in the functional abilities of the patients with these injuries should take place over a longer period.

- Identify problems regarding education on the rights of employees in the work place and labour law regulations in the country and investigate further.
- Psychosocial adjustment of patients who sustained these injuries should undergo investigation and be reported on so that patients can be treated holistically and not only have the focus on physical rehabilitation.
- There was paucity of literature regarding exact time to commence with leisure or sporting activities. An article found on the website from a hand clinic in the United Kingdom indicated that patients who have undergone tendon transfers and rehabilitation should be able to return to their leisure participation between 10 and 12 weeks post-tendon transfer.^{149,150} This area needs exploring at length and recording of specific timelines established, especially for those participating in high contact sports.

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7. APPENDICES

APPENDIX A – GAUTENG PROVINCIAL TREATMENT PROGRAMME FOR OCCUPATIONAL THERAPY



GAUTENG HEALTH OCCUPATIONAL THERAPY HANDS TREATMENT PROTOCOL

GENERAL OVERVIEW

1. OBJECTIVES

The objective of the general overview is to provide a general overview of the evaluation and treatment of the hand

2. EVALUATION OF THE HAND

Acquiring subjective information is through verbal communication with the patient as well as palpating and observation of the hand. Following the subjective evaluation of the hand, specific measuring instruments will acquire the objective information.

2.1 Subjective information

Ask about the history of the injury, condition of any other pertinent medical information.

- Observe the posture of the hand. The normal posture is slight extension of wrist with the fingers curled towards scaphoid bones.
- Observe the mobility of the hand by asking the client to open and close his hand and to move his thumb.
- Observe any obvious deformities of the hand
- Observe the condition of skin, e.g., skin loss, fragility and scarring due to a previous injury. Ascertain the phase of tissue healing. A scar that crosses a joint may limit ROM. An immature scar is reddish /purple and blanches when touched. A mature scar should be flatter and softer but be on the lookout for hypertrophic scarring.
- Observe the colour of the skin for signs of inflammation or impaired blood supply
- Ask the client about the way the hand feels, e.g., pain, numbness and tingling, dryness vs. sweaty

- Observe the hand for oedema
- Ask the client if he experiences pain in the hand, and to indicate the location of the pain, the frequency and what aggravates pain. A Visual Analogue or Rating Scale between 1(-) to 10(+) may be useful
- Palpate the hand to determine the presence of any masses or nodules, the temperature of skin, the texture of skin and to get a feel for the type of oedema
- Ask the client which is his dominant hand
- Obtain his work and leisure history

2.2 Objective information

Asses the following

- Oedema: Use a tape measure for circumferential measurements of the hand the area of the first palmar fold, the base of the thumb. Measure each finger separately; if no tape measure is available, use a flexible packaging tape or piece of a tightly wound string that could be measured against a ruler
- Range of Motion:
- Muscle strength: Record the strength of the eccentric muscles or groups (those that belong to the forearm and hand, e.g., the long flexor muscle) and the intrinsic muscles (those that belong entirely to the hand, e.g., intrinsic muscles whose origin and insertion are both in the hand)
- Sensory functions: Evaluation and record touch, pain, and temperature. Firstly, determine whether the client can feel it (yes/no answer) and whether he can locate the stimulus by indicating the area where he has been touched. Next, determine the quality of the sensory function by comparing it with a non-affected area. Use the Semmes-Weinstein monofilaments if it is available. For a basic stereognosis assessment, ask the client to identify a few a few similar objects, e.g., a paperclip and safety pin, a coin and a button, an eraser and a dice.
- Vascular assessment: Do the Allen test by asking the client to clench his fist. Compress the radial and ulna artery with one finger each and ask the client to relax his hand. The OT releases one finger and observes the effect (colour change) on the palm of the hand. Repeat the procedure and release the other finger
- Hand function could be assessed informally or by means of standardized tests, e.g., the Smith Hand Function Test
- Hand grasps: Assess the power grasps (spherical and cylindrical grasps) and the precision grasps (lateral prehension, two digit and three digit pinch grasps). Request the client to pick up the object and observe the positioning of the finger around the object. Next, to determine the strength of the grasp, attempt to remove the object.

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5. PRECAUTION AND CONTRA INDICATIONS

Do not remove any POP provided by the doctor.

Do not mobilize a joint until you have confirmed that you will not damage any recently sutured structure.

6. GENERAL TREATMENT PRINCIPLES

- Oedema: Request the client to do repeated maximal flexion and extension of the fingers with the hand elevated. Repeat several times a day. The hand at rest should be in an elevated position.
 - Range of Motion: Gentle stretching allows the various underlying soft tissue to adjust. The stretch should be enough to stretch the soft tissue without rupturing it. The stretching should be to the maximum, meaning taking it just to the point of discomfort, and holding for a few seconds. Residual pain after stretching indicate that stretching was too vigorous and may have damage some underlying soft tissue, therefore the myth of no pain no gain does not apply to passive stretching. Provide active stretching exercise that the client could do daily at home
 - Muscle strength: The stimulus for the hypertrophy (strengthening) of the muscle is the tension built up in the muscle. To improve muscle power (strength), the muscle must be loaded to the point of exhaustion.
 - Sensory functions: Sensory retraining should be in a quiet area without disturbances to facilitate concentration. The recommendation is four sessions, no longer than 10 minutes each. Vision must be occluded, but the client should not be blindfolded as it could result in anxiety.
- **Sensory retraining:** This can be in two phases:
- Early phase
Visual feedback can distinguish moving touch. The client initially concentrates on learning to match the sensory awareness of the stimuli with the visual stimulus. The client himself could

- stroke the skin with the eraser end of a pencil while verbalizing the sensory input he receives.
- Late –phase
Initially, the client should be able to distinguish and locate constant touch or pressure, followed by unambiguous (clear) recognition of touch at the fingertips. The client observes a non-moving stimulus, his vision is then occluded, and he verbalises the input the stimulus provides.
 - **De-sensitisation:** the application of graded stimuli to which the patient builds tolerance. Stimuli are applied for at least 10 minutes, twice to three times a day. The following methods are available:
 - Grading of the texture of the stimuli from soft to hard and the method of application (from touch to rub to tap)
 - The Downey Hand Center hierarchy of texture and vibration
 - Weight bearing pressure
 - Massage
 - Transcutaneous Electrical Stimulation (TENS)
 - Immersion in water. Include bilateral function activities to avoid non-use of the hand.
 - **Compensation:** the patient must learn how to compensate for the absence of extreme sensory functions to prevent tissue damage:
 - Adopt a good skin care routine, e.g., daily hydration and visual inspection of the skin for any damage.
 - Avoid concentrated high pressure and sharp tools by enlarging thin handles and keys and keys, and consciously only use as much force as necessary to grasp and hold objects. Therapists should avoid splints with straps that are too narrow or too tight.
 - Avoid potential scourges of extreme heat or cold by not sitting too close to an open fire or heater, use utensils with wooden handles and insulated cups.
 - Avoid repetitive movements and friction between the skin and objects by enlarging or padding the handles of utensil, wearing gloves, or alternating the grasps.
 - Adopt new routines in executing daily tasks to avoid damaging the skin and soft tissue
 - Increase reliance on other senses, e.g., use an unaffected limb to test temperature, vision when manipulating a sharp object, hearing to detect friction of clothes or the wheels of the wheelchair against the skin.
 - Additional aspects however also require attention when treating the impaired hand:
 - Isolated exercise, purposeful activity, and therapeutic occupation.
The treatment principles are repetition. Bilateral activities and electing the appropriate grasp.
 - Key joints of the hand. The wrist is the First key joint of the hand. Most activities require some wrist extension. Functional wrist extension is 30° to 45°. However, do not neglect the other wrist movements, as a few activities, such as dressing,

- require wrist flexion. The MP joints are the second key joint of the hand should obtain 90° flexion. Abduction of the thumb is the third key joint of the hand
- Length of the long flexors and extensors; there should be optimal length of both maintained. The exception is the hand that uses the tenodesis grasp, in which case the long flexors should be purposefully shortened.
- Exercises for the hand. Differential digital tendon gliding exercise, blocking exercises and place-and-hold exercises ADL, work, leisure

PRECAUTIONS AND INDICATIONS

Precautions

Due to lack of or diminished sensation, patients should be extra careful not to burn/injure themselves, as they will not be able to feel anything.

Contra-indications

If the joints become stiff and contracture results, a tendon transfer is not possible. For tendon transfers all the joints should be supple/mobile.

TREATMENT PROCESS

POST INJURY (INITIAL /ACUTE PHASE)

The main function in this initial phase is to maintain mobility and function.

This is by:

- ❖ Daily passive movement of all the joints by the patient
- ❖ State wrist extension splint or dynamic dorsal MP extension splint with the wrist in 30° and MPs in neutral, or simple future splint if there is nothing else of use in the department.

Level of Care

Tertiary level

Patients are seen in a specialized hand and microsurgery unit by a specialist/consultant then referred to OT.

Secondary and Primary Level

In the secondary level, a patient will be seen for follow-ups where there is no need for specialist intervention from a doctor or OT. In primary level, home visits can take place to

ensure the patients are doing their home programmes. If there is problem, they can be referred to a secondary level and then up.

Services Levels

Essential (minimum services) - tertiary and secondary

Quality (should provide) - tertiary and secondary

Excellent (nice to have) - tertiary

References

The Handbook – Edited by Ulrich Mennen

Unpublished notes

Addendums

Picture courtesy of Douglas Turnball, Kalafong Hospital Occupational Therapy Department.

RADIAL NERVE LESIONS

OBJECTIVES

To provide a uniform approach to assessment and treatment of patients who have a radial nerve palsy. To provide guidelines for intervention.

SCREENING AND ASSESSMENTS

❖ Screening

If you have a patient with a wrist drop (i.e. wrist in a flexed position) and he/she cannot actively extend the wrist, and if you passively position in extension and let go the wrist cannot maintain that position and will 'drop' into flexion. Usually, one sees this type of injury with a fracture of the humerus.

❖ Assessments

❖ Motor function

❖ Range of Motion can be done with the joints that are starting to become stiff due to lack of motor function. The metacarpals will not be able to extend actively as the radial nerve supplies the muscle responsible for that action, subsequently the other finger joints will also be affected. Usually, passive ROM will be full in all joints unless the patient is referred very late post-injury

❖ Sensation of the radial nerve distribution

❖ Muscle strength (later)

❖ Dominance

Neurotmesis- denote complete division of all elements of the nerve. Surgical repair necessary.

Reconstruction Phase (Tendon transfers)

Principles essential for Tendon transfers:

Full passive joint range of movement

- Usually done only 6 months post-op
- Donor muscles must have sufficient strength.

POST TENDON TRANSFERS

Week 1-4 – Patient’s hand placed in a POP splint in 30° extension, with MPs and PIPs each in 30° flexion. The DIPs can move free.

POP remains for 4 weeks.

Week 5-8

- POP removed, hands washed thoroughly, stitches carefully removed.
- A thorough evaluation takes place
- A static wrist extension splint can protect the tendon for at least another 2-3 weeks
- Depends on the type of work the patient does.
- Patient is instructed to do:
 - Scar tissue massage (make sure the skin is closed) three times daily, using the thumb of the unaffected hand to rub in circular movement. Can use topical agents such as Vaseline, aqueous cream, etc.
 - Remove splint five to eight times daily to do home exercise as follows:
 - Teach patients to do MP extension by flexing the wrist first
 - Then teach him to use the transferred muscle, by actively contracting the transferred muscle and doing the desired movement 10 times, not the “OLD TRICKS”
 - keep thumb mobile doing flexion/extension, abd/adduction and opposition without resistance
 - Do MP flexion with IPs flexed (20 repetitions)

-Gradually introduce added resistance

- Splints are washed daily in cold water and soap
- Hand is bathed daily in warm soapy water and patient can do the active flexion/extension exercise in the water
- The removal of splints is only when exercising.
- Activities that encourage active extension are recommended
- Patients can return to work about 6 weeks later still protecting tendon
- Follow- up appointment must be made to evaluate progress

Week 8

- Splint is taken away
- Full assessment
- Further management if necessary; discharge plan if ready.

Multi-disciplinary

Hand Surgeon – responsible for pre- and post-operative management

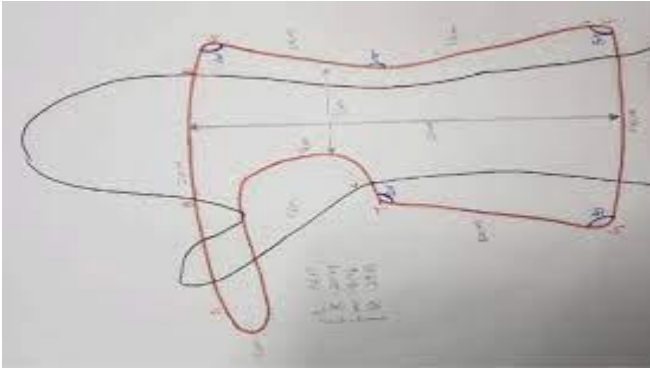
OT- responsible for pre- and post-operative therapy for the hand

Physio responsible for pain management, ROM

Nursing staff- monitoring of patient's condition post-op and dressing of wound

Patients/Family – Should be part of the patient's rehab programme and educated about the injury and its prognosis





- ❖ If joints are not supple contractures need correcting by splinting or else tendon transfers are not possible.
- ❖ Activities of Daily Living (ADL) are encouraged, and the patient can start participating in most activities as he/she waits for the return of motor function. Light duty work can commence +/- 2 weeks post injury.

Type of nerve injury /prognosis

Neuropraxia - When there is physiological interruption where the axons are? Intact. Motor loss is usually greater than sensory loss. Spontaneous recovery is the rule.

Axonotmseis - denotes incomplete interruption, i.e., only the axons are divided. Spontaneous recovery is likely after motor and sensory loss are complete.

APPENDIX B - PRINCIPLES OF TENDON TRANSFERS

Principles followed by the Orthopaedic Surgeon to ensure that best outcome is achieved following surgery are¹⁰⁶

- a) Donor tendon must be expendable so that its removal would not result in significant loss of function and its neuro-motor unit should be intact.
- b) The strength of the donor muscle must be normal or near normal.
- c) The excursion of glide of donor tendon must be sufficient to restore lost function.
- d) The direction of pull of recipient tendon should be in line with donor muscle, and transfer should cross one joint only.
- e) Transfer should not be placed on scared tissue that may limit excursion.
- f) Before surgery, the affected hand's joints should be supple and have full passive range of motion.
- g) Tendons with similar functions should be used for transfers. The synergistic action of donor muscle for the transfer and recipient muscle can facilitate muscle-retraining efforts.



APPENDIX C: INFORMATION LETTER AND INFORMED CONSENT (English, Sesotho and Afrikaans)

2 PARTICIPANT’S INFORMATION AND INFORMED CONSENT DOCUMENT

STUDY TITLE: Establishing functional outcomes of tendon transfers and occupational therapy intervention following radial nerve injury

Sponsor: None

Principal Investigator: Thabani Ncwane

Institution: University of Pretoria

HREC certificate number: 721/2018

DAYTIME AND AFTER HOURS TELEPHONE NUMBER(S):

Daytime number/s: 012 354 1655

Afterhour’s number: 012 354 1655

HREC number: 012 356 3084 or 012 356 3085

DATE AND TIME OF FIRST INFORMED CONSENT DISCUSSION:

			:
date	month	year	Time

Dear Prospective Participant

Dear Mr. / Mrs.

1) INTRODUCTION

You are invited to volunteer for a research study. I am doing research for a masters degree purpose at the University of Pretoria. This information in this document is to help you to decide if you would like to participate. Before you agree to take part in this study you should fully understand what is involved. If you have any questions, which are not fully explained in this document, do not hesitate to ask the researcher. You should not agree to take part unless you are completely happy about all the procedures involved.

2) THE NATURE AND PURPOSE OF THIS STUDY

The aim of this study is to evaluate the functional outcomes of tendon transfers following radial nerve injury and occupational therapy intervention. By doing so we wish to gain more intellectual insight about the occupational therapy intervention during the rehabilitation process.

3) EXPLANATION OF PROCEDURES AND WHAT WILL BE EXPECTED FROM PARTICIPANTS.

This study involves answering some questions with regarding your injury, age, gender, employment status, support system at home during recovery period using the demographics questionnaire. The following tests will be done for the research specifically

- Completing the Dash Questionnaire before you commence with occupational therapy intervention before surgery (15 minutes).
- You would be assessed by your treating Occupational Therapist concerning movements of your wrists, and hand (metacarpophalangeal) joints and thumb before you start occupational therapy intervention and when you are discharged (20 minutes).
- Muscle strength of your hand would also be assessed by the treating Occupational Therapist before you start occupational therapy intervention before surgery and completion of post-surgery occupational therapy intervention which would take 5 minutes .
- After surgery and completion of occupational therapy rehabilitation, you would be required to complete the DASH questionnaire again followed by assessment of your hand as previously done (40 minutes).

4) POSSIBLE RISKS AND DISCOMFORTS INVOLVED

There are no medical risks associated with the study. Participants would be treated according to the same method of treatment to those not participating in the study.

5) POSSIBLE BENEFITS OF THIS STUDY

Although you may not benefit directly. The study results may help us to improve body of knowledge which aims to improve the function and lives of future tendon transfer for radial nerve patients.

6) COMPENSATION

You will not be paid to take part in the study. There are no costs involved for you to be part of the study.

7) YOUR RIGHTS AS A RESEARCH PARTICIPANT

Your participation in this study is entirely voluntary and you can refuse to participate or stop at any time without stating any reason. Your withdrawal will not affect your access to other medical care.

8) ETHICS APPROVAL

This Protocol was submitted to the Faculty of Health Sciences Research Ethics Committee, University of Pretoria, telephone numbers 012 356 3084 / 012 356 3085 and written approval has been granted by that committee. The study has been structured in accordance with the Declaration of Helsinki (last update: October 2013), which deals with the recommendations guiding doctors and clinicians in biomedical research involving human/subjects. A copy of the Declaration may be obtained from the investigator should you wish to review it.

9) INFORMATION

If I have any questions concerning this study, I should contact:

Name: Mr. Thabani Ncwane Tel : 0123541665 or cell: 0834723338

10) CONFIDENTIALITY

All information obtained during the course of this study will be regarded as confidential. Each participant that is taking part will be provided with an alphanumeric coded number e.g. A001. This will ensure confidentiality of information so collected. Only the researcher will be able to identify you as participant. Results will be published or presented in such a fashion that patients remain unidentifiable. The hard copies of all your records will be kept in a locked facility at the Department of Occupational Therapy, The University of Pretoria.

11) CONSENT TO PARTICIPATE IN THIS STUDY

- I confirm that the person requesting my consent in this study has told me about the nature and process, any risks or discomforts, and the benefits of the study.
- I have also received, read and understood the above written information about the study.
- I have had adequate time to ask questions and I have no objections to participate in this study.
- I am aware that the information obtained in the study, including personal details, will be anonymously processed and presented in the reporting of results.
- I understand that I will not be penalised in any way should I wish to discontinue with the study and that withdrawal will not affect my further treatments.
- I am participating willingly.
- I have received a signed copy of this informed consent agreement.

Participant's name (Please print)

Date

Participant's signature

Date

Researcher's name (Please print)

Date

Researcher's signature

Date



KAROLO EA BOPHELO BA TŠEBELETSO TSA BOHLOKOA

TLHALO EA HO ITHUTA: Ho theha liphello tsa ts'ebetso ea tendon ea ho fetisetsa le ho phekoloa ha basebetsi ka mor'a ho hlaseloa ha methapo ea mali

Mofani: Ha ho .

Bafuputsi ba ka sehloohong: Thabani Ncwane

Mokhatlo: Univesithi ea Pretoria

Lethathamo la sekolo sa HREC: 721/2018

LETSATSI LE KA MOR'A HOURS TELEPHONE NUMBER (S):

Nomoro ea motšehare / s: 012 354 1655

Nomoro ea Afterhour: 0834723338

Nomoro ea HREC: 012 356 3084 kapa 012 356 3085

DATE LE NAKO EA HO HLAHLISWA KA SEBELE KA HO QALA:

letsatsi la	selemo	khoeli

:
Nako

Moratuo ea Ratehang

Ratehang Monghali / Mofumahali

1) SELELEKELA

U memeloa ho ithaopela ho etsa lipatlisiso. Ke ntse ke etsa lipatlisiso bakeng sa morero oa masters University of Pretoria. Lintlha tsena tse ngotsoeng lengolong lena ke ho u thusa ho etsa geto ea hore na u rata ho nka karolo. Pele u lumellana ho kenya letsoho thutong ena u lokela ho utloisisa hantle hore na ho ameha eng. Haeba u e-na le lipotso, tse sa hlalosoang ka ho feletseng hatikolong ena, u se ke ua qeaqea ho botsa mofuputsi. Ha ua lokela ho lumellana ho nka karolo ntle le haeba u thabile ka ho feletseng ka mekhoha eohle e amehang.

2) NAKO LE MORERO OA HO ITHUTA HO E TSA

Sepheo sa thuto ena ke ho hlahloba liphello tsa ts'ebetso tsa tendon tse fetisoang ka mor'a kotsi e bakoang ke methapo ea methapo le phekolo ea phekolo ea mosebetsi. Ka ho etsa joalo re lakatsa ho ithuta ho eketsehileng mabapi le phekolo ea phekolo ea mosebetsi ho latela ts'ebetso.

3) LITLHAHISO TSA MELAO LE SEO SE TLA SEBELISOA HO BATHO BA BANGATA.

Tlhahlobo ena e kenyelletsa ho arabela lipotso tse ling mabapi le kotsi ea hao, lilemo, tekano, boemo ba mosebetsi, tsamaiso ea tšehetso lapeng nakong ea ho phomola ho sebelisa lipotso tsa lipalo. Liteko tse latelang li tla etsoa bakeng sa patlisiso ka ho toba

- Ho tlatsa Potso ea Dash pele o qala ka ho phekoloa ha mosebetsi mosebetsing pele ho buuo (metsotso e 15).
- U tla hlahlojoa ke ngaka ea hau ea ho sebetsa mosebetsing mabapi le mekhoha ea matsoho a hau, le matsoho (metacarpophalangeal) le matsoho pele u qala phekolo ea meriana ea mosebetsi le ha u lokolloa (metsotso e 20).
- Matla a mesifa a letsoho la hau a ne a tla hlahlojoa ke ngaka ea Occupational Therapist pele u qala phekolo ea meriana pele u etsoa opereishene le ho phethoa ka mor'a ho buuo kalafo ea mosebetsi mosebetsing o ka nka metsotso e 5.
- Kamor'a ho buuo le ho phethoa ha phekolo ea phekolo ea phekolo, u tla tlameha ho tlatsa lengolo la lipotso la DASH hape le lateloa ke tlhahlobo ea letsoho la hau joaloka pele (40 metsotso).

4) LIPOTSO TSA BOHLOKOA LE LITHOBISO TSE BOTSOANG

Ha ho na likotsi tsa bongaka tse amanang le thuto. Barupeluo ba ne ba tla phekoloa ka mokhoa o tšoanang oa phekolo ho ba sa keneng thutong.

5) MOSEBETSI A HLOKHILENG A HO ITHUTA TSEO

Le hoja u ka se ke ua rua molemo ka ho toba. Liphello tsa thuto li ka re thusa ho ntlafatsa 'mele oa tsebo o reretsoeng ho ntlafatsa mosebetsi le bophelo ba ho fetisetsa mekhoha e metle bakeng sa bakuli ba methapo ea mahlaba.

6) COMPENSATION

U ke ke ua lefelloa ho kenya letsoho thutong. Ha ho na litšenyehelo tse hlokaahalang hore u be karolo ea thuto.

7) LITOKELO TSA HAO JOALOKA HO HLAHLAHALA KAROLO EA SEBELE

Ho kopanela ha hau thutong ena hoa ithaopela ho kenyelletsa kapa ho emisa nako leha e le efe ntle le ho bolela lebaka leha e le lefe. Ho tlohela ha hao ho ke ke ha ama tsela eo u fihletsoeng ka eona ho tlhokomelo e meng ea bongaka.

8) ETHICS APPROVAL

Ts'ebetso ena e ile ea fetisetsoa ho Komiti ea Boipheliso ea Boetliso ba Lipatlisiso tsa Bophelo ba Sciences, Univesithi ea Pretoria, linomoro tsa thelefono 012 356 3084/012 356 3085 le tumello e ngotsoeng e fanoa ke komiti eo. Thuto e entsoe ka tumellanong le Phatlalatsa ea Helsinki (tlhahiso ea ho qetela: October 2013), e sebetsanang le litlhahiso tse tataisang lingaka le baoki ka lipatlisiso tsa tlhaho tse amanang le batho / lihlooho. Kopi ea Phatlalatsa e ka fumanoa ho mofuputsi haeba u lakatsa ho e hlahloba.

9) LITABA

Haeba ke na le lipotso tse amanang le thuto ena, ke lokela ho iteanya le:

Lebitso: Monghali Thabani Ncwane TI: 0123541665 kapa sele: 0834723338

10) HO TŠEPAHALA

Lintlha tsohle tse fumanoang thutong ena li tla nkoa e le lekunutu. Sehlopha se seng le se seng se nkang karolo se tla fanoa ka nomoro e ngotsoeng ea alphanumeric e.g. A001. Sena se tla etsa bonnete ba hore boitsebiso bo bokelloa. Ke mofuputsi feela ea tla tseba ho u khetholla. Liphello li tla hatisoa kapa ho hlahisoa ka mokhoa o joalo hore bakuli ba lule ba sa tsejoe. Likopi tse thata tsa litlaleho tsohle tsa hau li tla bolokoa mohahong o koetsoeng Lefapheng la Bophelo ba Bophelo, The University of Pretoria.



11) TŠEPA HO SEBELISA KATENG HO ITHUTA HO E TSA

- Ke netefatsa hore motho ea batlang tumello ea ka thutong ena o mpoletse ka mofuta le ts'ebetso, likotsi leha e le life kapa tse sa utloiseng, le melemo ea thuto.
- Ke fumane hape, bala le ho utloisisa tlhahiso e ngotsong ka holimo ka thuto.
- Ke na le nako e lekaneng ea ho botsa lipotso 'me ha ke na lipelaelo tsa ho kopanela thutong ena.
- Kea tseba hore boitsebiso bo fumanoeng thutong, ho kenyetsetsa le lintlha tsa botho, bo tla tsejoa ka mokhoa o sa tsejoeng le ho hlahisa tlaleho ea liphetho.
- Kea utloisisa hore nke ke ka fua phoso ka tsela leha e le efe eo ke lokelang ho e tlohela ka thuto le hore ho tlohela ho ke ke ha ama litla-morao tsa ka tse ling.
- Ke kopanela ka boithatelo.
- Ke fumane kopi e saennweng ea tumellano ena ea tumellano.

Lebitso la mohoeletsi (Ka kōpo hatisa)	Letsatsi
--	----------

Letšoao la mohoeletsi	Letsatsi
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Lebitso la mofuputsi (Ka kōpo hatisa)	Letsatsi
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Letšoao la mofuputsi	Letsatsi
----------------------	----------

HO HLAHALA HORE HO HLOKAHALA HORE HO HLOMOE KA MOTHO OA SEBELETSO

'Na, ea ngolisitsoeng tlaase,, ke baliloe mme ke hlalositse ka botlalo ho ea nkang letsoho, ea bitsoang, tokomane ea tumello ea tsebo , e hlalolang sebopeho le morero oa thuto eo ke mo kōpileng ho e etsa. Tlhaloso eo ke faneng ka eona e boletse likotsi le melemo ea thuto. Morupeluo oa bontšitse hore o utloisisa hore o tla lokoloha ho tlohela thutong ka nako leha e le efe ka lebaka leha e le lefe le ntle le ho beha bophelo ba hae tlhokomelo e kotsing.

Ke netefatsa hore mokuli o lumetse ho kenya letsoho thutong ena.

Lebitso la mohoeletsi (Ka kōpo hatisa)	Letsatsi
Letšoao la mohoeletsi	Letsatsi
Lebitso la Mofuputsi (Ka kopo o hatise)	Letsatsi
Letšoao la Mofuputsi	Letsatsi
Lebitso la motho ea boneng tumello ea tsebo (Ka kōpo hatisa)	Letsatsi
Letšoao la Paki	ea Paki

STUDIETITEL: Die vestiging van funksionele uitkomst van tendon-oordragte en arbeidsterapie-intervensie as gevolg van radiale senuwee besering

Borg: Geen

Hoofnavorsers: Thabani Ncwane

Inrigting: Universiteit van Pretoria

HREC sertifikaat nommer: 721/2018

DAGTYD EN NA-UUR TELEFOONNOMMER (S):

Dagtijd nommer / s: 012 354 1655

Naweek se nommer: 0834723338

HREC nommer: 012 356 3084 of 012 356 3085

DATUM EN TYD VAN EERSTE INLIGTING TOESTEMMING BESPREKING:

datum	maand	jaar

:
tyd

Geagte Voornemende Deelnemer

Geagte Meneer / Mevrouw

1. INLEIDING

U word uitgenooi om vrywillig te wees vir 'n navorsingsstudie. Ek doen navorsing vir 'n magistergraad doel aan die Universiteit van Pretoria. Hierdie inligting in hierdie dokument is om u te help om te besluit of u wil deelneem. Voordat jy saamstem om aan hierdie studie deel te neem, moet jy ten volle verstaan wat betrokke is. As u enige vrae het wat nie volledig in hierdie dokument verduidelik word nie, moet asseblief nie huiwer om die navorser te vra nie. U moet nie saamstem om deel te neem nie tensy u heeltemal gelukkig is oor al die betrokke prosedures.

2) DIE AARD EN DOEL VAN HIERDIE STUDIE

Die doel van hierdie studie is om die funksionele uitkomst van tendon-oordragte te evalueer as gevolg van radiale senuwee besering en arbeidsterapie intervensie. Deur dit te doen, wil ons meer leer oor die arbeidsterapie-intervensie na die operasie.

3) VERKLARING VAN PROSEDURES EN WAT SAL VANAF DEELNEMERS UITGEVOER WORD.

Hierdie studie behels die beantwoording van 'n paar vrae met betrekking tot jou besering, ouderdom, geslag, werkstatus, ondersteuningsstelsel by die huis tydens herstelperiode deur gebruik te maak van die demografiese vraelys. Die volgende toetse sal spesifiek vir die navorsing gedoen word

- Voltooi die Dash-vraelys voordat u met arbeidsterapie-ingryping begin voor operasie (15 minute).
- U sal geassesseer word deur u behandelende Arbeidsterapeut oor bewegings van u pols en hand (metakarpofaleangeale) gewrigte en duim voordat u begin met arbeidsterapie-intervensie en wanneer u ontslaan word (20 minute).
- Spierkrag van u hand sal ook deur die behandelende Arbeidsterapeut geassesseer word voordat u begin met arbeidsterapie intervensie voor die operasie en voltooiing van die operasie-operasie-intervensie na die operasie wat 5 minute sal neem.
- Na die operasie en voltooiing van arbeidsterapie-rehabilitasie sal u die DASH-vraelys moet voltooi, gevolg deur die evaluering van u hand soos voorheen gedoen (40 minute).

4) MOONTLIKE RISIKO'S EN BESPREKINGS BETROKKEN

Daar is geen mediese risiko's wat met die studie verband hou nie. Deelnemers sal volgens dieselfde behandelingsmetode behandel word aan diegene wat nie aan die studie deelneem nie.

5) MOONTLIKE VOORDELE VAN HIERDIE STUDIE

Alhoewel u nie direk baat kan vind nie. Die studieuitslae kan ons help om die kenniskennis te verbeter wat daarop gemik is om die funksie en lewens van toekomstige sena-oordrag vir radiale senuweepasiënte te verbeter.

6) VERGOEDING

U sal nie betaal word om aan die studie deel te neem nie. Daar is geen koste verbonde aan jou om deel te wees van die studie nie.

7) JOU REGTE AS 'N NAVORSINGSDELEENT

U deelname aan hierdie studie is heeltemal vrywillig en u kan enige tyd weier om deel te neem of te stop sonder om enige rede te verskaf. U onttrekking sal nie u toegang tot ander mediese sorg beïnvloed nie.

8) ETIEK GOEDKEURING

Hierdie protokol is by die Fakulteit Gesondheidswetenskappe Navorsingsetiekkomitee, Universiteit van Pretoria, ingedien, telefoonnommers 012 356 3084/012 356 3085 en skriftelike toestemming is deur die komitee verleen. Die studie is gestruktureer in ooreenstemming met die Verklaring van Helsinki (laaste opdatering: Oktober 2013), wat handel oor die aanbevelings wat dokters en klinici in biomediese navorsing met betrekking tot mense / vakke aanbied. 'N Afskrif van die Verklaring kan van die ondersoeker verkry word indien u dit wil hersien.

9) INLIGTING

As ek enige vrae het oor hierdie studie, moet ek kontak:

Naam: Mnr. Thabani Ncwane Tel: 0123541665 of sel: 0834723338

10) VERTROULIKHEID

Alle inligting wat tydens die studie verkry is, word as vertroulik beskou. Elke deelnemer wat deelneem, sal voorsien word van 'n alfanumeriese gekodeerde nommer, bv. A001. Dit sal die vertroulikheid van inligting so versamel. Slegs die navorser sal u as deelnemer kan identifiseer. Resultate sal op so 'n manier gepubliseer of aangebied word dat pasiënte onidentifiseerbaar bly. Die harde kopieë van al u rekords sal in 'n geslote fasiliteit by die Departement Arbeidsterapie, die Universiteit van Pretoria, gehou word.

11) TOESTEMMING OM IN HIERDIE STUDIE TE DEEL

- Ek bevestig dat die persoon wat my toestemming in hierdie studie versoek het, my vertel het van die aard en proses, enige risiko's of ongemak, en die voordele van die studie.
- Ek het ook bogenoemde skriftelike inligting oor die studie ontvang, gelees en verstaan.
- Ek het genoeg tyd gehad om vrae te stel en ek het geen besware om aan hierdie studie deel te neem nie.
- Ek is bewus daarvan dat die inligting wat in die studie verkry is, insluitend persoonlike besonderhede, anoniem verwerk en aangebied sal word in die rapportering van resultate.
- Ek verstaan dat ek nie op enige manier gepenaliseer sal word as ek wil staak met die studie nie en dat die onttrekking my verdere behandeling nie sal beïnvloed nie.
- Ek deel gewillig.
- Ek het 'n getekende afskrif van hierdie ingeligte toestemmingsooreenkoms ontvang.

Deelnemer se naam (druk asseblief)

Datum

Deelnemer se handtekening

Datum

Navorser se naam (asseblief druk)

Datum

Navorser se handtekening Datum

BEVESTIGING VAN INLIGTINGVERGUNNING DEUR 'N ILLITERATE PARTICIPANT

Ek, die ondergetekende, het gelees en het ten volle verduidelik aan die deelnemer, genaamd, die ingeligte toestemmingsdokument, wat die aard en doel van die studie beskryf waarin ek hom / haar gevra het om deel te neem. Die verduideliking wat ek gegee het, het albei die moontlike risiko's en voordele van die studie genoem. Die deelnemer het aangedui dat hy / sy verstaan dat hy / sy vry is om enige tyd van die studie te onttrek van die studie en sonder om sy / haar standaardsorg te benadeel.

Hiermee sertifiseer ek dat die pasiënt ingestem het om aan hierdie studie deel te neem.

_____	_____
Deelnemer se naam (druk asseblief)	Datum
_____	_____
Deelnemer se handtekening	Datum
_____	_____
Navorsers se Naam (Druk asseblief)	Datum
_____	_____
Ondersoeker se Handtekening	Datum
_____	_____
Naam van die persoon wat getuig het die ingeligte toestemming (asseblief druk)	Datum
_____	_____
Handtekening van die Getuie	Datum

APPENDIX D - Demographics Form

Participant number			
Age		Gender	
Area of residence		Date of injury	
Date of admission to Occupational Therapy		Date of discharge from Occupational Therapy	
Diagnosis/Mechanism of Injury		Hand Dominance	
Do you live on your own			
Employment status/title			
How many weeks did it take to return to work?			
Were you accommodated into light duties?			
How long did it take you to return to your normal duties?			
Are you coping with your normal duties?			

APPENDIX E – NON –DISCLOSURE AGREEMENT FOR O.T. Technicians

You have been selected to *participate in the study by keeping the details of patients involved in the research project* confidential for **Thabani Ncwane** on the research project **“Establishing the functional outcomes of tendon transfer and occupational therapy intervention following radial nerve injury”**. The ethical guidelines of this study require that you read and sign this form, signifying that you are willing to enter into a confidentiality agreement with respect to the data collected in this study.

In order to protect confidentiality of patients participating in the study, you are not allowed to reveal which patients are participating in this study. You will ensure that all records and identifying information are kept confidential (i.e., materials are never left unattended and are secured when not being used). By signing below, you agree not to reveal any information about what is contained on the forms. Furthermore, you agree not to discuss anything regarding the participants or the data collected in this study with anyone other than the principal investigator.

By signing below you are indicating that you have read and understand the above agreement and that you will follow all of the specified conditions.

Name: _____

Contact Telephone: _____

Contact E-mail: _____

Signature: _____

Date: _____

APPENDIX F - PERMISSION LETTER TO USE DASH FROM AUTHORS

Important notice: This is an automated response. Your submission is subject to quality review and the decision may change, in which case you will be contacted by DASH coordinator.

User Profile Submission Results

Thank you for your interest in DASH, your submission has been received.

Based on the information you submitted, you or your organization qualify for free use of the DASH/*QuickDASH* in non-profit projects.

Please note that by accessing the DASH and *QuickDASH* Outcome Measures and the translated versions, the User agrees to the following terms and conditions:

- The use of instruments, without charge, is limited to clinicians using them only for treatment or assessment of a patient, to researchers using them only for non-commercially related research and to other not-for-profit users.
- The instruments may not be changed, sold or incorporated into a product to be sold, by anyone.
- Copyright in the DASH and *QuickDASH* Outcome Measures is the sole property of the Institute for Work & Health, which reserves all rights in connection therewith. Users must give credit to the developers when using or referencing any DASH tool. If using a translated version of the DASH and *QuickDASH*, translators should also be acknowledged.

You can review our Conditions of Use and Disclaimer at www.dash.iwh.on.ca/terms-and-conditions.



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T: (416) 927-2027 | F: (416) 927-4167

**APPENDICE G - THE DASH QUESTIONNAIRE (SA ENGLISH & AFRIKAANS
VERSION)**

DISABILITIES OF THE ARM, SHOULDER AND HAND

THE **DASH**

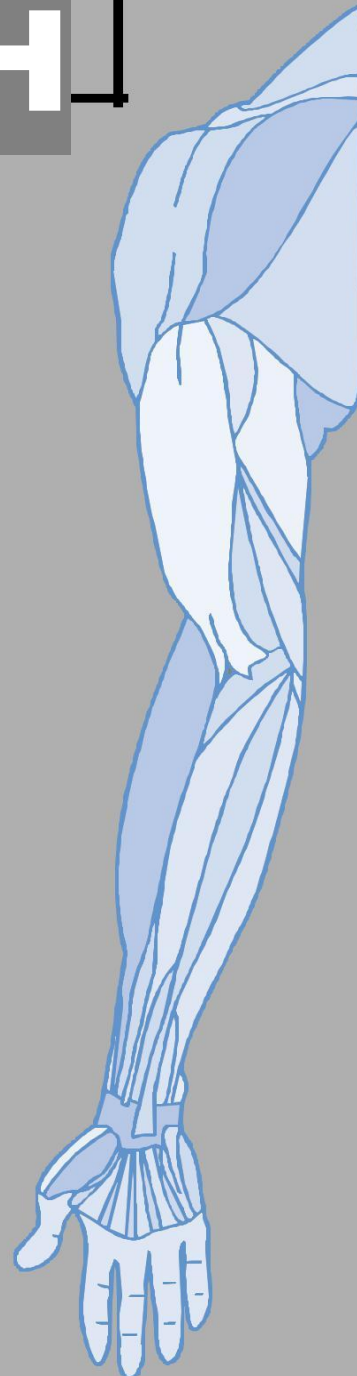
INSTRUCTIONS

This questionnaire asks about your symptoms as well as your ability to perform certain activities.

Please answer *every question*, based on your condition in the last week, by circling the appropriate number.

If you did not have the opportunity to perform an activity in the past week, please make your *best estimate* on which response would be the most accurate.

It doesn't matter which hand or arm you use to perform the activity; please answer based on your ability regardless of how you perform the task.



DISABILITIES OF THE ARM, SHOULDER AND HAND

Please rate your ability to perform the following activities in the last week by circling the number below the appropriate response.

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. Open a tight or new bottle.	1	2	3	4	5
2. Write.	1	2	3	4	5
3. Turn a key.	1	2	3	4	5
4. Prepare a meal.	1	2	3	4	5
5. Push open a heavy door.	1	2	3	4	5
6. Place an object on a shelf above your head.	1	2	3	4	5
7. Do heavy household chores (e.g. wash walls, wash floors).	1	2	3	4	5
8. Garden or do yard work.	1	2	3	4	5
9. Make a bed.	1	2	3	4	5
10. Carry a shopping bag or briefcase.	1	2	3	4	5
11. Carry a heavy object (over 5 kg).	1	2	3	4	5
12. Change a light bulb overhead.	1	2	3	4	5
13. Wash or blow-dry your hair.	1	2	3	4	5
14. Wash your back.	1	2	3	4	5
15. Put on a pullover jersey.	1	2	3	4	5
16. Use a knife to cut food.	1	2	3	4	5
17. Recreational activities which require little effort (e.g. card playing, knitting, etc.).	1	2	3	4	5
18. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g. golf, hammering, tennis, etc.).	1	2	3	4	5
19. Recreational activities in which you move your arm freely (e.g. playing frisbee, badminton, etc.).	1	2	3	4	5
20. Manage transportation needs (getting from one place to another).	1	2	3	4	5
21. Sexual activities.	1	2	3	4	5

DISABILITIES OF THE ARM, SHOULDER AND HAND

	NOT AT ALL	SLIGHTLY	MODERATELY	QUITE A LOT	EXTREMELY
22. During the past week, <i>to what extent</i> has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups? <i>(Circle number.)</i>	1	2	3	4	5

	NOT LIMITED AT ALL	SLIGHTLY LIMITED	MODERATELY LIMITED	VERY LIMITED	UNABLE
23. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem? <i>(Circle number.)</i>	1	2	3	4	5

Please rate the severity of the following symptoms in the last week. *(Circle number.)*

	NONE	MILD	MODERATE	SEVERE	EXTREME
24. Arm, shoulder or hand pain.	1	2	3	4	5
25. Arm, shoulder or hand pain when you performed any specific activity.	1	2	3	4	5
26. Tingling (pins and needles) in your arm, shoulder or hand.	1	2	3	4	5
27. Weakness in your arm, shoulder or hand.	1	2	3	4	5
28. Stiffness in your arm, shoulder or hand.	1	2	3	4	5

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	SO MUCH DIFFICULTY THAT I CAN'T SLEEP
29. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? <i>(Circle number.)</i>	1	2	3	4	5

	STRONGLY AGREE	DISAGREE	NEITHER AGREE NOR DISAGREE	AGREE	STRONGLY AGREE
30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem. <i>(Circle number.)</i>	1	2	3	4	5

DASH DISABILITY/SYMP TOM SCORE = $\left[\frac{(\text{sum of } n \text{ responses})}{\text{responses. } n} - 1 \right] \times 25$, where n is equal to the number of completed

A DASH score may not be calculated if there are more than 3 missing items.

DISABILITIES OF THE ARM, SHOULDER AND HAND

WORK MODULE (OPTIONAL)

The following questions ask about the impact of your arm, shoulder or hand problem on your ability to work (including homemaking if that is your main work role).

Please indicate what your job/work is: _____

I do not work. (You may skip this section.)

Please circle the number that best describes your physical ability in the past week. Did you have any difficulty...

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. ...using your usual technique for your work?	1	2	3	4	5
2. ...doing your usual work because of arm, shoulder or hand pain?	1	2	3	4	5
3.doing your work as well as you would like?	1	2	3	4	5
4. ...spending your usual amount of time doing your work?	1	2	3	4	5

SPORTS/PERFORMING ARTS MODULE (OPTIONAL)

The following questions relate to the impact of your arm, shoulder or hand problem on playing *your musical instrument or sport or both*.

If you play more than one sport or instrument (or play both), please answer with respect to that activity which is most important to you.

Please indicate the sport or instrument which is most important to you: _____

I do not play a sport or an instrument. (You may skip this section.)

Please circle the number that best describes your physical ability in the past week. Did you have any difficulty...

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. ...using your usual technique for playing your instrument or sport?	1	2	3	4	5
2. ...playing your musical instrument or sport because of arm, shoulder or hand pain?	1	2	3	4	5
3. ...playing your musical instrument or sport as well as you would like?	1	2	3	4	5
4. ...spending your usual amount of time practising or playing your instrument or sport?	1	2	3	4	5

SCORING THE OPTIONAL MODULES: Add up assigned values for each response; divide by 4 (number of items); subtract 1; multiply by 25.

An optional module score may not be calculated if there are any missing items.

GESTREMDHEDE VAN DIE ARM, SKOUER EN HAND

Die

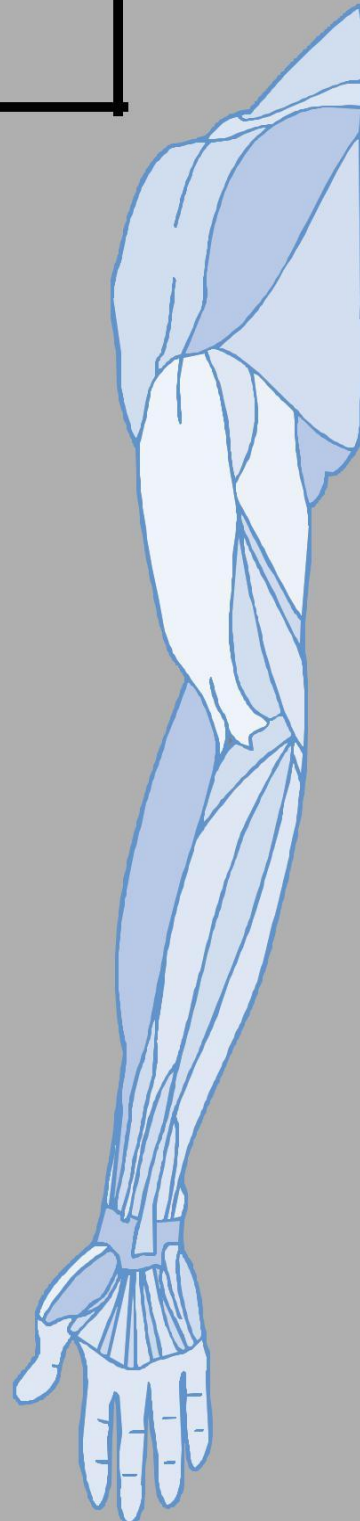


OPDRAGTE

Hierdie vraelys handel oor u simptome, asook u vermoë om sekere aktiwiteite uit te voer.

Beantwoord asseblief elke vraag, gebaseer op u toestand die afgelope week, deur die gepaste syfer te omkring.

As u die afgelope week nie die geleentheid gehad het om 'n sekere aktiwiteit uit te voer nie, doen asseblief



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GESTREMDHEDE VAN DIE ARM, SKOUER EN HAND

Beoordeel asseblief u vermoë tydens die afgelope week om onderstaande aktiwiteite uit te voer deur die syfer onder die gepaste antwoord te omring.

	GLAD NIE MOEILIK NIE	EFFENS MOEILIK	MATIG MOEILIK	UITERS MOEILIK	ONMOONTLIK
1. 'n Nuwe bottel of 'n bottel met 'n deksel wat styf pas oop te maak.	1	2	3	4	5
2. Skryf.	1	2	3	4	5
3. 'n Sleutel draai.	1	2	3	4	5
4. 'n Maaltyd voorberei.	1	2	3	4	5
5. 'n Swaar deur oopstoot.	1	2	3	4	5
6. 'n Voorwerp op 'n rak bokant u kop plaas.	1	2	3	4	5
7. Swaar huishoudelike werk doen (soos mure was, of vloere was).	1	2	3	4	5
8. Tuinmaak of buite werk.	1	2	3	4	5
9. Bed opmaak.	1	2	3	4	5
10. 'n Inkopiesak of aktetas dra.	1	2	3	4	5
11. 'n Swaar voorwerp dra (meer as 5 kg).	1	2	3	4	5
12. 'n Gloeilampie bokant u kop vervang.	1	2	3	4	5
13. U hare was of droogblaas.	1	2	3	4	5
14. U rug was.	1	2	3	4	5
15. 'n Oortrektrui aantrek.	1	2	3	4	5
16. 'n Mes gebruik om kos mee te sny.	1	2	3	4	5
17. Ontspanningsaktiwiteite wat min inspanning verg (soos kaartspeel, brei, ens.).	1	2	3	4	5
18. Ontspanningsaktiwiteite met 'n mate van krag of impak via u arm, skouer of hand (bv. gholf, hamerslae, tennis, ens.).	1	2	3	4	5
19. Ontspanningsaktiwiteite waartydens u u arm vryelik beweeg (soos frisbee of pluimbal speel, ens.).	1	2	3	4	5
20. Hantering van vervoerbehoefes (om van een plek na 'n ander te gaan).	1	2	3	4	5
21. Seksuele aktiwiteite.	1	2	3	4	5

GESTREMDHEDE VAN DIE ARM, SKOUER EN HAND

	GLAD NIE	EFFENS	MATIG	HEELWAT	TOT DIE UITERSTE
22. Gedurende die afgelope week, in watter mate het u probleem met u arm, skouer of hand met u normale sosiale aktiwiteite saam met familie, vriende, bure of groepe ingemeng? (Omkring syfer.)	1	2	3	4	5

	GLAD NIE BEPERK NIE	EFFENS BEPERK	MATIG BEPERK	BAIE BEPERK	ONVERMOË
23. Gedurende die afgelope week, het u probleem met u arm, skouer of hand u beperk sover dit u werk of ander gereelde daaglikse aktiwiteite aangaan? (Omkring syfer.)	1	2	3	4	5

Beoordeel asseblief hoe erg onderstaande simptome die afgelope week vir u was. (Omkring syfer.)

	AFWESIG	LIG	MATIG	ERG	UITERS ERG
24. Pyn in die arm, skouer of hand.	1	2	3	4	5
25. Pyn in die arm, skouer of hand wanneer u enige spesifieke aktiwiteit uitvoer.	1	2	3	4	5
26. Prikkeling (naalde-en-spelde) in u arm, skouer of hand.	1	2	3	4	5
27. Swakheid in u arm, skouer of hand.	1	2	3	4	5
28. Styfheid in u arm, skouer of hand.	1	2	3	4	5

	GLAD NIE MOEILIK NIE	EFFENS MOEILIK	MATIG MOEILIK	UITERS MOEILIK	SO MOEILIK DAT EK NIE KAN SLAAP NIE
29. Hoe moeilik het die pyn in u arm, skouer of hand dit gedurende die afgelope week vir u gemaak om te slaap? (Omkring syfer.)	1	2	3	4	5

	STEM GLAD NIE SAAM NIE	STEM NIE SAAM NIE	DIS VIR MY OM'T EWE	STEM SAAM	STEM VOLMONDIG SAAM
30. Die probleem met my arm, skouer of hand laat my voel asof ek minder bevoeg is, minder selfvertroue het, of minder nuttig is. (Omkring syfer.)	1	2	3	4	5

GESTREMDHEDE VAN DIE ARM, SKOUER EN HAND

WERKSMODULE (OPSIONEEL)

Die volgende vrae handel oor die impak van u probleem met u arm, skouer of hand op u vermoë om te werk (tuisteskepping ingesluit as dit u hoofwerksrol is).

Dui asseblief aan watter werk u doen: _____ Ek werk nie. (U kan hierdie deel oorslaan.)

Omkring asseblief die syfer wat u fisiese vermoë die afgelope week die beste beskryf. Het u dit moeilik gevind ...

	GLAD NIE MOEILIK NIE	EFFENS MOEILIK	MATIG MOEILIK	UITERS MOEILIK	ONMOONTLIK
1. ... om van u gewone tegniek gebruik te maak vir u werk?	1	2	3	4	5
2... om u gewone werk te doen, as gevolg van pyn in u arm, skouer of hand?	1	2	3	4	5
3. ... om u werk so goed te doen as wat u sou wou?	1	2	3	4	5
4. ... om netsoveel tyd as gewoonlik aan u werk te bestee?	1	2	3	4	5

SPORT-/UITVOERENDEKUNSTEMODULE (OPSIONEEL)

Die volgende vrae hou verband met die impak van u probleem met u arm, skouer of hand op u vermoë om u musiekinstrument te bespeel of aan sport deel te neem of albei.

As u aan meer as een sport deelneem of meer as een musiekinstrument bespeel (of aan sport deelneem én 'n musiekinstrument bespeel), antwoord asseblief ten opsigte van die aktiwiteit wat vir u die belangrikste is.

Dui asseblief aan watter sport of instrument vir u die belangrikste is: _____

Ek neem nie aan sport deel nie en bespeel nie 'n instrument nie. (U kan hierdie deel oorslaan.)

Omkring asseblief die syfer wat u fisiese vermoë die afgelope week die beste beskryf. Het u dit enigszins moeilik gevind ...

	GLAD NIE MOEILIK NIE	EFFENS MOEILIK	MATIG MOEILIK	UITERS MOEILIK	ONMOONTLIK
1. ... om van u gewone tegniek gebruik te maak wanneer u aan sport deelneem of u instrument bespeel?	1	2	3	4	5
2. ... om u musiekinstrument te bespeel of aan sport deel te neem as gevolg van pyn in u arm, skouer of hand?	1	2	3	4	5
3... om u musiekinstrument so goed te bespeel as wat u sou wou of om so goed te vaar in u sport as wat u sou wou?	1	2	3	4	5
4. ... om netsoveel tyd as gewoonlik aan die bespeeling van u instrument/musiek-oefen of deelname/oefening ten opsigte van u sport te bestee?	1	2	3	4	5

APPENDIX H – OXFORD STANDARD SCALE FOR MUSCLE STRENGTH

- 0 No evidence of contraction
- 1 Contraction felt but there is no movement
- 2- Part moves through an incomplete range of movement with gravity eliminated
- 2 Part moves through a complete range of movement with gravity eliminated
- 2+ Part moves through an incomplete range of movement against gravity or through complete range of movement with gravity eliminated against slight resistance.
- 3- Part moves through incomplete range of movement against gravity.
- 3 Part moves through complete range of movement against gravity.
- 3+ Part moves through complete range of movement against gravity and slight resistance.
- 4 Part moves through a complete range of movement against gravity and moderate resistance.
- 5 Part moves through a complete range of movement against gravity and full resistance.

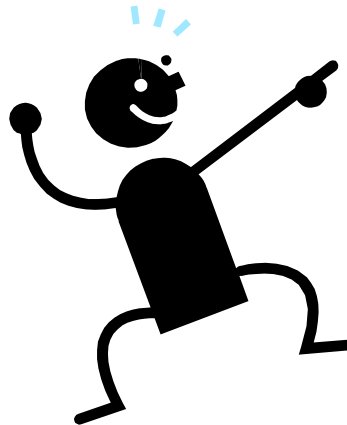
APPENDICE I – UPPER LIMB ASSESSMENT FORM COMPLETED BY OCCUPATIONAL THERAPISTS

BIOMECHANICAL ASSESSMENT

Occupational Therapy

Steve Biko Academic Hospital

Patient Number:	Date of Referral:
Diagnosis:	Student:
Date of assessment:	Therapist:



1. RANGE OF MOTION

Left		Degrees	Joint movement	Degrees	Right	
PROM	AROM				PROM	AROM
		80°	Wrist flexion	80°		
		70°	Wrist extension	70°		
		20°	Wrist radial deviation	20°		
		30°	Wrist ulnar deviation	30°		
Thumb						
		15°	CM flexion	15°		
		20°	CM extension	20°		
		50°	MP flexion - extension	50°		
		80°	IP flexion - extension	80°		
Index finger						
		90°	MP flexion	90°		
		100°	PIP flexion	100°		
		90°	DIP flexion	90°		
Middle finger						
		90°	MP flexion	90°		
		100°	PIP flexion	100°		
		90°	DIP flexion	90°		
Ring finger						
		90°	MP flexion	90°		
		100°	PIP flexion	100°		
		90°	DIP flexion	90°		
Little finger						
		90°	MP flexion	90°		
		100°	PIP flexion	100°		
		90°	DIP flexion	90°		

2. MUSCLE STRENGTH

CODE	
0	No evidence of contraction
1	Contraction felt but there is no movement
2-	Part moves through an incomplete range of movement with gravity eliminated
2	Part moves through a complete range of movement with gravity eliminated
2+	Part moves through an incomplete range of movement against gravity or through complete range of movement with gravity eliminated against slight resistance.
3-	Part moves through incomplete range of movement against gravity.
3	Part moves through complete range of movement against gravity.
3+	Part moves through complete range of movement against gravity and slight resistance.
4	Part moves through a complete range of movement against gravity and moderate resistance.
5	Part moves through a complete range of movement against gravity and full resistance.

Left	MOVEMENT	Right
Upper extremity		
	Wrist Flexion	
	Wrist Ulnar deviation	
	Wrist Radial deviation	
Thumb		
	Flexion	
	Extension	
	Abduction	
	Adduction	
	Opposition	

Fingers		
	Flexion	
	Extension	
	Abduction	
	Adduction	
	Opposition	

OCCUPATIONAL AREAS

3. ADL

Feeding		Grooming	
Handling utensils		Handling toothpaste and toothbrush	
Eating		Brushing teeth	
Drinking from a cup		Brushing hair	
Dressing		Washing	
Shirt		Handling taps	
Pants/skirt		Handling soap/sponge/cloth	
Underwear		Washing hands	
Socks		Washing face	
Buttons/Zip		Washing upper body	
Other		Washing lower body	
Urinary and bowel continence		Washing hair	
Bed mobility, e.g., rolling, lying to sitting		Drying hair	

Describe the patient's transfers from a wheelchair to:

Bed:	
Chair:	
Bath/shower:	
Toilet:	

4. WORK:

5. LEISURE:

APPENDIX J – POSITIONING PROCEDURE OF UPPER LIMB ASSESSMENT BY OCCUPATIONAL THERAPISTS

a) ROM Evaluation

- **Wrist**

- Place the affected forearm on the table in mid-position.
- Place the goniometer on the radial styloid as axis to wrist motion.
- Position the stationary arm over the radius and the movable arm along the metacarpals of the index finger.
- Record the maximum active range of motion in degrees (see Appendix D).

- **Fingers**

- Use finger goniometer to measure active range of motion of the MPs.
- Place goniometer on the dorsum to the joint of each finger,.
- The stationary arm should be aligned with the metacarpal and the movable arm with the proximal phalanx.
- Record the maximum active range of motion in degrees (see Appendix D).

- **Thumb**

- The forearm must be positioned in the mid-position and the wrist slightly positioned in extension.
- The MCP joint is measuredis at 0° of flexion.
- The goniometer placed on the dorsum of the thumb over the MCP joint.
- Stationary arm is parallel to the longitudinal axis of the shaft of the metacarpal.
- Movable arm should be parallel to the longitudinal axis of the proximal phalanx
- The patient extentends the MCP to the limit of motion

b) Muscle strength testing

- Wrist extension: The patient places hand on palmar surface of forearm, supported in pronation on table, wrist is neutral. Patient actively extends the wrist through range. For grades 4 to 5, apply resistance through dorsal aspect of hand in a direction opposite to extension. To satisfy grade 5, 'normal muscle' performance criteria, the patient must have the ability to move through complete range of

motion (active resistance testing) against maximum resistance. The therapist then grades the movement reached based on the resistance applied.⁴¹

- MCPJ Extension: The patient's forearm is placed in pronation with the wrist in neutral on the table surface. MP joints and IP joints are in relaxed flexion posture. The occupational therapist stabilises the wrist in pronation and places their index finger of the resistance hand across the dorsum of all proximal phalanges just distal to the MCP joints. The therapist applies resistance in the direction of flexion and the patient extends their MCPJ against the therapist's finger. The therapist then grades the movement reached based on the resistance applied.⁴²
- Thumb abduction/extension: The patient sits with the wrist in neutral, and thumb relaxed in adduction on the table surface; the occupational therapist stabilises the metacarpals by maintaining the wrist in neutral position, similar to handshake simulation. The occupational therapist applies resistance to the lateral aspect of proximal phalanx in the direction of adduction. The patient lifts thumb toward ceiling against resistance and is graded by the therapist based on the movement reached with resistance.⁴²

APPENDICE K – STORAGE FORM

**Principal Investigator's Declaration for the storage of research
data and/or documents**

I, the Principal Investigator, Thabani Ncwane, of the following study titled: Establishing functional outcomes of tendon transfers and occupational therapy intervention following radial nerve injury, will be storing all the research data and/or documents referring to the aforementioned study at the following non-residential address:

**Office Number 31411, Level 3
Department of Occupational Therapy
Steve Biko Academic Hospital
Corner Steve Biko & Malan Street
Pretoria, 02000**

I understand that the storage of the abovementioned data and/or documents must be for a minimum of 15 years from the end of this study.

START DATE OF STUDY: 01/03/2019 END DATE OF STUDY: 31/06/2020

Name Thabani Ncwane



© Signature _____ Date 27/05/2018

APPENDIX L - FACULTY OF HEALTH SCIENCES ETHICS COMMITTEE LETTER



Faculty of Health Sciences

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 03/14/2020.

1 April 2019

Approval Certificate New Application

Ethics Reference No.: 721/2018

Title: Establishing the functional outcomes of tendon transfers and occupational therapy intervention following radial nerve injury

Dear Mr TM Ncwane

The **New Application** as supported by documents received between 2019-02-01 and 2019-03-27 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 2019-03-27.

Please note the following about your ethics approval:

- Ethics Approval is valid for 1 year and needs to be renewed annually by 2020-04-01.
- Please remember to use your protocol number (721/2018) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:

- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

Additional conditions:

Researcher to please note that after the pilot study is done, you should submit the amended questionnaire only if there are substantive changes to the questionnaire and protocol.

We wish you the best with your research.

Yours sincerely



Dr R Sommers

MBChB MMed (Int) MPharmMed PhD

Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 45. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles

Research Ethics Committee
Room 4-60, Level 4, Tswelopele Building
University of Pretoria, Private Bag X323
Arcadia 0007, South Africa
Tel +27 (0)12 356 3084
Email deepeka.behari@up.ac.za
www.up.ac.za

Fakulteit Gesondheidswetenskappe
Lefapha la Disaense tša Maphelo

**APPENDIX M - PERMISSION LETTER TO CONDUCT RESEARCH AT STEVE
BIKO ACADEMIC HOSPITAL**

Permission to do Research, access Records/Files/Database at the Steve Biko
Academic Hospital

To: Chief Executive Officer/Information Officer **From:** The Investigator
Steve Biko Academic Hospital **Steve Biko Academic Hospital**
Dr M. Mathebula Mr. T. Ncwane

Re: Permission to do research at Steve Biko Academic Hospital

Mr. Thabani Ncwane is a researcher working at the Orthopaedics___Unit, Department of **Occupational Therapy** at **Steve Biko Academic** Hospital. I am requesting permission to conduct a study on the hospital grounds that involves access to patient records.

The request is lodged with you in terms of the requirements of the Promotion of Access to Information Act. No. 2 of 2000.

The title of the study is: **Establishing the functional outcomes of tendon transfer and occupational therapy interventions following radial nerve injury.**

The researchers request access to the following information:

Access to the clinical files, record book and the database.

I intend to publish the findings of the study in a professional journal and/ or at professional meeting like symposia, congresses, or other meetings of such a nature.

I intend to protect the personal identity of the patients by assigning each patient a random code number.

I undertake not to proceed with the study until we have received approval from the Faculty of Health Sciences Research Ethics Committee, University of Pretoria.

Yours sincerely

Permission to do the research study at this hospital and to access the information as requested is hereby approved.

Chief Executive Officer _____ Hospital _____

Dr _____ Signature of the CEO

**Hospital Official
Stamp**

APPENDIX N – STATISTICIANS LETTER

Letter of statistical support. FORM 3

LETTER OF STATISTICAL SUPPORT

Date: 08/01/2018

This letter is to confirm that the student Thabani Ncwane studying at the University of Pretoria discussed the Project with the title “Investigate functional outcome of tendon transfers following radial nerve injury” with me.

I hereby confirm that I am aware of the project and also undertake to assist with the statistical analysis of the data generated from the project.

The DATA ANALYSIS will consist of
Initial analysis will include mean, median, minimum, maximum and the standard deviation given for continuous variables. Frequency counts and proportions together with their associated standard error and 95% confidence intervals will be given for categorical variables. Chi-squared test will be used to establish the association of hand functionality and day to day activities. For the purpose of determining the range of motion of the affected wrist, metacarpophalangeal joints and thumb extension before and after radial nerve tendon transfer, paired t-test will be used; if data are not normally distributed, then non-parametric equivalent will be used. All analysis will be done using STATA 15 and will be evaluated at 5% level.

The SAMPLE SIZE CALCULATION was made as follows:

A sample size of 73, which was approximated to 80, was obtainable based on the 95% prevalence of patients who had experienced functional improvement and a 5% difference.

Name: Nkwenika Tshifhiwa

Signature



Date: 08/01/2018

MEDICAL RESEARCH COUNCIL
Biostatistics Unit
Private Bag X385
Pretoria
0001
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