

Mini-dissertation

CARPAL TUNNEL SYNDROME:

COMPARATIVE STUDY BETWEEN THE

SECOND AND FIFTH DIGIT ANTI-SENSORY

VERSUS

THE FOURTH DIGIT ANTI-SENSORY STUDY

J Du Plessis

(Student Number: 217000071)

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External Supervisor: Mrs. JE Le Roux

Internal Supervisor: Mrs C Bezuidenhout

Abstract

CARPAL TUNNEL SYNDROME: COMPARATIVE STUDY BETWEEN THE SECOND AND FIFTH DIGIT ANTI- SENSORY VERSUS THE FOURTH DIGIT ANTI- SENSORY

^aJ DU PLESSIS, ^bJE LE ROUX, ^cC BEZUIDENHOUT

^aDepartment of Health Sciences, Central University of Technology, Bloemfontein

^b Department of Neurology, University of the Free State, Bloemfontein

INTRODUCTION

This research followed a retrospective study design involving patients who received nerve conduction (NSC) studies in the original study (Study A) on which this retrospective study was based. A NCS is useful in detecting carpal tunnel syndrome (CTS) because a NCS test can assess individual nerves by measuring the ability of a specific nerve to conduct an electrical impulse to the innervated muscle. In some instances, the physician may request needle electromyography (EMG) which can be used to assess the health of specific muscles and the nerves which innervates them. Both the NCS, as well as the EMG, must always be correlated with the clinical picture. This led to this comparative study between the second and fifth digit anti-sensory *versus* the fourth digit anti-sensory study in carpal tunnel syndrome. This retrospective study aimed to compare two sensory nerves (median and ulnar sensory nerves) by using anti-sensory stimulation to see which test most accurately reflects the severity of carpal tunnel syndrome.

METHODOLOGY

This study was conducted at Universitas Academic Hospital, Department of Neurology, Bloemfontein. The study was done retrospectively using fictitious data. The number of patients included in the study was 30. The sample size included males and females of any ethnicity, older than 18 years of age, with symptoms of carpal tunnel syndrome and who participated in the original study by signing consent. The study did not need any ethical clearance as it was a retrospective study.

RESULTS AND DISCUSSION

Firstly, the distribution of the variables of the two protocols was investigated. According to the Shapiro-Wilk test, all the variables were skewed ($p<0.05$), except for the distribution of the median which followed a normal distribution. Since the differences between the median and ulnar had to be established, the distribution of the median was also considered as skewed. Next, the median difference in latency between the two protocols was compared. According to the Shapiro-Wilk test, the distribution of the difference was skewed. According to the signed-rank test, the median difference between the two protocols was not significant. Thus, there was no significant difference in the difference in latency between the two protocols. Since the difference between the median and ulnar was established, the distribution of the median was considered as skewed. Consequently, the median and inter-quartile range (IQR) of all 4 variables were reported. Of the 30 patients whose results/data were used in this study, 43% of the females had a normal NCS while 57% of the females had an abnormal NCS, which confirmed a diagnosis of CTS. Among the males, 33% had normal NCS, while 67% of the males had an abnormal NCS confirming a diagnosis of CTS.

CONCLUSION

In conclusion, the difference in the latency between the two protocols is the same however Protocol 2 showed a higher sensitivity towards detecting CTS, in comparison with that of Protocol 1. In this study, females were more often referred to the NCS laboratory with suspected CTS, than males.

KEYWORDS

Carpal tunnel syndrome, motor nerves, sensory, anti-sensory

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PHONE NUMBER: 074 84 59 399
.....


DATE

18 August 2020
E-mail: du.Plessis.jariske@gmail.com

18 Augustus 2020

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List of Abbreviations

CMAP	Compound Muscle Action Potential
CTR	Carpal Tunnel Release
CTS	Carpal Tunnel Syndrome
EDX	Electrodiagnostic
EEG	Electroencephalograph
EMG	Electromyography
IP	Interphalangeal
MCP	Metacarpal phalangeal
NCS	Nerve Conduction Studies
NIH	National Institute of Health
OPD	Out-Patient Department
SNAP	Sensory Nerve Action Potential
TCL	Transverse Carpal Ligament
US	United States

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CHAPTER 1

INTRODUCTION

The carpal tunnel located at the wrist acts as a passageway through which the median nerve travels from the forearm to the palm. The carpal tunnel consists of a combination of bones, ligaments, and tendons. In the case of carpal tunnel syndrome (CTS), the transverse carpal ligament (TCL) becomes irritated and/ or inflamed, reducing the space in the carpal tunnel, which compresses on the median nerve, leading to symptoms such as numbness, pain, and paraesthesia (Bethesda, 2018). The signs and symptoms of CTS will be discussed in detail in Chapter 2.

When diagnosing a suspected case of CTS, there are various steps involved to follow (Gujarat, 2020). The first step is always to take a thorough medical history. When the history points towards CTS, a physical exam is performed on the neck, shoulder, and arm to exclude fractures or other possible problems that may present as CTS. The wrist may be examined for signs of swelling, tenderness, or color change. The power of the muscles that are innervated by the nerves associated with CTS may also be evaluated and can be tested at the hand, arm, and shoulder. A physical exam may follow for sensory testing of the digits (by using cotton wool or a needle) and motor testing of the muscles at the base of the hand.

In some cases, the physician may order a routine laboratory test such as an X-ray to exclude fractures, arthritis, and other diseases that may have a damaging effect on the nerves. If all the possibilities have been narrowed to CTS, provocative tests are performed that replicate the symptoms of CTS. If there is evidence of thenar atrophy and/ or persistent, the referring physician may request an electrodiagnostic (EDX) tests such as a nerve conduction study (NCS) or needle electromyography (EMG) to confirm a CTS (Chazerain, 1997).

A NCS is useful in detecting CTS because a NCS test can assess individual nerves by measuring the ability of a specific nerve to conduct an electrical impulse to the innervated muscle. In some instances, the physician may request a needle (EMG) which can be used to assess the health of specific muscles and the nerves which innervates them. Both the NCS as the EMG must always be correlated with the clinical picture. A diagnosis should not be solely based on the results of a NCS and/ or an EMG, because these tests are considered as an extension of the clinical examination.

This led to this comparative study between the second and fifth digit anti-sensory versus the fourth digit anti-sensory study in carpal tunnel syndrome.

Chapter 2:

LITERATURE REVIEW

2.1 ANATOMY OF CARPAL TUNNEL SYNDROME

2.1.1 Anatomy of the bones of the hand

The skeletal structure of the hand is divided into three categories which consist of the bones of the carpal (with eight carpal bones), metacarpals (comprised of five metacarpal bones), and the phalanges (which consist of fourteen phalangeal bones). The carpal bones are at the wrist, the metacarpals at the palm, and the phalanges the bones of the fingers. Shown in Figure 1 are the bones of each part of the hand. The differences between the carpal bones, metacarpals, and phalanges are illustrated (Ross, 2018).

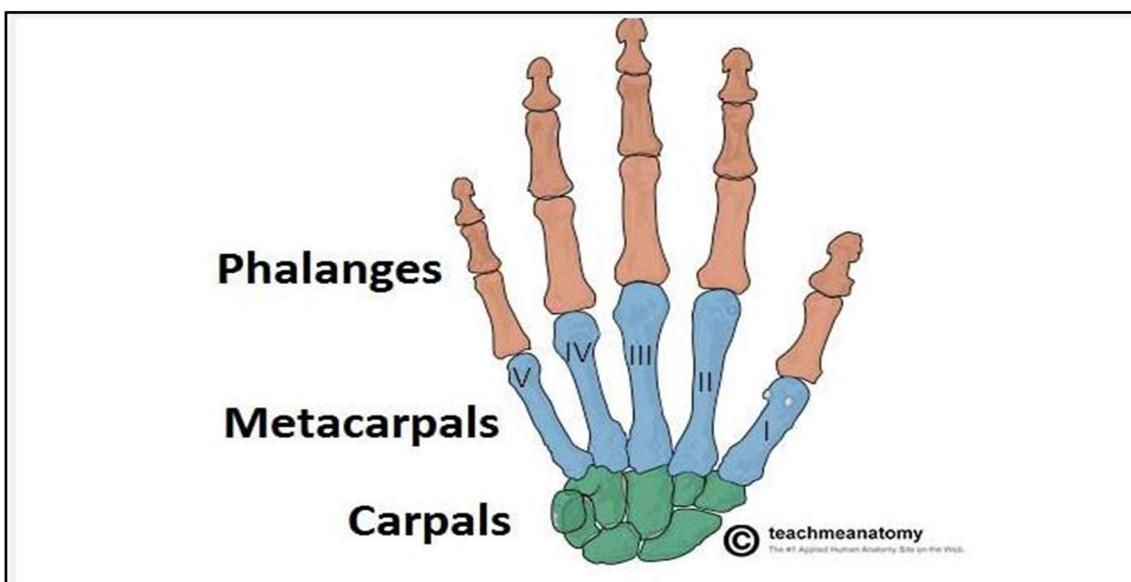


Figure 1: Illustrated above is a top view of the differences between carpal bones, metacarpal bones and phalanges bones (Ross, 2018).

2.1.1.1 The carpal bones

At the most distal part of the forearm (at the distal end of the radius and the ulnar) there is a set of eight carpal bones. All the bones located at the wrist are small marble-like-sized bones and these bones are responsible for offering the flexibility of the soft tissues

and also provide support to the soft tissues. The carpal bones are named according to appearance. The carpal bones are arranged into two irregular rows which each consist of four bones. These rows of carpal bones can be divided into the proximal carpal row and the distal carpal row (Theskeletalsystem.net, 2018). The proximal carpal row articulates with the lower arm bones (the radius and ulna bones) and is in order from the radius side to the ulna side as follow:

- Scaphoid bone
- Lunate bone
- Triquetrum bone
- And the pisiform bone

In the case of the proximal row, only the scaphoid and the lunates carpal bones articulate with the radius to form the wrist joint (Marieb, 2001). The distal carpal row is attached to/ articulates with the metacarpal bones of the hand. The distal carpal row is described in order from the radius to the ulnar and consist of the following carpal bones (Jones, 2019):

- Trapezium bone
- Trapezoid bone
- Capitate bone
- And the hamate bone (also referred to as the hook bone)

The first carpal bone in the distal carpal row, which is the trapezium bone, articulates with the first metacarpal (of the thumb). The second carpal bone in the distal carpal row which is the trapezoid bone articulates with the second metacarpal (which is the metacarpal of the index finger). Therefore, the third carpal bone (capitate) articulates with the third metacarpal, and the fourth carpal bone in the distal carpal row (the hamate hook bone) articulates with the fourth as well as the fifth metacarpal. Seen below in Figure 2 is an illustration depicting the carpal bones of the hand (Ross, 2018).

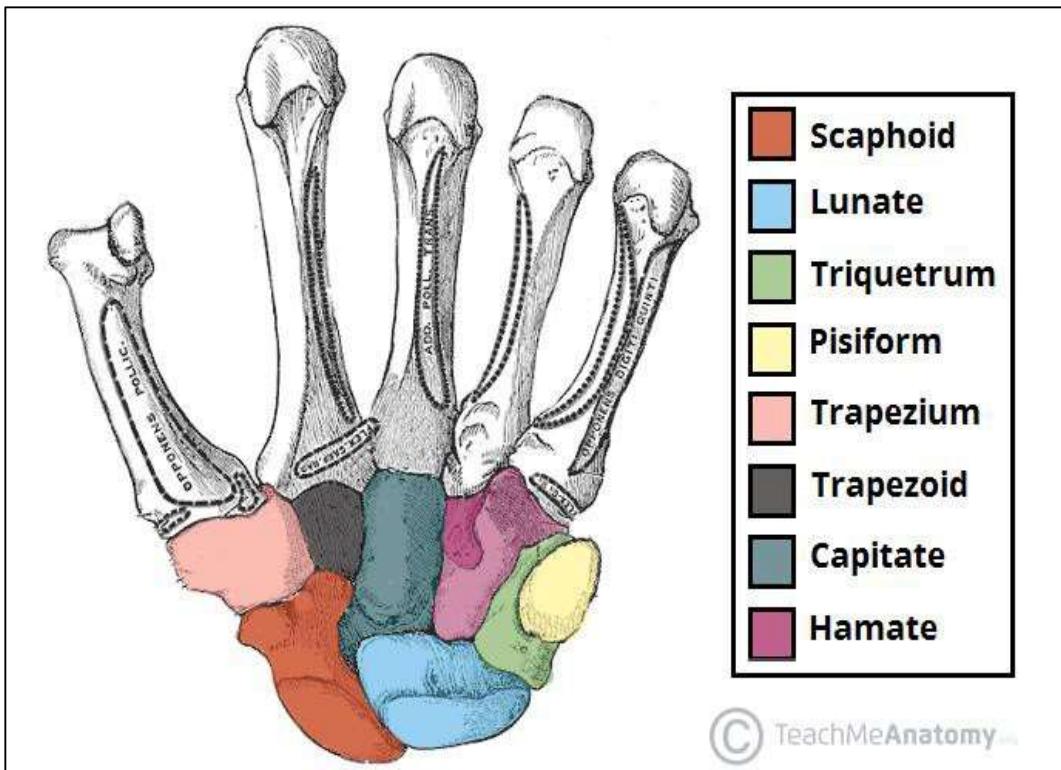


Figure 2: Illustration of the central bones of the hand (Jones, 2019).

2.1.2 Anatomy of the muscles of the hand

There are four main groups of muscles in the hand that will soon be discussed in detail:

- The thenar muscles
- Hypothenar muscles
- The interossei
- Lumbrical muscles

2.1.2.1 The thenar muscles

The thenar muscles are three small muscles that are located at the thumb base. The bellies in the muscle create a bulge, known as the Thenar eminence. They are responsible for delicate thumb movements. According to Oliver Jones (2018), all the thenar muscles are innervated by the median nerve. The thenar muscles are the Opponens Pollicis, Abductor Pollicis Brevis, Flexor Pollicis Brevis. Seen below is an example of the thenar muscles and where it is located.

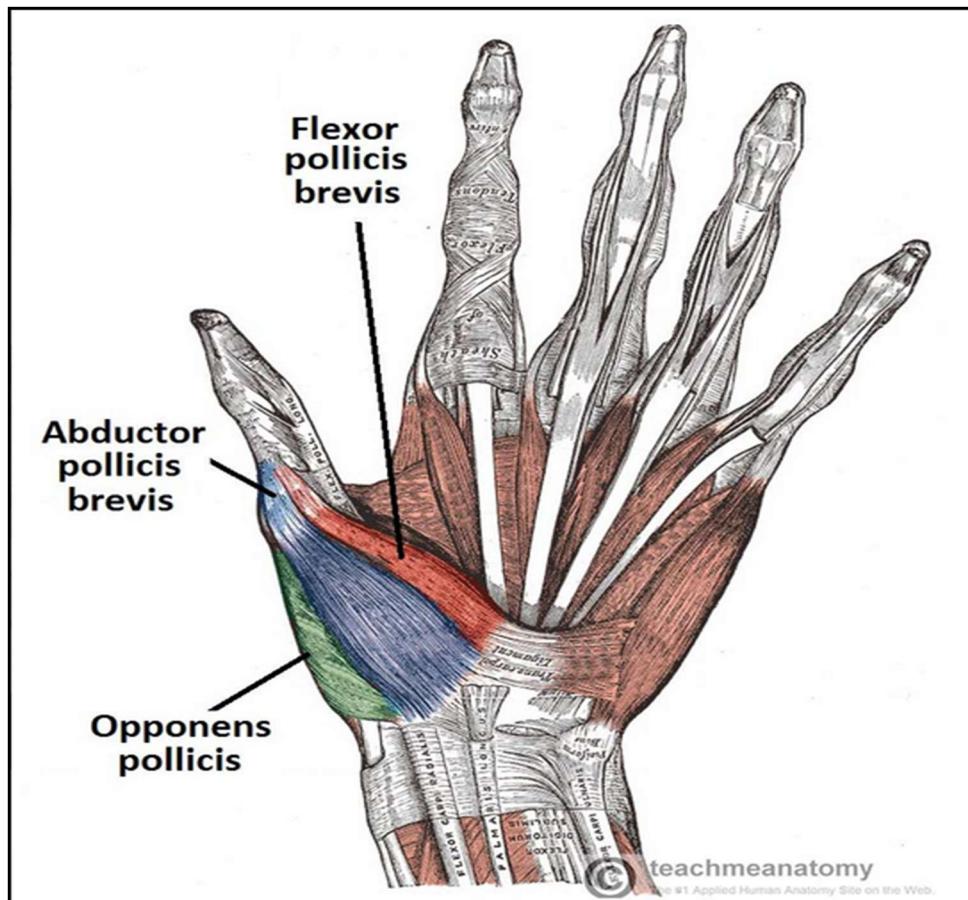


Figure 3: Illustration of the thenar muscles depicted (Jones, 2018).

2.1.2.2 The hypothenar muscles

The hypothenar muscles create the hypothenar eminence-a muscular protrusion at the base of the little finger on the medial side of the hand. Such muscles are similar in name and organization, to that of the thenar muscles. According to Oliver Jones (2018), the ulnar nerve innervates the hypothenar eminence muscles. The hypothenar, as with the thenar muscles, consists of three muscles which are the opponens digiti minimi, abductor digiti minimi, and the flexor digiti minimi Brevis. Seen below is an example of the three hypothenar muscles.

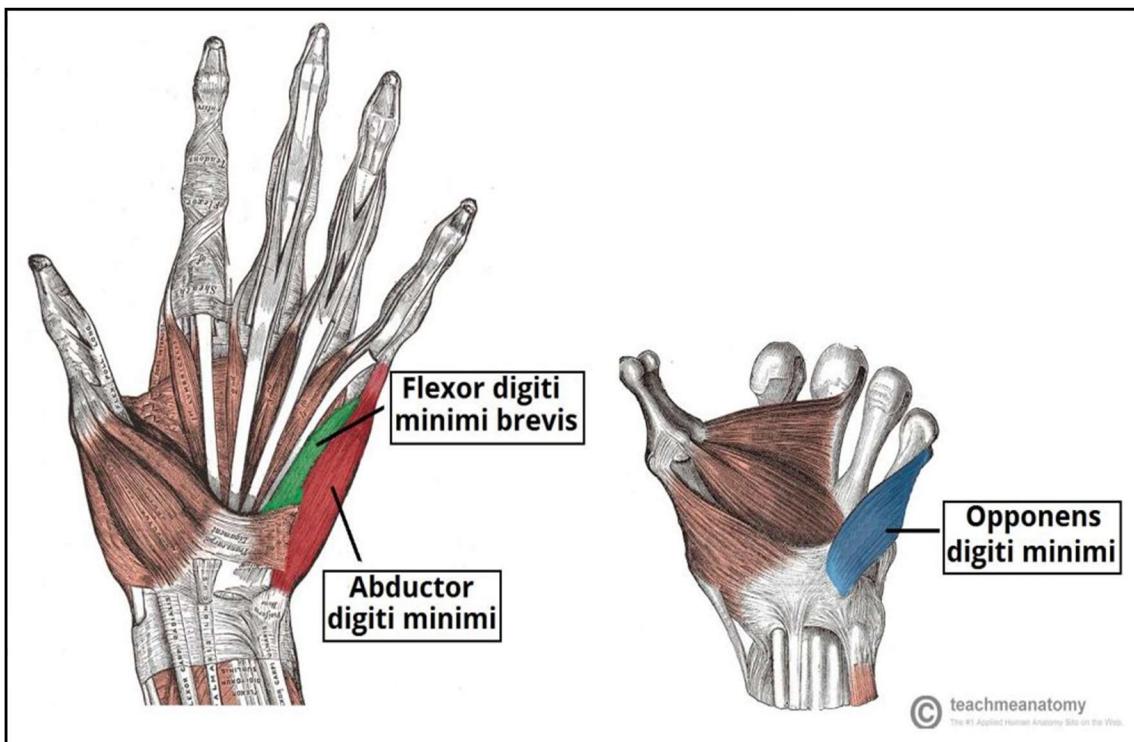


Figure 4: Depicted above is the hypotenar muscles (Jones, 2018).

2.1.3 INNERVATION OF THE HAND

Very few areas in the human body show as much branching and complexity as the hand nerves. The supply of nerves to an area is generally divided into a superficial (or cutaneous) group and a motor group. The pattern of distribution of these nerves has many variations (Norman, 2012). The general area of the hand includes 4 nerves:

- Radial
- Posterior antebrachial cutaneous
- Median
- Ulnar

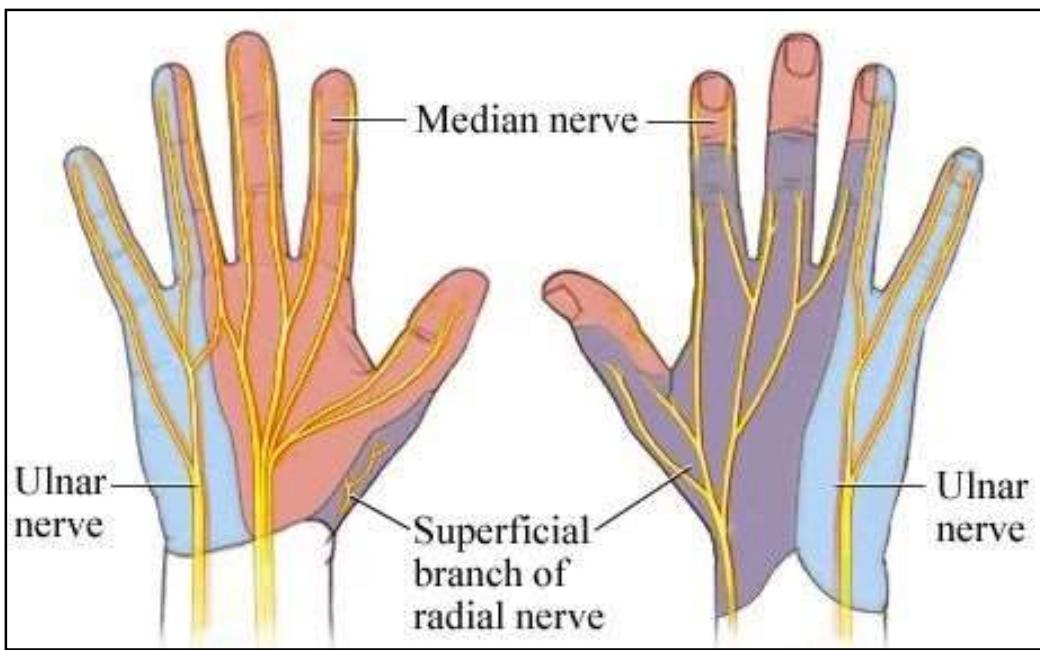


Figure 5: Nerve distribution of the hand responsible for sensation (Alexander, 2020).

The primary composition of the hand innervation is composed of three major nerves. These three nerves include the nerves of the Radial, Ulnar, and Median (Alexander, 2020). Each of these nerves, according to David Alexander, has multiple branches each but these nerves are usually located to some parts of the hand's posterior and anterior views of the hand. As mentioned, these innervations contain branches of nerve plexuses and contain fibers from more than one segment of the spinal cord.

As for the motor function, some of the muscles in the hand are innervated by the median nerve through two branches. The median nerve's recurrent branch innervates the thenar muscles - muscles associated with thumb movements. The palmar digital branch interferes with the lateral two lumbricals - these muscles conduct flexion at the metacarpophalangeal joints and extension at the index and middle finger interphalangeal joints. The deep branch of the ulnar nerve innervates much of the intrinsic hand muscles.

These muscles include the following:

- Hypotenar muscles
- Adductor pollicis
- Medial two lumbricals
- Palmar and dorsal interossei of the hand
- Palmaris Brevis

Seen below is a visual representation of the innervation of the hand.

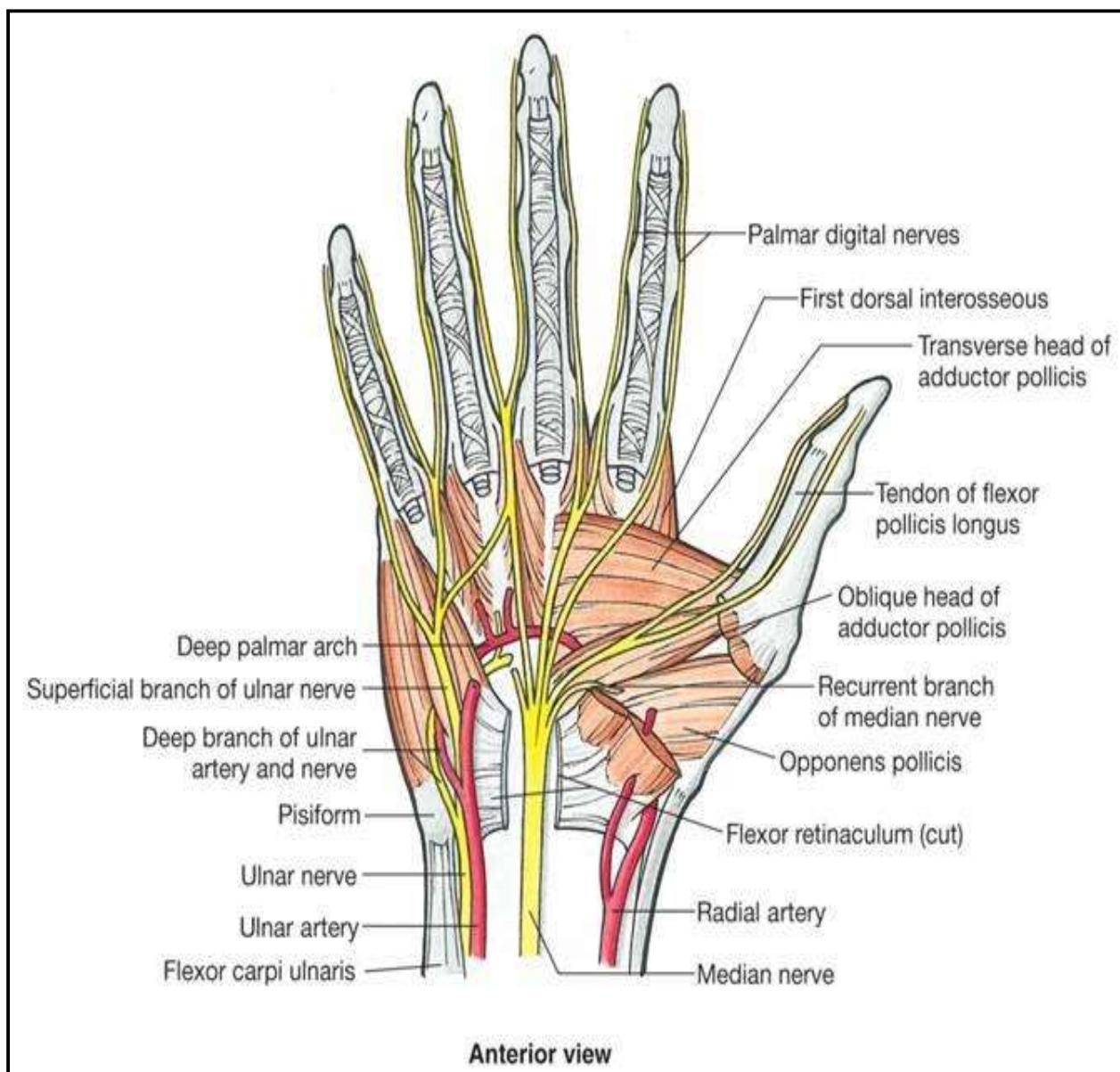


Figure 6: Illustrated above is the nerves along with the muscles which are innervated by each nerve (Alexander, 2020)

2.2 PATHOPHYSIOLOGY OF CARPAL TUNNEL SYNDROME

Neuropathy with trapping combines compression and friction phenomena. Nerve compression and traction can cause intraneuronal microcirculation disorders, lesions in the myelin sheath and axon, as well as alterations in the connective tissue supporting it. The entrapment of peripheral nerve results from its movement into an anatomical space that has become too narrow, resulting in altered function within the nerve and nerve dysfunction/damage from the compression site and beyond. According to Aboonq (2015), the most common example of this is the median nerve entrapment in the carpal tunnel at the wrist.

2.3 CLINICAL SIGNS AND SYMPTOMS

There is a range of symptoms a patient can suffer from because of carpal tunnel syndrome (CTS). These symptoms include the following:

- **Numbing and tingling:** The numbness and tingling in the hand may vary from unpleasant to painful for people with carpal tunnel syndrome. It is always initially a mild symptom, but it increases in severity as the disease progresses. Another distinguishing characteristic of carpal tunnel syndrome is that the small finger (fifth digit) isn't going to be as badly affected because it has a different nerve from the others (Gromatzky, 2018).
- **Cannot feel hot or cold:** When the nerves in the hand get trapped or injured, they can stop sensing temperature. This is potentially dangerous, as it means that a person can do terrible injury to his or her hands unknowingly.
- **Morning stiffness:** The muscles and joints are tense in the mornings because they are still for too long. Stiff muscles are generally only temporary, though, and the muscles are typically able to work normally after a little stretching and moving about. Nevertheless, people with carpal tunnel syndrome frequently find their hands' mobility seriously affected in the morning (Gromatzky, 2018).
- **Night-time pain:** One symptom of carpal tunnel syndrome is nocturnal pain in the hands. Although the pain is still experienced during the day, carpal tunnel syndrome sufferers report night-time pain being worse. Sometimes the pain is intense enough to arouse the patient.

- ***Difficulty holding objects:*** Carpal tunnel syndrome affects the finger- and thumb-moving muscles. Consequently, it can become difficult even to grasp. People with carpal tunnel syndrome can sometimes unexpectedly lose control, causing them to drop anything that they hold at the time.
- ***Muscle weakness:*** When carpal tunnel syndrome begins the power in the hands may be lost. At first, this loss of strength may be mild, but it worsens gradually as the disease progresses. When the hands are weak, then it is increasingly difficult to do even daily activities (Gromatzky, 2018).
- ***Swollen finger sensation:*** When the nerves in the fingers are trapped or injured due to carpal tunnel syndrome, the fingers may feel swollen even though they are not. This can significantly reduce dexterity. Which makes it harder than normal to carry out more delicate tasks.
- ***Itching:*** Itching may occur in carpal tunnel syndrome, for no apparent cause. People with symptoms of carpal tunnel syndrome can feel like their hands and fingers are constantly itching. The condition is a result of the compression of the median nerve inside the carpal tunnel (Gromatzky, 2018).
- ***Burning sensation:*** Carpal tunnel syndrome may cause somebody to feel a burning sensation even though nothing is hot. This phenomenon also happens when the hand is placed in the same place for a prolonged period, for example when a person sleeps. The sensation will wake the person.

There are several tests to lock out the symptoms of CTS. These tests are known as provocative tests and are essential in determining the diagnosis of CTS in conjunction with NCS, and the severity of the CTS.

The provocative tests are as follow:

- ***The Phalen's test:*** this test according to Shiri (2014), is performed with the arms in front of the patient. The patient should flex the wrist so that the back of the hands presses against each other for 30- 60 seconds. If there is an onset of pain or paraesthesia in the median nerve distribution, the test is positive for CTS.

- **Tinel's sign:** This was one of the first nerve neuropathy provocative tests. In the case of CTS, you can use your fingers to tap the median nerve around the carpal tunnel region (Shiri, 2014). When you feel pins and needles or discomfort in the distal or proximal areas of a particular nerve, this may also be a positive indication of CTS. This test can also be used for other neuropathic nerves.

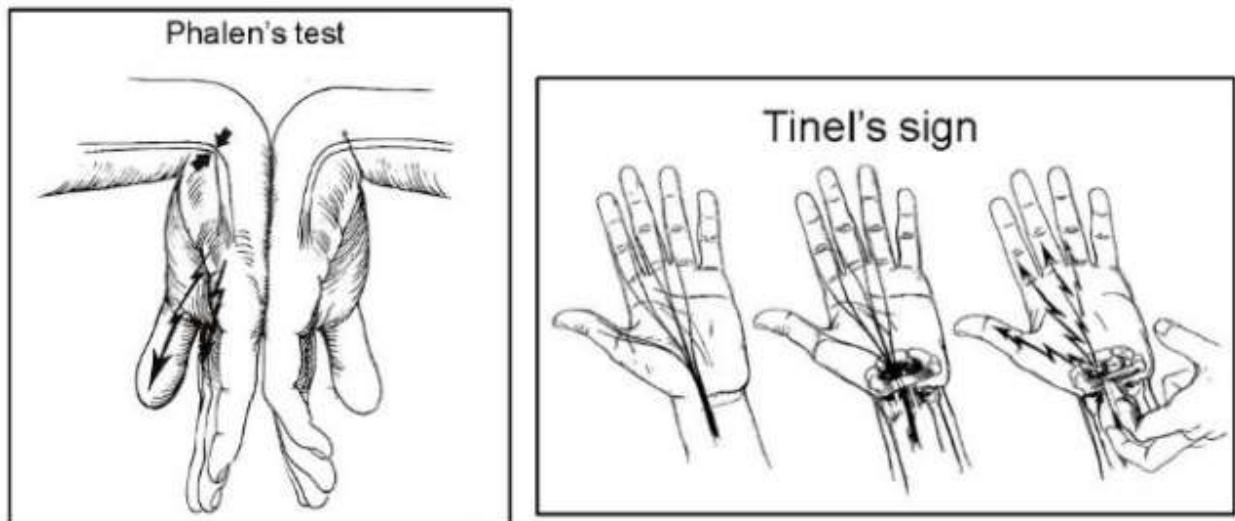


Figure 7: Seen above is an example illustrating how the Phalen's test and Tinel's sign is performed (Shiri, 2014).

- **The Durkan's test:** This is done by placing the thumb over the carpal tunnel region and holding it under pressure for 30 seconds (Shiri, 2014). If there is an onset of pain or paraesthesia in the median nerve distribution in 30 seconds, it is a positive indication of CTS.

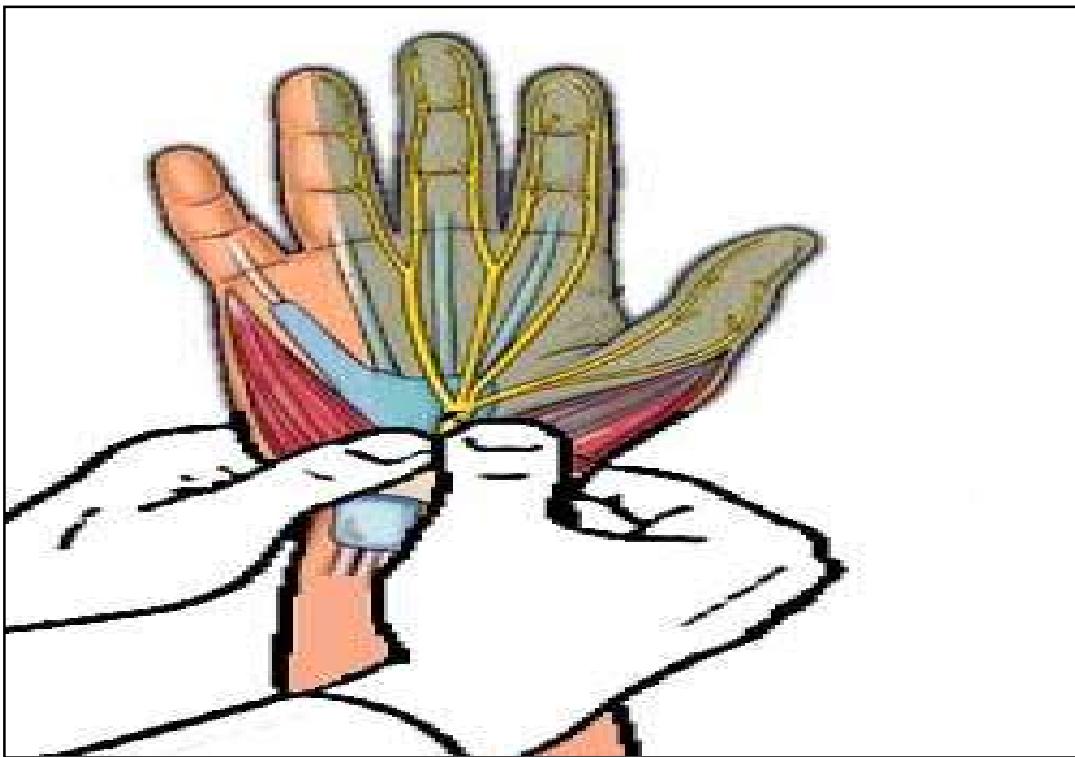


Figure 8: Illustrated above is an example depicting how the Durkan test is performed (Shiri, 2014).

2.4 TECHNICAL SPECIFICATIONS

2.4.1 ANTI-SENSORY VS ORTHODROMIC STIMULATION

Anti-sensory is also sometimes referred to as antidromic. Sensory nerve action potentials (SNAP) spread proximally towards the dorsal root ganglion from the sensory nerve endings (Chu, 2019). During NCS, the propagation of an induced action potential moves proximally and distally in both directions. The recording electrodes, in an orthodromic study, measure the potential action going in the physiological direction.

The recording electrodes measure, in an antidromic study, the action potential traveling opposite the physiological direction. All motor NCS are orthodromic. Sensory NCS can be either orthodromic or antidromic (Chu, 2019). The amplitudes of an antidromic SNAP are higher than the amplitudes of orthodromic SNAP. This phenomenon is distally attributed to the more superficial path of the sensory nerves so that the recording electrode is closer to the produced signal.

Many reasons for the decreased amplitude of orthodromic sensory Nerve conduction studies (NCS) include the smaller and/or less excitable distal branches of the nerves (Chu, 2019). The nerve is stimulated proximally during antidromic recordings and the recording electrode is placed distally. The sensory nerve is stimulated distally during orthodromic recordings, and the recording electrode is placed proximally.

2.4.2 SENSORY NERVE CONDUCTION STUDIES

2.4.2.1 Second digit anti-sensory (median sensory antidromic stimulation)

Electrode placement

- Reference electrode: The reference electrode is located at or around the index finger's distal interphalangeal flexion crease so that a distance of at least 3sm between the active and reference electrode is maintained (Nestor & Nelson, 1990).
- Active (recording) electrode: The active recording electrode is connected to the index finger (Nestor & Nelson, 1990) at the midpoint of the distance between the phalangeal flexion crease and the index finger's (second digit) webspace, so that a distance between the stimulating electrode and the active electrode is maintained not less than 10 cm but not more than 14 cm.
- Ground electrode: The ground electrode should be positioned between the active and stimulating electrodes at the dorsum of the hand.

Electrostimulation

The percutaneous electrostimulation shall be applied as follows:

- The stimulation between the flexor digitorum sublimis and the flexor carpi radialis tendons proximal to the transverse carpal ligament is performed at the wrist (Nestor & Nelson, 1990).

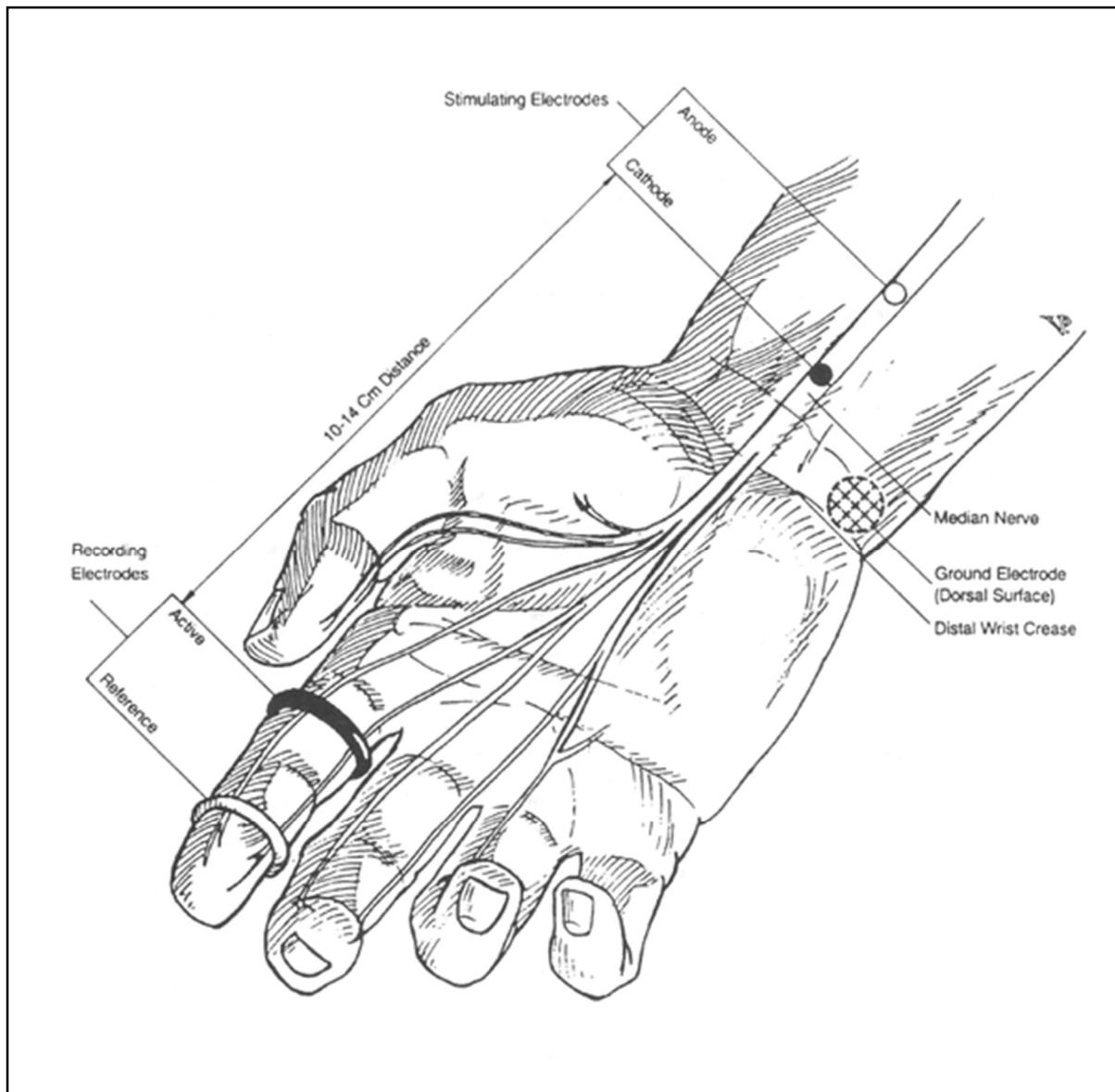


Figure 9: Illustrated above is the position of the recording electrodes, distances, and anatomical stimulation position when doing a second digit antidromic stimulation (Nestor & Nelson, 1990).

2.4.2.2 Fifth digit anti-sensory (ulnar sensory antidromic stimulation)

Electrode placement

- Reference: The reference electrode is positioned at or around the small finger's distal interphalangeal joint line (fifth digit) so that a distance of no less than 3 cm between the active and reference electrode is maintained (Nestor & Nelson, 1990).

- Active: The active recording electrode is attached to the small finger at the midpoint of the small finger's proximal phalanx (Nestor & Nelson, 1990) so that the stimulating electrode and the active electrode maintain a distance of no less than 10 cm but no more than 14 cm.
- Ground: The ground electrode should be positioned between the active and stimulating electrodes at the dorsum of the hand.

Electrostimulation

The percutaneous electrostimulation shall be applied as follows:

Stimulation is performed at the wrist, medial, or lateral to the flexor carpi ulnaris tendon (Nestor & Nelson, 1990).

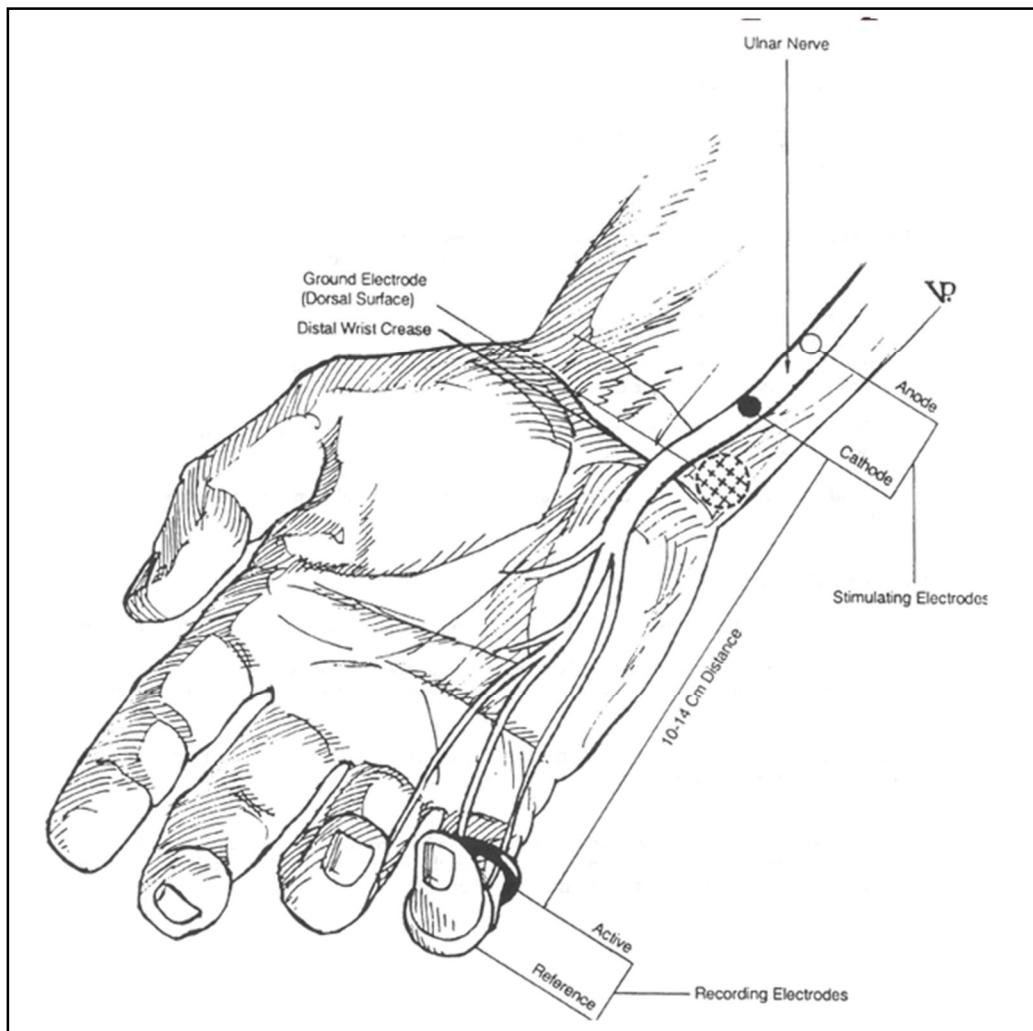


Figure 10: Illustrated above is the position of the recording electrodes, the distance from which to stimulate, and where to stimulate (Nestor & Nelson, 1990).

2.4.2.3 Digit four sensory study (median vs ulnar anti-sensory stimulation)

Electrode placement

- Reference electrode: The reference electrode is positioned 3–4 cm distally over the interphalangeal distal joint (Bruno & McCaughan, 2019).
- Active: The active reference electrode is placed over the metacarpal- phalangeal joint (Bruno & McCaughan, 2019).
- Ground: The ground electrode should be positioned between the active and stimulating electrodes at the dorsum of the hand.

Electrostimulation

- The median nerve at the wrist: the stimulation will be performed between the tendons to the flexor carpi radialis and palmaris longus 12–14 cm from the active recording electrode in the center of the wrist.
- Ulnar nerve at the wrist: Stimulation will take place at the medial wrist, adjacent to the flexor carpi ulnaris tendon 12–14 cm from the active electrode (Bruno & McCaughan, 2019).
- The same distance must be used for median and ulnar stimulation.

2.5 AIM

This retrospective study aimed to compare two sensory nerves (median and ulnar sensory nerves) by using anti-sensory stimulation to determine which test most accurately reflects the severity of carpal tunnel syndrome.

2.6 OBJECTIVES

In reaching the aim of this study, the following were the objectives:

- Carpal tunnel syndrome Protocol 1
 - Values obtained from the second digit anti sensory stimulation were collected.

- Values obtained from fifth digit anti sensory stimulation were collected.
 - The latency between median and ulnar was determined.
- Carpal tunnel syndrome protocol 2
 - The values obtained from the fourth digit comparative study between the median and ulnar anti sensory stimulation were collected.
 - The latency between the median and ulnar was determined.
- The most sensitive protocol for detecting carpal tunnel syndrome was established.

CHAPTER 3

METHODOLOGY

3.1 Study location

This study was performed at the electroencephalograph (EEG)/ electromyography (EMG) Clinic, at the Universitas Academic Hospital's Outpatient Section. This hospital is located in Bloemfontein, in the Free State, South Africa.

3.2 Study design

This study followed a retrospective analytical study design, involving patients that received nerve conduction studies (NCS) in the original study (Study A), on which this retrospective study is based. Only patients that adhered to the inclusion criteria, had been selected to take part in this study. Pre-recorded data had been altered slightly, to become fictitious for this study.

3.3 Research team

Main Researcher:

Jarike du Plessis

4th-year Technology Student (Neurophysiology)

Universitas Academic Hospital, Bloemfontein, Free State, South Africa

Cell: 074 845 9399

External/ Main Supervisor:

Mrs. JE le Roux

Head of Clinical Technology (Neurophysiology)

Universitas Academic Hospital, Bloemfontein, Free State, South Africa

Cell: 082 564 3968

Internal Supervisor:

Mrs. C Bezuidenhout

Central University of Technology

Bloemfontein

Cell: 082 775 2842

3.3.1 Expected research outcomes

The research took place in partial fulfillment of the BTech degree and will also be presented at the BTech day of the Central University of Technology (CUT), end November 2020.

3.4 Study layout

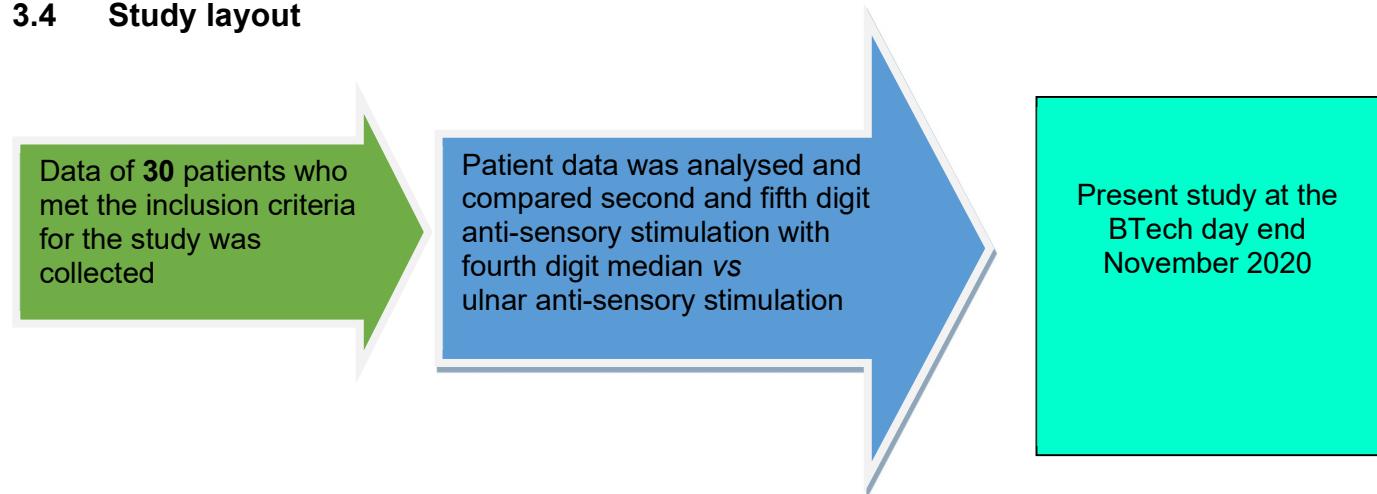


Figure 11: Study layout by the researcher.

3.5 Study population

3.5.1 Number of subjects

This study involved the results of the last 30 consecutive hands that received nerve conduction studies (NCS) at the EEG/EMG Clinic. The participants met the inclusion criteria of the original study (Study A) on which this retrospective study is based.

3.5.2 Subject identification

All patients were referred from the Hand Clinic situated at the Pelonomi Hospital in Bloemfontein. They had a preliminary diagnosis of carpal tunnel syndrome (CTS) and were scheduled for carpal tunnel release surgery as part of the original parent study on which this retrospective study is based.

3.5.3 Inclusion- and Exclusion criteria

3.5.3.1 Inclusion criteria

- Males and females
- Any ethnicity
- Aged older than 18 years
- Patients with symptoms of carpal tunnel syndrome
- Any referred patient that participated in the original study by signing a consent

3.5.3.2 Exclusion criteria

- Patients 18 years and younger

Patients with previous:

- Hand surgery to the same hand
- Proximal median nerve pathology
- Nerve root pathology
- Brachial plexopathy
- Peripheral neuropathy

The above-mentioned may be an indication of other peripheral neuropathies.

3.6 Special investigations

Permission was granted to collect the patient data from February 2019 to September 2019. The data was accessed at Universitas Academic Hospital at the Outpatient Department Neurology, where the data has originally been recorded. The data was available on a computer system in the EMG laboratory.

During the recording of the sensory nerve action potential (SNAP) (in Study A), recording electrodes were placed on the fingers by using ring electrodes. The ring electrodes were used to record the SNAP from the fingers because the nerves are closer to the surface of the skin. Therefore, the second digit anti-sensory stimulation examined the median nerve, the fifth digit anti-sensory stimulation examined the ulnar sensory nerve and the SNAP recorded at the fourth digit compared anti-sensory stimulation of the median sensory nerve with the ulnar sensory nerve.

3.7 Statistical analysis

The researcher gathered patient information from Study A (the parent study). The data was recorded electronically onto data sheets in Excel. All further analysis was done by a statistician using SAS Version 9.2. Descriptive statistics namely frequencies and percentages were calculated for categorical data and means and standard deviations or medians and percentiles were calculated for numerical data. The Shapiro-Wilk test was used to investigate the distribution of numerical data. For the dependent data, the mean difference in latency between the 2 protocols was calculated. Analytical statistics, namely the dependent T-test (or signed ranked test) were used to compare means (or medians) in the different protocols. A significance level (α) of 0.05 was used.

3.8 Ethical Aspects and Good Clinical Practice

3.8.1 Safety variables

3.8.1.1 Project safety

This was a retrospective study involving pre-recorded data.

3.8.1.2 Patient safety

This was a retrospective study and therefore there was no contact with the patients. Specific patient ID's were allocated to each participant to keep their identities and personal information confidential.

3.8.1.3 Premature discontinuation of study

The analysis would have been prematurely stopped if the researcher or study leaders believed that the confidentiality of a patient might have been compromised, or if any unethical procedures occurred.

3.8.1.4 Good Clinical Practice (GCP)/ Quality assurance

All clinical work conducted under this protocol was subjected to the GCP Guidelines (The Principles of ICH GCP, 2004). The declaration of Helsinki's basic principle number 3 states that research should be conducted only by scientifically qualified people and under the supervision of adequately qualified people (World Medical Association, 2002).

3.8.2 Financial implications to patient

This was a retrospective study and therefore there were no financial consequences for the patient. Only pre-recorded patient data was used. The data was slightly altered to become fictitious.

3.8.3 Withdrawal criteria

This was a retrospective study so the criterion for withdrawal did not apply.

3.8.4 Confidentiality

As far as possible, personal information of the patients who took part in this particular study was kept confidential. This study was confidential. No detail of any of the patients was disclosed to any other person at any point during the study, as to who the patient consented to.

CHAPTER 4

RESULTS

In this section, the results of the study will be reported for the 30 patients that were included in the study.

Firstly, the distribution of the variables of the two protocols was investigated. According to the Shapiro-Wilk test, all the variables were skewed ($p < 0.05$) as seen in Table 1 below except for the distribution of the Median which followed a normal distribution. Since the difference between the Median and Ulnar must be established the distribution of the Median will also be considered as skewed. Consequently, the median and inter-quartile range (IQR) of all 4 variables will be reported.

Table 1: Results of the Shapiro-Wilk test for normality (n = 30).

Protocol	Variable	W-statistic	p-value
Protocol 1	2 nd Digit anti-sensory	0.803	< 0.0001
	5 th Digit anti-sensory	0.689	< 0.0001
Protocol 2	Median	0.955	0.2252
	Ulnar	0.697	< 0.0001

Table 2 below shows the descriptive statistics of the variables for the 2 protocols (n = 30). For protocol 1 the median 2nd digit anti-sensory value was 4.35 and the median 5th digit anti-sensory value was 2.90. For protocol 2 the median Median value was 4.1 and the median Ulnar value was 3.1.

Table 2: Descriptive statistics of the two protocols (n = 30).

Protocol	Variable	Median	IQR	Minimum	Maximum
Protocol 1	2 nd Digit anti-sensory	4.35	3.3 – 4.8	2.9	10.5
	5 th Digit anti-sensory	2.90	2.8 – 3.4	2.4	6.1
Protocol 2	Median	4.100	3.2 – 5.6	0.800	8.300
	Ulnar	3.100	3.0 – 3.9	2.600	7.400

Next, the difference in latency for each protocol is determined and the descriptive statistics for the differences are shown in Table 3 below. According to the Shapiro-Wilk test the distribution of both these differences were skewed (Protocol 1: $W = 0.799$, $p < 0.0001$; Protocol 2: $W = 0.85196$ $p = 0.0007$). For protocols 1 and 2 the median difference in latency was 1.45 and 0.90 respectively.

Table 3: Descriptive statistics of the difference between the two protocols (n = 30).

Protocol	Median difference	IQR for the difference	Minimum difference	Maximum difference
Protocol 1	1.45	0.60 – 2.10	0.20	7.70
Protocol 2	0.90	0.30 – 2.60	0.00	5.10

Next, the median difference in latency between the two protocols was compared and Table 4 below shows the descriptive statistics for the difference observed. According to the Shapiro-Wilk test, the distribution of the difference was skewed ($W = 0.859$, $p = 0.0010$) and the median and IQR were reported. The median difference for the difference in latency between the two protocols is 0.100. According to the Signed Rank test, the median difference between the two protocols is not significant ($p = 0.3227$). Thus, there is no significant difference in the difference in the latency of the two protocols.

Table 4: Descriptive statistics of the difference in latency between the two protocols (n = 30).

Median difference	IQR for the difference	Minimum difference	Maximum difference
0.100	-0.20 – 0.30	-3.1	4.50

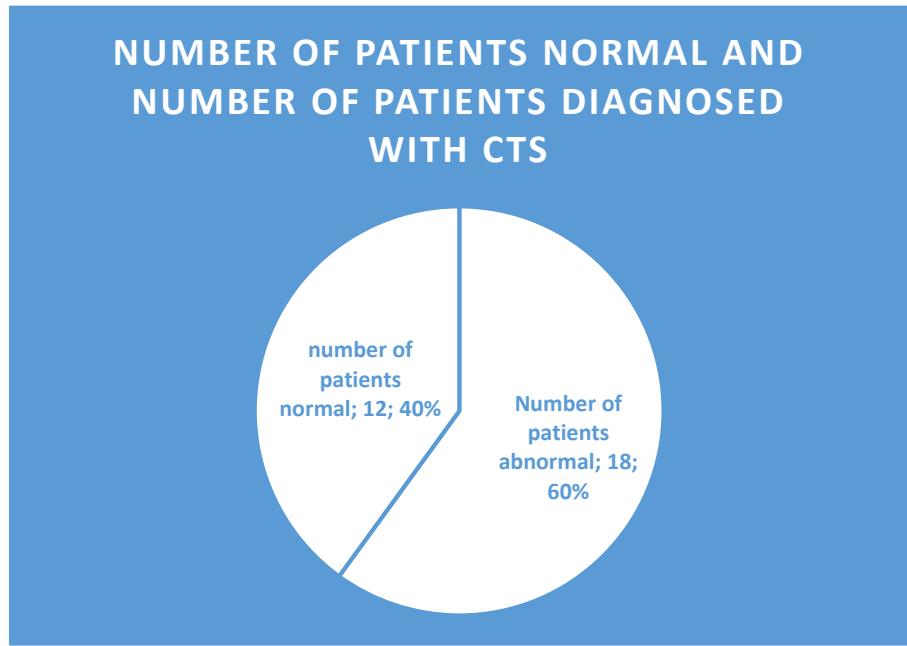


Figure 12: Seen above is a pie chart depicting the number of patients who had a normal NCS compared with the number of patients who had an abnormal NCS.

Seen in the pie chart above is the number of normal patients compared with the number of patients with abnormal NCS. The majority of patients whose data was involved in this retrospective study had abnormal NCS.

Number of normal females vs number of females with confirmed CTS.

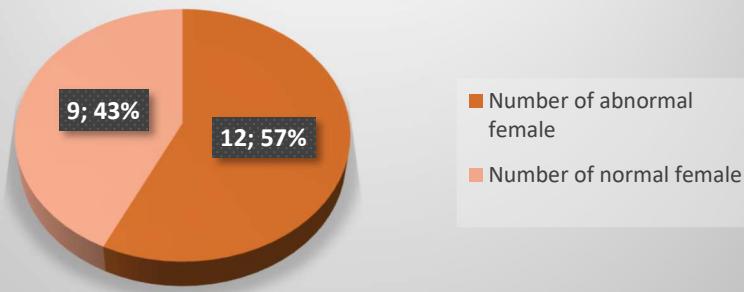


Figure 13: Above is a pie chart depicting the number of females who had a normal NCS compared with number of females who had an abnormal NCS.

As shown in the graph above the number of females with abnormal NCS is 12 (57%) while the number of females with normal NCS is 9 (43%). There were more females with abnormal NCS than females with normal NCS in this retrospective study.

Number of normal males vs males with confirmed CTS.

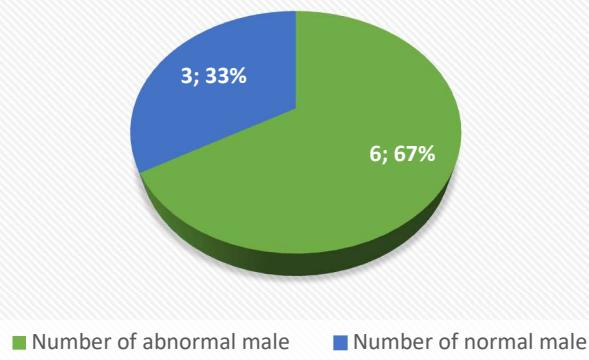


Figure 14: Pie chart showing the number of males with normal NCS and comparing it to the number of males with a normal NCS.

Illustrated above the pie chart shows the number of males with normal NCS to be 3 (33%) and the number of males with abnormal NCS is 6 (67%). Therefore, there are more males with abnormal NCS than males with normal NCS in this retrospective study.

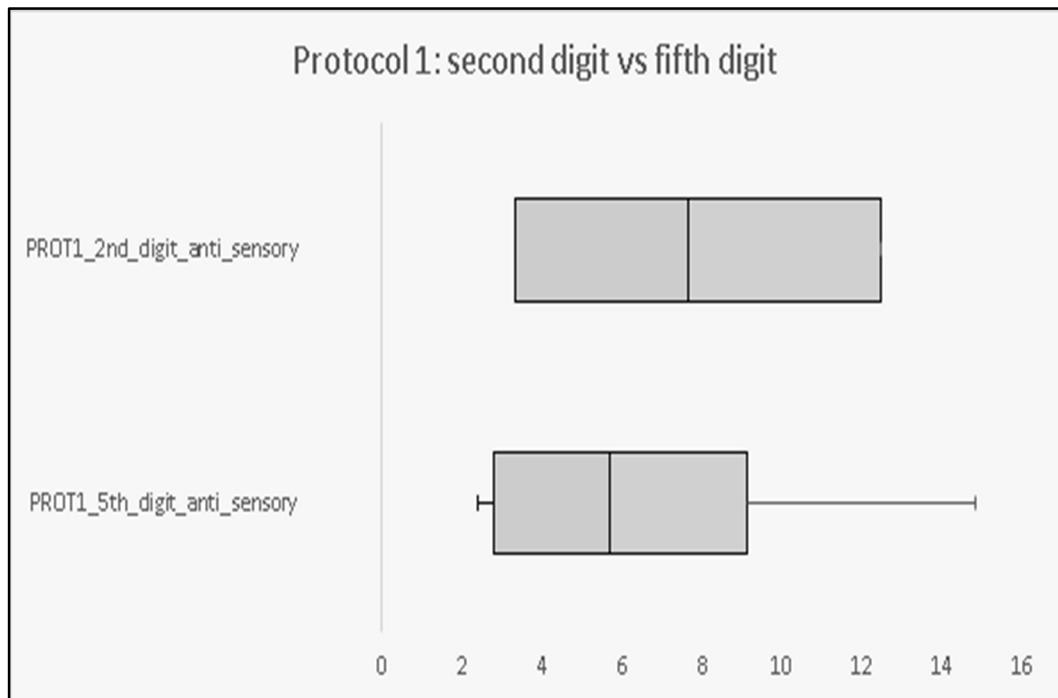


Figure 15: Above is a box- and- whisker graph showing the distribution of Protocol 1.

Seen in the box- and- whisker diagram of the second digit and fifth digit (collectively referred to as Protocol 1) the second digit anti sensory seems to follow a normal distribution while the fifth digit anti sensory shows data to be skewed to the left.

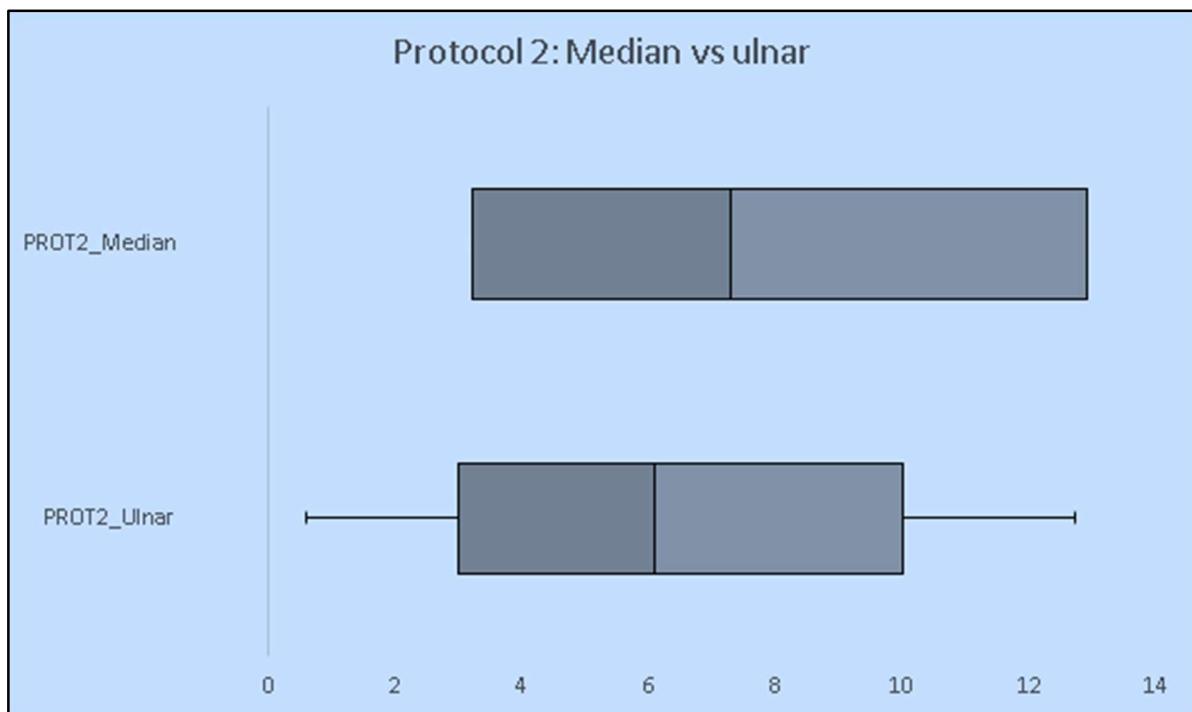


Figure 16: Box- and whisker diagram showing the distribution of Protocol 2.

Depicted in the box- and- whisker diagram of the median nerve and the ulnar nerve (collectively referred to as protocol 2) the median nerve has a normal distribution seeing as the data is centered and the ulnar nerve seems to follow normal distribution seeing as the data is centered.

CHAPTER 5

DISCUSSION

In this section, the results of the study will be reported for the 30 patients that were included in the study.

An investigation into the distribution of the variables of the two protocols showed that all the variables were skewed ($p < 0.05$) except for the distribution of the Median which followed a normal distribution ($p > 0.05$). Since the difference between the Median and Ulnar was established the distribution of the Median was considered as skewed. Consequently, the median and inter-quartile range (IQR) of all 4 variables will be reported. For protocol 1 the median 2nd digit anti-sensory value was 4.35, the median 5th digit anti-sensory value was 2.90 and the median difference in latency was 1.45 [IQR: 0.06 – 2.10]. For protocol 2 the median Median value was 4.10, the median Ulnar value was 3.10 and the difference in latency was 0.90 [IQR: 0.30 – 2.6]. Lastly, the median difference for the difference in latency between the two protocols is 0.100 [IQR: -0.20 – 0.30] Since $p = 0.3227 < 0.05$ there no significant difference in the difference in latency of the two protocols.

It is seen that 60% of the patients had an abnormal NCS which confirmed a diagnosis of CTS, while the remaining 40% had normal NCS. Of the 30 patients whose results/data was used in this study, 43% of the females had a normal NCS while 57% of the females had an abnormal NCS, which confirms a diagnosis of CTS.

Among the males, 33% had normal NCS, while 67% of the males had an abnormal NCS confirming a diagnosis of CTS. The box- and- whisker diagram of Protocol 1, showed the data of the second digit to be centered (following a normal distribution) while the data of the fifth digit is skewed to the left (does not follow a normal distribution). With regards to Protocol 2, the box-and-whisker diagram showed the data of both the median sensory nerve and the ulnar sensory nerve were centered (follows normal distribution).

CHAPTER 6

CONCLUSION

In conclusion, the difference in the latency between the two protocols was the same.

Of the 30 patients whose data was modified for this retrospective study, 21 (70%) was female and 9 (30%) was male. Of the 21 females, 12 (57%) showed abnormal NCS indicative of CTS while 9 of the female patients showed normal NCS. Of the 9 male patients, 6 showed abnormal NCS indicative of CTS while the other 3 showed normal NCS. Therefore it can be concluded that females are more often referred to the NCS lab for CTS diagnosis than males.

Protocol 2 showed more sensitivity towards detecting CTS, in comparison with that of Protocol 1.

6.1 LIMITATIONS

Limitations include the following:

- The patient can have an abnormal NCS because of a possible pathological abnormality such as entrapment neuropathies of the upper extremities, giving a false indication of CTS.
- NCS may have high sensitivity as a diagnostic tool, but NCS also has low specificity.
- The sample size was relatively small.

6.2 RECOMMENDATIONS

The following are recommended to compensate for the limitations of this study:

- Using a larger sample size
- Using EMG along with the NCS to rule out any myopathies, muscular dystrophies, or other pathologies affecting the muscles showing symptoms similar to CTS.
- Consideration should be given to using alternative diagnostic tests or tools based on the results of the NCS to rule out other possible conditions mimicking CTS symptoms and/ or NCS results.

CHAPTER 7

REFERENCES

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Norman, W. (2012). *Nerves of the Hand* [online]. Available:
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CHAPTER 8

APPENDICES

APPENDIX A: Curriculum vitae

APPENDIX B: Data Collection Sheet

APPENDIX C: Correspondence

APPENDIX D: Plagiarism and Declaration of Independent Work

Appendix A

Curriculum Vitae

Jarike Du Plessis

Personal information

Language:

Bilingual (Afrikaans and English)

Date of Birth:

19 August 1997

Place of Birth:

Kuruman

Northern Cape

Nationality:

South African

Identification Number:

9708190074087

Drivers license:

Learner and in the progress of getting my license

Health:

Average

Marital Status:

Not married

Contact details

Cellphone number:

0748459399

Physical Address:

94 Constantia park, Hendrietta Grove Street

Langenhoven Park

Bloemfontein

9301

Email address:

duplessisjarike@gmail.com

Academic record

School:

High School Kalahari (Kuruman); Matriculated 2015

Subjects Grade 10-12:

- Afrikaans
- English
- CAT (Computer Application Technology)
- Life Science
- Physical Science
- Maths
- Life orientation

Extended program (Bachelor of Science) (UFS) - 2016

Subjects

- Introduction to Biology
- The Interdependence of plants and life on earth
- Organic Chemistry
- Introduction to chemistry-development module
- Physical Chemistry
- Inorganic Chemistry
- Organic Chemistry
- Computer Literacy part 1
- English Academic Literacy for Natural Sciences
- Mathematics and Applied Mathematics
- Introduction to University Mathematics 1
- Preparatory learning for Natural Sciences

BTech Clinical Technologist Neurophysiology 2017 - current

Subjects

- Anatomy
- Physiology
- Physics
- Calculations and Statistics
- Organ and Systemic Pathophysiology
- Pharmacology
- Biomedical Apparatus and Procedures
- Psychodynamics
- Clinical Technology (Neurophysiology III)
- Clinical Practice (Neurophysiology III)
- Biomedical Apparatus and Procedures (Neurophysiology III)

Work experience

Kalahari pharmacy:

- Cashier
- Counter Assistant
- Self-medicate
- Assisting patients with over the counter medicine

Time frame in which I worked:

- December 2013 (School holiday)
- July 2014 (School holiday)
- December 2014 (School holiday)
- December 2017 (University holiday)

Built It:

- Helping with admin duties and filling.
- Helped with shelving and storage

Time frame in which I worked:

- July 2015 (School Holiday)

CURRICULUM VITAE

OF

Juanita Le Roux (Main Supervisor)

BIOGRAPHICAL DETAILS:

FULL NAMES: Juanita Elizabeth Le Roux

DATE OF BIRTH: 21/10/1982

NATIONALITY: South African

SOUTH AFRICAN ID NO.: 8210210013089

HEALTH: Good

HOME LANGUAGE: Afrikaans

OTHER LANGUAGES: English

CONTACT DETAILS:

WORK ADDRESS: Department of Neurology, OPD, Universitas Hospital, Logemanstreet,
Bloemfontein.

TELEPHONE (W): +27 51 405 3536

MOBILE: 082 564 3968

E-MAIL: juanitalerouxsa@gmail.com

QUALIFICATIONS

1. N. dipl. Clinical Technology Neurophysiology - 2003 (CUT formally known as Free State Technicon.)
2. B.Tech. Clinical Technology Neurophysiology - 2005 (CUT formally known as Free State Technicon.)
3. N. dipl. Clinical Technology Additional Category Pulmonology: 2005 (CUT formally known as Free State Technicon.)

WORK EXPERIENCE:

1. I completed my **practical training** at **Universitas Hospital** for Neurophysiology and Pulmonology: 2003-2005
2. **Private Practice in Clinical Neurophysiology:** Jaco Smith & Partners (Benoni) 2006-2010
3. **Department of Internal Medicine at Universitas Academic Hospital (Pulmonology-primary responsibility Polysomnography and related sleep studies):** 2011-2017
4. **Department of Neurology at Universitas Academic Hospital** (Neurophysiology Department) 2018-02/2019
5. **Part-time work in Private practice for Bernard van Niekerk:** (After-hours Neurophysiology services to the private hospitals in Bloemfontein.) 2011-2018.
6. **Part-time lecturer at CUT (Central University of Technology):** Department of Health Sciences; Programme: Clinical Technology Neurophysiology (Third and Fourth years): 2017-2018

Subjects: Clinical Technology Practice III

Clinical Practice III

Biomedical Apparatus III

Clinical Neurophysiology IV

7. Part-time work in Private practice for Dr. E. Pretorius (Neurologist at Mediclinic):

After hour's Neurophysiological Services) 02/2018-02/2019.

2001-2002

WORK SKILLS

1. **Neurophysiological services** including (Routine EEG's; Long-term EEG's with and without video telemetry; ICU EEG long-term monitoring; Neonatal EEG's; Polysomnography; CPAP titration and initiating CPAP therapy and follow-up; Nerve conduction studies; Assisting in EMG studies; Evoked potentials including VEP's; BAEP's; SSEP's) and interpretation of reports on abovementioned patients. I also obtained some experience in theatre neurophysiology monitoring.

2. **Pulmonology skills acquired:** Spirometry pre- and post-bronchodilator;

Full lung function studies including Body Plethysmography

Lung Diffusion Capacity

FRC (N₂ Washout Technique)

Assisting with bronchial provocation test

Capillary blood gas testing.

6-minute walk test

Dexa scans; Bone density scans

Polysomnography and CPAP/BIPAP titration and treatment have given

Pediatric polysomnography

3. Teaching experience:

Teaching polysomnography and CPAP/BIPAP therapy skills during my time spent at Pulmonology (I assisted in the teaching of practical as well as theory; and also helped with assessments regarding the sleep laboratory skills - I was responsible for teaching both the Neurophysiology students and Pulmonology students of Clinical Technology program at the CUT (Third and Fourth years).

Teaching theory and practical training for third- and fourth-year Clinical Technology Neurophysiology students at Universitas Hospital and theory training of long-distance learning students in the field of Neurophysiology. Students that are registered at the CUT.

Undergraduate Examiner: N Diploma. Clinical Technologist Neurophysiology; students at the CUT.

Undergraduate Moderator: Moderator of the third-year Neurophysiology examinations at DUT (2018)

Teaching Neurophysiology skills to the post-graduate MMed (Registrars of Neurology). The registrars rotate on a four-monthly basis through the Neurophysiology Department, where I am responsible for teaching the necessary Neurophysiology skills that the Registrar Neurologist requires to pass their final examinations.

4. Management skills:

I was mainly responsible for managing the sleep laboratory services at Universitas Hospital; including scheduling of patients, bookings of the beds, report generating, CPAP therapy machines inventory as well as the inventory of the sleep laboratory, maintaining adequate stock levels, keeping the polysomnography as well as other sleep-related equipment in working condition, etc.

I was transferred to the Neurology Department; where I am still managing the Neurophysiology Department.

October 2018; I was elected to be the Free State representative for CNSSA (Clinical Neurophysiology Society of South Africa)

5. **Co-Investigator in a post-graduate research study (MMed)** for Dr. DL Nkoane-Erasmus (Registrar for Neurology) “*Electrophysiological Outcomes of Carpal Tunnel Release for Carpal Tunnel Syndrome*”

CURRICULUM VITAE (ABRIDGED)

Colleen Bezuidenhout (Internal Supervisor)

1. PERSONAL DETAILS

Name and Surname: Colleen Bezuidenhout
Date of birth: 18 April 1965
Identity number: 650418 0128 089
Nationality: South African
Gender: Female
Marital status: Married
Postal Address: PO Box 12810, Brandhof, Bloemfontein, 9324
Business Address: University of the Free State, PO Box 339 (G40), Bloemfontein, 9300
Contact Details:
082 775 2482
(051) 401 7792 (w)
(051) 436 8678 (h)
E-mail: bezuidenhoutc@ufs.ac.za/colleenbez@gmail.com

2. QUALIFICATIONS

- **Matric**
1983 Afrikaanse Hoërskool, Kroonstad
- **BSc**
1986 Faculty of Science, University of the Free State, Bloemfontein
- **BSc(Hons) (Plant Physiology) (Cum laude)**
1987 Faculty of Science, University of the Free State, Bloemfontein
- **MSc (Plant Physiology)**
1992 Faculty of Science, University of the Free State, Bloemfontein

3. PREVIOUS POSITIONS HELD

01/01/1988 - 31/12/1989	Temporary Fulltime Technical Laboratory Assistant (Botany and Genetics – University of the Free State UFS)
01/01/1990 - 01/11/1993	Temporary Fulltime Professional Assistant (Botany and Genetics - UFS)
Nov. 1993 - 1995	Medical Scientist - Free State Provincial Government (Faculty Health Sciences)
1995 - 1996	Senior Medical Scientist (Free State Provincial Government - Faculty Health Sciences)
1996 - 2000	Medical Natural Scientist, Principal (Free State Provincial Government - Faculty Health Sciences)
2001 – April 2004	Specialist Medical Scientist (NHLs - Faculty Health Sciences)
2004 – July 2010	Bloemgate Total – Family Business

August 2010 – Dec. 2010	Substitute Teacher, Sentral Primary School Bloemfontein
Jan 2011 – Jun 2011	PA of the Principal, Sentral Primary School Bloemfontein
Jul 2011 – Dec 2011	Senior Clinical Data Coordinator, Quintiles (Clinical Data Management)
Jan 2012 – present	Assistant Officer, Faculty of Health Sciences, Dean's Office, UFS
Currently	<u>Part-time:</u> Clinical Technology, Department of Health Sciences, Central University of Technology, Bloemfontein

4. PAPERS AND POSTERS PRESENTED – see detailed CV

Papers/Posters (Local Congresses)	13
Lectures on invitation at:	
Local symposia	3
National congresses	13
Publications	2
Attended <i>various</i> workshops and courses	
GCP	

Appendix B

Data Collection Sheet

	Patient number	Protocol 1			Protocol 2		
		Second digit anti-sensory (ms)	Fifth digit anti-sensory (ms)	Difference in latency (ms)	Median (ms)	Ulnar (ms)	Difference in latency (ms)
1	776829	3,2	3,8	0,6	3,4	3,7	0,3
2	891007	3,1	2,8	0,3	3,2	3	0,2
3	2602849	3,7	2,8	0,9	3,9	2,7	1,2
4	39681	3,9	3	0,9	3,1	4	0,9
5	573322	4,6	2,8	1,8	6,8	3,2	3,6
6	729779	6,5	2,7	3,8	2,9	2,8	0,1
7	729779	4,8	2,8	2	6,1	3	3,1
8	775970	4,7	3,5	1,2	4,8	3,9	0,9
9	91325	6,8	3,8	3	5,6	3	2,6
10	445040	4,2	2,8	1,4	4,3	2,9	1,4
11	112578	2,9	2,7	0,2	2,9	2,9	0
12	710129	3,2	2,9	0,3	3,7	3,4	0,3
13	247214	3,3	4,3	1	3,3	4,2	0,9
14	756735	5,5	3,4	2,1	7,5	7,4	0,1
15	387804	3,2	2,8	0,4	3,2	2,8	0,4
16	16352	4	3,2	0,8	3,9	3,1	0,8
17	772101	10,5	2,8	7,7	6,2	3	3,2
18	259274	3,3	3	0,3	3,4	3	0,4
19	388914	3,8	5,8	2	0,8	4,5	3,7
20	494780	4,7	2,7	2	8,3	3,2	5,1
21	163624	6,6	2,8	3,8	3	3,1	0,1
22	3918709	4,7	2,4	2,3	4,8	2,6	2,2
23	762724	3	3,3	0,3	3,2	3,3	0,1
24	771118	5	2,7	2,3	5,6	3,1	2,5
25	390816	4,4	6,1	1,7	4,8	4,1	0,7
26	295392	5,3	2,9	2,4	6	3,1	2,9
27	344850	4,8	3,3	1,5	4,5	4,4	0,1
28	283579	4,3	2,6	1,7	5,4	2,6	2,8
29	775970	4,7	3,5	1,2	4,8	3,9	0,9
30	302578	3,5	2,9	0,6	3,7	3,3	0,4

Appendix C

Correspondence

Head of OPD Neurology
Universitas Hospital
Bloemfontein
9301

Dear Mrs. JE le Roux

Request for permission to utilize hospital data to conduct a research study

Hereby I, Jarike du Plessis, a registered student in Clinical Technology (student number 217000071) at Bloemfontein's Central University of Technology, are compelled to conduct a research study to complete my studies towards a B-Tech degree in Clinical Technology.

Title of the study: Carpal tunnel syndrome: a comparative study between the second and fifth digit anti-sensory *versus* the fourth digit anti-sensory study

To receive my B-Tech degree, I would like to seek permission from the Department Head to use the patient data from the Universitas Hospital Department of Neurology. The patient data will be treated with strict confidentiality and will not be exposed to any unauthorized persons.

Kindly find attached a copy of the protocol.

Please contact me if there are any other inquiries.

Regards

Jarike du Plessis
0748459399

Approval of project Inbox x



Makhafola Tshepiso <jmakhafola@cut.ac.za>

Mar 17, 2020, 4:09 PM



to boitym18@gmail.com, beatenagel@gmail.com, rubenjvrens@gmail.com, cobus3pienaar@gmail.com, smitlara97@gmail.com, me, elsa.vblerk@gmail.com, elzetzk ▾

Dear student

This email serves to inform you that your project is approved.

Regards

Dr TJ Makhafola

BTech Co-ordinator



www.cut.ac.za

Dr Tshepiso J Makhafola (PhD)

Assistant Dean: Research, Innovation and Engagement

Faculty of Health and Environmental Sciences

Tel: +27 51 507 3369 | E-mail: jmakhafola@cut.ac.za

Central University of Technology, Free State (CUT)

Private Bag X20539, Bloemfontein, 9300, South Africa

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Maryn Viljoen

Statistics Consulting Services

082 823 5731
maryn.viljoen1@gmail.com

Protocol & research methodology consultation | Ethical consultation | Database construction & capturing of data
Analysing data using statistical software packages (SAS Version 9.2) | Statistics consultation services to analyse and interpret data
Conveys results with statistical tables & figures where needed

3 July 2020

To whom it may concern,

Title: "CARPAL TUNNEL SYNDROME: COMPARATIVE STUDY BETWEEN THE SECOND AND FIFTH DIGIT ANTI-SENSORY VERSUS THE FOURTH DIGIT ANTI-SENSORY STUDY."

Researcher: J du Plessis (Student number: 217000071)
B. Tech Clinical Technology
Department of Clinical Sciences: Programme Clinical Technology
Faculty of Health and Environmental Sciences
Central University of Technology, Free State

I have seen and read through this protocol. I will be the biostatistician responsible for the analysis of the data.

Maryn Viljoen
M.Sc. Risk Analysis (UFS)
maryn.viljoen1@gmail.com
082 82 35 731

Appendix D

Plagiarism and declaration of independent work



Central University of
Technology, Free State

PLAGIARISM AND DECLARATION OF INDEPENDENT WORK

I Jurie du Plessis (student number: 317000071) am registered for a B. Tech at CUT.

The title of the project:

Carpal tunnel syndrome: Comparative study between the second and fifth digit anti-sensory versus fourth digit anti-sensory study

I acknowledge the following:

- That plagiarism is the use of someone else's work without their permission and/or without acknowledging the original source.
- That plagiarism is wrong.
- In completing this project, I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the Central University Of Technology, Free State may take disciplinary action against me if there is a belief that this is not my own unaided work or if I have failed to acknowledge the ideas or writing.

I declare that the work submitted for this project, is my own independent work, except where I have stated otherwise. I declare that this work was not previously submitted by me or any other person in fulfilment of the requirements for the attainment of any credits or a qualification.

Signature of student

23 June 2020
Date