1998

Relationship Between Sensibility Loss and Performance on the Jebsen-Taylor Hand Function Test in Non-Surgical Carpal Tunnel Syndrome Patients

Bethany J. Navarre  
*Grand Valley State University*

Elizabeth A. Ware  
*Grand Valley State University*

Follow this and additional works at: [http://scholarworks.gvsu.edu/theses](http://scholarworks.gvsu.edu/theses)

Part of the [Physical Therapy Commons](http://scholarworks.gvsu.edu/theses)

Recommended Citation

[http://scholarworks.gvsu.edu/theses/398](http://scholarworks.gvsu.edu/theses/398)

This Thesis is brought to you for free and open access by the Graduate Research and Creative Practice at ScholarWorks@GVSU. It has been accepted for inclusion in Masters Theses by an authorized administrator of ScholarWorks@GVSU. For more information, please contact [scholarworks@gvsu.edu](mailto:scholarworks@gvsu.edu).
RELATIONSHIP BETWEEN SENSIBILITY LOSS AND PERFORMANCE ON THE JEBSEN-TAYLOR HAND FUNCTION TEST IN NON-SURGICAL CARPAL TUNNEL SYNDROME PATIENTS

By

Bethany J. Navarro
Elizabeth A. Ware

THESIS

Submitted to the Department of Physical Therapy at Grand Valley State University Allendale, Michigan in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN PHYSICAL THERAPY

1998
ABSTRACT

The assumed correlation between sensibility loss in carpal tunnel syndrome (CTS) and hand function has not been supported by research. The purpose of this study is to examine this relationship. Thirteen subjects with CTS, no previous hand surgeries, hypothyroidism, or diabetes participated. The Weinstein Enhanced Sensory Test was used to assess sensibility and the Jebsen-Taylor Hand Function Test was used to assess hand function. No correlations were found between sensibility loss and hand function. Despite a small sample, lack of correlation between sensibility loss in CTS and hand function is significant. It suggests that further research is needed.
ACKNOWLEDGEMENTS

The investigators would like to extend their appreciation to the following individuals for giving graciously of their time and assistance: Keith Krueger and Dr. George Sturm. The investigators wish to extend special thanks to Cynthia Grapczynski, MS, OTR, committee chairperson; Tim Mullen, MS, OTR, content expert; Dr. Brian Adrian, methodologist. Their many long hours of assistance helped provide a valuable learning experience.
Operational Definitions

Arm- The portion of the upper extremity extending from the shoulder to the elbow.

Carpal Tunnel- The osseofibrous canal in the wrist bounded laterally by the scaphoid and trapezium bones, medially by the pisiform bone and the hook of the hamate, and superiorly by the flexor retinaculum; contains the flexor tendons and the median nerve.

Carpal Tunnel Syndrome- Paresthesias, pain or numbness affecting some part of the median nerve distribution of the hand caused by compression of the median nerve in the carpal tunnel.

Exteroceptors- Sense organs, as found in the eye, ear, or skin, adapted for the reception of stimuli from outside the body.

Graphesthesia- The recognition of numbers, letters, or symbols traced on the skin.

Mechanoreceptors- Sensory receptors that respond to mechanical deformation of the surrounding area.

Median Nerve- A major nerve of the upper extremity formed in the axilla by the union of a lateral root from the lateral cord and a medial root from the medial cord of the brachial plexus. The median nerve passes deeply in the forearm to supply many of the muscles in the anterior part of the forearm. The median nerve enters the hand through the carpal tunnel and supplies motor fibers to the three thenar muscles and the first and second lumbrical muscles. It also sends cutaneous sensory fibers to the lateral palmar surface, the sides of the first three digits, the lateral half of the fourth digit, and the dorsum of the distal halves of these digits.

Nocioceptors- Sensory receptors that respond to noxious stimuli and result in the perception of pain.

Proprioceptors- Sense organs that respond to stimuli originating within the body itself, especially that respond to pressure, position, or stretch.

Reliability- The degree of consistency with which an instrument or rater measures a variable.
**Sensation**- The conscious perception of basic sensory input.

**Sensibility**- The capacity to receive and respond to neural events occurring at the periphery, nerve fibers, and nerve receptors.

**Stereognosis**- The ability to recognize the form of objects by touch.

**Thermoreceptors**- Sensory receptors that respond to changes in temperature.

**Touch (Point or Tactile) Localization**- The ability to recognize a stimulus at the exact point at which it is applied.

**Two-point Discrimination**- The ability to recognize whether one is being touched by one or two points of a caliper as the distance between the two points is varied.

**Validity**- The degree to which an instrument measures what it is intended to measure.
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>OPERATIONAL DEFINITIONS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>viii</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Background to the Problem</td>
<td>1</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td>3</td>
</tr>
<tr>
<td>Purpose</td>
<td>3</td>
</tr>
<tr>
<td>Hypothesis</td>
<td>3</td>
</tr>
<tr>
<td>Significance</td>
<td>4</td>
</tr>
<tr>
<td>2. LITERATURE REVIEW</td>
<td>5</td>
</tr>
<tr>
<td>Carpal Tunnel Syndrome</td>
<td>5</td>
</tr>
<tr>
<td>Etiology</td>
<td>6</td>
</tr>
<tr>
<td>Symptoms</td>
<td>7</td>
</tr>
<tr>
<td>The Hand</td>
<td>8</td>
</tr>
<tr>
<td>Nerve Distribution of the Hand.</td>
<td>9</td>
</tr>
<tr>
<td>Tactile Sensation</td>
<td>10</td>
</tr>
<tr>
<td>Sensory Receptors</td>
<td>11</td>
</tr>
<tr>
<td>Sensibility in the Hand.</td>
<td>12</td>
</tr>
</tbody>
</table>
### CHAPTER

<table>
<thead>
<tr>
<th>The Sensibility Test.</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Functional Test.</td>
<td>16</td>
</tr>
<tr>
<td>Summary.</td>
<td>18</td>
</tr>
</tbody>
</table>

#### 3. METHODS.

<table>
<thead>
<tr>
<th>Study Design.</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Limitations.</td>
<td>19</td>
</tr>
<tr>
<td>Research Site.</td>
<td>20</td>
</tr>
<tr>
<td>Subjects.</td>
<td>20</td>
</tr>
<tr>
<td>Instrumentation.</td>
<td>21</td>
</tr>
<tr>
<td>Validity and Reliability.</td>
<td>22</td>
</tr>
<tr>
<td>Procedures.</td>
<td>23</td>
</tr>
<tr>
<td>Data Analysis.</td>
<td>28</td>
</tr>
</tbody>
</table>

#### 4. RESULTS.

| 29 |

#### 5. DISCUSSION.

<table>
<thead>
<tr>
<th>Discussion of Findings.</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limitations.</td>
<td>35</td>
</tr>
<tr>
<td>Application to Practice.</td>
<td>36</td>
</tr>
<tr>
<td>Conclusions.</td>
<td>37</td>
</tr>
</tbody>
</table>

REFERENCES. 38

APPENDIX A - INFORMED CONSENT FORM. 42

APPENDIX B - PATIENT HISTORY FORM. 44

APPENDIX C - DATA COLLECTION SHEET. 45

APPENDIX D - JTHFT DATA. 46

APPENDIX E - WEST DATA. 47


LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Table Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Intrarater Reliability Study Results.</td>
<td>29</td>
</tr>
<tr>
<td>2.</td>
<td>Mean Times, Standard Deviations, and Correlations of Subjects with Dominant Hand Affected.</td>
<td>31</td>
</tr>
<tr>
<td>3.</td>
<td>Mean Times, Standard Deviations, and Correlations of Subjects with Non-Dominant Hand Affected.</td>
<td>31</td>
</tr>
</tbody>
</table>
CHAPTER 1
INTRODUCTION

Background to the Problem

Carpal tunnel syndrome (CTS) is one of the most prevalent industrial injuries plaguing the work force today. Over the last decade, technological advances have affected the nature of work performed in the industrial setting, causing a shift from overall body labor to more hand intensive work (Dagostino, 1989). With advances in technology, higher productivity demands have supplanted considerations of health care for workers (Louis, 1995; Siebenaler and McGovern, 1992). "Increased work loads, at faster production speeds, with little variation, all contribute to the problem of repetitive trauma which is associated with the development of CTS" (Siebenaler and McGovern, 1992, p. 64).

In recent years CTS has become an increasingly expensive problem for employers. "After totaling worker's compensation payments and medical expenses, a conservative estimate for treating an industrial CTS case over the period of one year averages over $20,000" (Dagostino, 1989, p. 38). Palmer (1995) stated that 400-500,000 surgical CTS cases per year alone equal an economic cost of two billion dollars. The costs of CTS for employers can be divided into two categories, direct and indirect. The direct costs include worker's compensation payments, medical and rehabilitation costs, and insurance premiums based on the frequency and total cost of claims. The indirect costs of CTS, which can equal or even exceed the direct costs, include worker
absenteeism, new employee training, productivity losses, increased turnover, declines in product quality, potential safety problems, and increased clerical time to process claims (Dagostino, 1989; Sipos, 1995; Siebenaler and McGovern, 1992). Early detection of CTS symptoms in workers is essential to minimize both the direct and indirect costs. Specifically, recognition of sensibility loss, the ability to perceive and respond to sensory stimuli, is important for this early detection.

CTS is a compression neuropathy caused by pressure on the median nerve as it passes through the carpal tunnel (Siebenaler and McGovern, 1992). Early and progressive symptomatology in CTS is diminished sensibility in the median nerve distribution of the hand, namely the first three digits and the radial aspect of the fourth digit. This affects the ability to discern light touch, deep pressure, and protective sensation in areas of the hand innervated by the median nerve, which is known as the "eye" of the hand. With time, edema develops within the carpal tunnel and causes fibrosis of the nerve.

It is assumed by clinicians that the sensibility loss associated with CTS also affects functioning of the hand. However, no current studies have been found that establish this correlation. It is important for clinicians to examine the relationship between loss of sensibility and functional decline in CTS patients in order to increase the chances of early detection before job performance is affected and the direct and indirect costs accumulate.

A number of evaluative techniques have been studied in an effort to increase detection of early changes in sensibility associated with CTS. Among these is the use of the Semmes-Weinstein Monofilament (SWMF) aesthesiometer thresholds, which are one
of the earliest indicators of neuropathy (MacDermid, Kramer & Roth, 1994). Bell-Krotoski and Tomancik (1987) reported that the Semmes-Weinstein Monofilaments are a sensitive measure of peripheral nerve function. Moreover, Szabo, Gelberman, and Dimick (1984) reported that the filaments are highly sensitive for detecting sensory abnormalities in CTS.

Improvements have been made in the SWMF test since its creation in 1960. A new version of the monofilaments, the Weinstein Enhanced Sensory Test (WEST) is now being recognized as an enhanced tool for the evaluation of sensibility. The WEST has been proven to give the same results as the SWMF test (Weinstein, 1993). However, there is no correlation shown between objective sensibility test and tasks representative of daily functional activities. Such a correlation would show that the WEST has a functional component, which is an aspect third party payors focus on for reimbursement.

**Problem Statement**

The problem addressed in this study is that no studies have been found showing the relationship between the results of standardized sensibility tests and tasks representative of everyday functional activities in the hand.

**Purpose**

The purpose of this study is to examine the relationship between loss of sensibility and functional performance in the hand.

**Hypothesis**

The authors of this study hypothesize that there will be a positive correlation between sensibility threshold as demonstrated by the WEST, and hand function as
demonstrated by performance on the Jebsen-Taylor Hand Function Test in the hands of non-surgical CTS patients.

**Significance**

Showing the correlation between sensibility loss and functional deficits specifically in CTS patients will not only be of benefit to employers, but to insurance companies, physicians, and to the general community as well. An established interrelationship of sensibility loss and loss of function will be a building block to early identification and subsequent early intervention to prevent progression of symptoms, thenar atrophy, neurofibrosis, and cost. This will also increase the recognition that some sensibility deficits are conservatively treatable. Showing no correlation between the two variables would also be of benefit in that it would uphold the need for clinical research to support or reject assumptions made by clinicians, such as the assumption that hand function and sensibility are related.
CHAPTER 2
LITERATURE REVIEW

In order to examine loss of sensibility and functional performance of the hand in relation to CTS, a thorough review of the literature is essential. The following chapter includes background information, discussions of previous studies, and descriptions of the standardized tests pertaining to the purpose of this study as obtained from the literature. The first portion of the literature review contains information about CTS, including etiology and symptoms. The second portion of the literature review contains a discussion of the hand, its function, and its neurological composition, as well as a discussion of sensibility as it pertains to the hand. The last section of the literature review contains information about the tests utilized in this study: the Weinstein Enhanced Sensory Test and the Jebsen-Taylor Hand Function Test.

Carpal Tunnel Syndrome

Although the identification of CTS was first reported in 1854, the first article published giving information about CTS was a self-report by Phalen in the 1970s (Kemp Miller, 1993; Siebenaler and McGovern, 1992). Prior to this time, information about CTS was incomplete and rarely reported in medical journals. Recently, published research and information about CTS has increased. CTS is now being categorized as one of many occupationally related illness, as a result of work requiring repetitive hand movements, forceful gripping, and/or awkward wrist positioning (Dagostino, 1989; Siebenaler and McGovern, 1992). Many factors have been hypothesized to contribute to the increased awareness of this common condition among the public, health
professionals, and employers (Dagostino, 1989; Kemp Miller, 1993; Siebenaler and McGovern, 1992). With a shift in the workforce to labor that requires repetitive hand movements and new types of specialized jobs which demand higher productivity levels, there has been a subsequent increase in work stress placed on the hand and wrist (Dagostino, 1989). In addition, the workforce has become more aware of the causes and symptoms of CTS and, therefore reports of the condition have increased (Dagostino, 1989). Other factors that contribute to an increased awareness of CTS in the workforce include a dramatic rise in the direct and indirect costs of CTS to employers and the financial, emotional, and psychological costs to workers diagnosed with CTS.

Etiology

CTS is a compression neuropathy of the median nerve as it passes through the carpal tunnel. The causes are divided into direct and indirect. The carpal tunnel is an osseofibrous canal in the wrist, formed inferiorly by eight carpal bones and superiorly by the transverse carpal ligament. The tunnel contains nine flexor tendons and the median nerve as it enters the hand. The space in the carpal tunnel is limited, therefore any enlargement in the flexor tendons puts pressure on the median nerve, which is structurally not as strong as the tendons (Siebenaler and McGovern, 1992). In addition, pressure within the carpal tunnel increases as the wrist deviates from neutral. This, in conjunction with edema from repetitive movements, results in acute compression of the median nerve.

Increased pressure in the carpal tunnel can result in either direct nerve compression or vascular insufficiency of the nerve. Direct nerve compression may be caused by thickening of the transverse carpal ligament, swelling of the common flexor sheath, neoplasms, malaligned fractures or trauma to the carpal tunnel. Vascular
insufficiency of the median nerve may be caused by conditions that increase the fluid volume within the carpal tunnel, such as pregnancy, hypothyroidism, diabetes mellitus, gout or rheumatoid arthritis (Kemp Miller, 1993; Sipos, 1995). Hansford, Blood, Kent and Lutz (1986) report significant blood flow changes in the radial and ulnar arteries after 1 1/2 hours of manual labor. This decreased blood flow may predispose industrial employees to CTS.

Populations in which the incidence of CTS is commonly reported include cashiers, typists, carpenters, assembly line workers, and long distance drivers (Siebenaler and McGovern, 1992; Sipos, 1995). These occupations involve repetitive work in which the wrist is in constant flexion or other awkward postures (Kemp Miller, 1993; Siebenaler and McGovern, 1992). Siebenaler and McGovern (1992) report forceful exertions of the upper extremities and mechanical stresses also lead to industrial cases of CTS. For example, Kemp Miller (1993) reports "workers using hand-held vibrating tool(s) needing forceful grasping are reporting CTS in greater numbers" (p. 53).

Symptoms

The onset of CTS is usually insidious, unless the symptoms follow trauma to the wrist (Kessler and Hertling, 1996). Compression of the median nerve in the carpal tunnel typically causes paresthesias in the thumb, first finger, second finger, and radial aspect of the third finger. Other sensory symptoms include pain and burning in the wrists, which may radiate into the fingers or forearm, and decreased sensitivity. Another common symptom is numbness in the hands that worsens at night (Kemp Miller, 1993; Kessler and Hertling, 1996; Siebenaler and McGovern, 1992). Kemp Miller (1993) reports that because the numbness felt with CTS is temporary and not debilitating, it is often ignored.
"As median nerve compression becomes chronic, motor changes may occur" (Kemp Miller, 1993, p. 53). Motor deficits are most often manifested as clumsiness with activities requiring fine finger movements (Kemp Miller, 1993; Kessler and Hertling, 1996; Siebenaler and McGovern, 1992). However, these motor changes are inconsistent and can be attributed to other causes. Kessler and Hertling (1996) report that subjective complaints of actual weakness in cases of CTS are rare. However, in chronic cases of CTS, there may be atrophy of the thenar eminence, the fleshy prominence at the base of the thumb (Kemp Miller, 1993; Siebenaler and McGovern, 1992).

CTS can be misdiagnosed because of its intermittent and nonspecific symptoms. "C6 or C7 nerve root involvement and thoracic outlet syndrome (TOS) often present as paresthesias in a similar distribution as that of CTS" (Kessler and Hertling, 1996, p. 265). However, nerve root involvement differs from CTS in that use of the hand does not bring on symptoms, and with TOS, the paresthesias are more likely to involve the entire hand (Kessler and Hertling, 1996).

The Hand

The hand is a complex tool which serves many vital functions in the performance of everyday tasks. The hand possesses the powers of grasp and pinch in order to secure objects while they are manipulated (Bell-Krotoski, 1991). In addition, the hand may serve as a tactile organ or a means of expression. Bell-Krotoski (1991) describes hands as "...a visual part of the body which cannot be hidden if one is to participate in almost any activity" (p. 5) The inability to use one's hands deeply affects one's self image and sense of usefulness (Bell-Krotoski, 1991). The ability to use one's hands effectively in
daily functional tasks is contingent on anatomic integrity, mobility, muscle strength, sensation, and coordination (Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969).

Nerve Distribution of the Hand

Sensory nerve supply to the hand comes from the median, ulnar, and radial nerves. These three nerves are terminal branches of the brachial plexus, coming directly from spinal cord segments C5-T1. Although there is some overlap in the areas that these nerves supply, the areas of most distinct supply can be explicitly identified in the hand.

The median nerve, composed of spinal segments C5-8 and T1, is formed in the axilla by the union of a lateral root from the lateral cord and a medial root from the medial cord of the brachial plexus (Moore, 1992). The nerve passes deeply in the forearm to supply some flexor muscles (Moore, 1992). The median nerve becomes superficial near the wrist, passing between the tendons of the flexor digitorium superficialis and the flexor carpi radialis and enters the hand through the carpal tunnel (Moore, 1992).

Once in the hand, the median nerve supplies motor fibers to abductor pollicis brevis, flexor pollicis brevis, and opponens pollicis. It also supplies motor fibers to the first and second lumbricals. In addition, the median nerve "sends cutaneous sensory fibers to the lateral plammar surface, the sides of the first three digits, the lateral half of the fourth digit, and the dorsum of the distal halves of these digits" (Moore, 1992, p. 603).

The ulnar nerve, composed of spinal segments C8 and T1, is the larger of the two terminal branches of the medial cord of the brachial plexus. Moore (1992) states that this nerve is referred to as the "nerve of fine movements" (p. 606) because it innervates muscles that are involved with fine movements of the hand. Just proximal to the wrist,
the ulnar nerve gives off palmar and dorsal cutaneous branches. The palmar cutaneous branch supplies the skin on the medial side of the palm. The dorsal cutaneous branch supplies the medial half of the dorsum of the hand, the fifth digit, and the ulnar aspect of the fourth digit (Moore, 1992). Motor fibers to the hypothenar muscles, the medial two lumbrical muscles, and all the interosseous muscles are supplied by the deep branch of the ulnar nerve (Moore, 1992).

The third nerve innervating the hand, the radial nerve, supplies no hand muscles. It provides the major nerve supply to the extensor muscles of the arm and cutaneous sensation to the skin of the extensor region and hand (Moore, 1992).

In summary, there are three main nerves arising from the brachial plexus that supply the hand; the median, ulnar, and radial nerves. Injury to one of these nerves can occur at any level in the course of the nerve from the axilla to the hand. Pain from an injured wrist or hand is rarely referred. However, this region is a common site of referred pain or paresthesias from the cervical or shoulder areas (Scully & Barnes, 1989).

Tactile Sensation

Tactile sensations can be classified on the basis of type or location of the receptor that responds to a particular stimulus (O'Sullivan and Schmitz, 1994). Exteroceptors receive stimuli from the external environment by way of the skin and subcutaneous tissue and are involved with superficial sensations such as pain, temperature, light touch, and pressure. Proprioceptors receive stimuli from muscles, ligaments, joints, and fascia and are involved with deep sensations such as position sense, movement sense, and vibration (O'Sullivan and Schmitz, 1994).
Another category of tactile sensations is the combined, or cortical, sensations. This category is composed of a combination of the superficial and deep sensory receptors. Cortical sensations require information from the cortical sensory association areas in addition to information from the exteroceptors and proprioceptors (O'Sullivan and Schmitz, 1994). Cortical sensations include stereognosis, two-point discrimination, graphesthesia, texture recognition, and tactile localization.

Sensory Receptors

All tactile sensations are transported via peripheral sensory mechanisms. The peripheral sensory system is composed of sensory receptors and axons. The sensory receptors respond to stimuli and the axons enter the dorsal root ganglion to convey sensory impulses into the spinal cord (Scully and Barnes, 1989). The sensory receptors convert various stimuli into generator potentials. An action potential is then generated along the axon into the central nervous system once a threshold value is achieved. In this way, the sensory receptors act as transducers to convert one form of energy (mechanical) into another form of energy (electrical) in the axons (Scully and Barnes, 1989).

Sensory receptors can be classified according to their structural design and the type of stimulus to which they respond (O'Sullivan and Schmitz, 1994). These classifications include mechanoreceptors, thermoreceptors, nocioceptors, chemoreceptors, and photic receptors. Mechanoreceptors, thermoreceptors, and nocioceptors are the three classes of cutaneous sensory receptors. These receptors are positioned at the distal portions of afferent nerve fibers. The density of these sensory receptors differs throughout the body and therefore, the ability to sense stimuli applied to various areas of the skin also differs (Conn, 1995; O'Sullivan and Schmitz, 1994). For example, "the
density of cutaneous receptors in the fingertips is much greater than those in the palm or back of the hand” (Conn, 1995, p. 437). The density of sensory receptors also differs with skin thickness, i.e. calluses. Receptor density is an important consideration when interpreting sensory assessments for given areas of the body (O’Sullivan and Schmitz, 1994).

**Sensibility in the Hand**

“The ability of the hand to function, and to interact and explore the environment is dependent upon good sensibility” (Anthony, 1993, p. 55). Sensibility, which differs from sensation, is what clinicians evaluate in patients. Sensation refers to the conscious perception of basic sensory input (Anthony, 1993). The term sensibility refers to the capacity to receive and respond to stimuli (Thomas, 1993). These stimuli evoke neural events which occur at peripheral nerve fibers and receptors.

Anthony (1993) describes two types of sensibility; protective and functional. Protective sensibility refers to the ability to perceive and respond to pinprick, touch, and temperature. A high degree of protective sensibility is necessary in order to prevent unintentional self-inflicted damage. This is especially important in industrial workers who use their hands regularly, at fast speeds with little variation. With diminished protective sensibility hand injuries are more likely to occur in this population. The second type of sensibility Anthony describes is functional sensibility. This refers to a level of sensibility that enables the hand to participate in full activities of daily living, including those with vision occluded while the hand manipulates objects (Anthony, 1993). A high degree of functional sensibility is also important for workers to allow
maximal functioning and thus optimal production at fast speeds and, as with protective sensibility, to prevent hand injury.

When evaluating sensibility clinicians have two major goals: (1) to determine the presence of changes in sensibility for nerve compression and (2) to determine the status of sensibility in a way that reflects hand function (Anthony, 1993). Sensibility assessments can be performed using threshold tests or functional tests (Anthony, 1993; Tubiana, 1996). Threshold tests are used to determine the minimum stimulus that can be perceived and include heat/cold, touch/pressure, and vibration sense. Functional tests are used to determine the quality of sensibility and include static and dynamic two-point discrimination, touch localization, and various object pick-up tests.

The Sensibility Test

The Semmes-Weinstein monofilament test (SWMF) was developed by Stanley Weinstein, a neuropsychologist, and his collaborator, Josephine Semmes, in the late 1950's. Dr. Weinstein spent considerable time and energy on the development of quantifiable tests during his graduate education. "I spent all my time creating tests to quantify what neurologists were clinically using to diagnose neurological impairments. However, my tests [including the SWMF] were so precise and objective that they could detect impairments often undetected by neurologists." (Weinstein, 1993, p.14).

Weinstein's doctoral dissertation required him to test men with penetrating brain and peripheral nerve wounds. "The greatest challenge [of his study] was to find a valid, convenient, and rapid test to replace the older, less reliable, and inconvenient von Frey hairs to test pressure sensitivity." (Weinstein, 1993, p.14) The von Frey instruments consist of horsehairs connected to handles, the length of which is controlled in order to
dictate the force of application. The von Frey instruments have many disadvantages which include: 1) the horsehairs vary in width; 2) the hairs absorb moisture and are damaged easily; 3) the hairs require recalibration every time one wishes to change the force exerted; and 4) increased time is required for administration (Weinstein, 1993). In an attempt to correct the inherent disadvantages of the von Frey instruments, the first SWMF kit was developed. The nylon filaments were calibrated on a chemical balance. This kit was not only used for Weinstein’s dissertation, but also for detecting minor losses of sensation at an early stage.

“The Semmes-Weinstein monofilaments (SWMF) are frequently used in hand therapy practice to diagnose sensory abnormalities, document severity of sensory loss, and follow patient progression in response to treatment that affects the sensory system” (MacDermid, et al, 1994, p. 158). In addition to being a useful clinical tool, the SWMF test has been used in many research studies to measure sensibility/pressure threshold of various populations. Some of the more recent studies include “Focused assessment of foot care in older adults” (Plummer & Albert, 1996) and “Carpal tunnel release. Correlations with preoperative symptomatology” (Whitman, Winters, Gelberman, & Katz, 1996). The SWMF test is highly respected among researchers as well as clinicians due to its high degree of sensitivity, reliability, and validity.

MacDermid, et al. (1994) describe the SWMF test as being one of the earliest detectors of change in nerve function as well as being specifically sensitive in detecting CTS sensory abnormalities. Because the monofilaments are calibrated to a constant length and correct diameter for the force desired, the forces applied are repeatable (Bell-Krotoski & Tomancik, 1987). The intertester reliability is enhanced because any
vibration of the examiner's hand is absorbed by the bend of the filaments (Bell-Krotoski, 1995). Bell-Krotoski, Fess, Figarloa, and Hiltz (1995) state “the SWMF test remains the only handheld instrument specifically designed to control application force variables, and to meet sensitivity and repeatability requirements for an objective test instrument when calibrated correctly” (p. 155). The SWMF test is a true test of sensibility because it has been shown to activate cutaneous mechanoreceptors proportional to the amount of force exerted by the filament (Greenspan & LaMotte, 1993).

Despite the advantages of the SWMF test, there are limitations. The traditional kit is very cumbersome and time consuming, containing 20 monofilaments of various diameters. To address this problem, the mini-kit was introduced containing the five most commonly tested diameters. Bell-Krotoski, Weinstein, and Weinstein (1993) state that the mini-kit “increase[s] reliability clinically, because it minimizes patient fatigue and the possibility for distraction” (p. 120). However, problems still remain. The monofilaments have smooth, flat, cylindrical surfaces that pose two problems. First, there is a high rate of monofilament slippage during administration, which increases the amount of time required to perform the test correctly. Second, when the monofilaments bow, the surface in contact with the skin produces a crescent shape stimulus which slightly changes the value of force exerted. The durability of the thinner filaments is poor, requiring frequent replacement to maintain accuracy (Weinstein, 1993). Another limitation described by Weinstein (1993) is “current manufactureres of the filaments do not measure the force delivered from each filament. They rely instead upon the diameter and length of the monofilament to define the force “ (p. 121).
To advance sensibility testing, Dr. Stanley Weinstein, Dr. Ronald Drozdenko, and Mr. Curt Weinstein developed the Weinstein Enhanced Sensory Test (WEST) using the same principles as the SWMF, but improving on the design. To improve even further on portability and amount of time required for the test, the WEST was designed with a single handle and five filaments that can be positioned in such a way that the examiner doesn’t have to stop during the evaluation to pick up different filaments. To improve the filaments themselves, the WEST was designed with hemispherical textured tips that reduce the amount of slippage from 5% to 0.05% and keeps the stimulus constant throughout the application of the monofilament (Weinstein, 1993). Al-Quattan (1995) shows an even greater improvement of slippage, from 10% (SWMF) to 0% (WEST). The creators of the WEST have also increased it’s durability so that even dropping it on the floor does not affect its calibration (Weinstein, 1993). Another improvement of the WEST upon the SWMF test is that it is manufactured by only one company. Connecticut Bioinstruments, Inc. calibrates each filament to exert the exact amount of force it is meant to create, giving the instrument greater reliability (Weinstein, 1993).

The inventors of the WEST performed a comparative study on normals, using it and the SWMF test, finding that they gave the same results, with a correlation of .99 (Weinstein, 1993). Due to the proven advantages of the WEST, this test will be utilized in this study to obtain sensibility measurements.

The Functional Test

In 1969, Dr. Robert Jebsen, Dr. Neal Taylor, Dr. Roberta Treischmann, Ms. Martha Trotter, and Ms. Linda Howard developed the Jebsen-Taylor Hand Function Test.
This test was designed to be representative of various hand activities in an attempt to "assess disability and the effectiveness of treatment . . . and to evaluate a patient's functional capabilities" (Jebsen, Taylor, Treischmann, Trotter, and Howard, 1969, p. 311). Previous hand function tests were inadequate because these tests were subjective, uncontrolled, and took lengthy amounts of time to administer.

These creators developed this test to meet the following goals:

1. Provide objective measurements of standardized tasks with norms against which patient performance can be compared.
2. Assess broad aspects of hand function commonly used in activities of daily living.
3. Be able to document a continuum of ability within each category of hand function tested.
4. Be easily administered in a short period of time (15 minutes for both hands).
5. Utilize test equipment and materials that are readily available.

(Jebsen, et al. 1969, p. 311)

The Jebsen-Taylor Hand Function Test consists of seven subtests including: (1) Writing, (2) Turning over 3-by-5 inch cards (simulating page turning), (3) Picking up small common objects, (4) Simulated feeding, (5) Stacking checkers, (6) Picking up large, light objects, and (7) Picking up large, heavy objects (Jebsen, et al.). The normative study conducted by Jebsen, et al. (1969) showed a significant difference in test performance between men and women, and also between those below and above the age of 60.

Some people believe that for testing sensibility, functional tests specific to sensibility should be administered to obtain a correlation. However, this study is focused on the bigger picture: How will sensibility loss affect daily activities? Jebsen, et al. (1969) express this concern well when they state:
It is important to recognize that hand function is not an isolated aspect of patient function but is dependent upon the ability of the proximal portion of the upper extremity to position the hand for function and also upon mental status and other factors. Thus a test of hand function must test hand function per se, allowing all these other factors to have an effect on the test (p. 318).

Summary

The literature reveals CTS, or entrapment of the median nerve in the wrist, is a common occupationally related condition prevalent among cashiers, typists, carpenters, assembly line workers, and long distance drivers. Although it is believed CTS symptoms occur because of repetitive work, there appears to be no research regarding what degree of repetitive movement will result in these symptoms. Furthermore, there is no research related to awkward positions of the hand and wrist, such as continuous flexion, and their relationship to CTS.

CTS results in motor and/or sensory loss in the radial side of the palm of the hand. Although it is assumed that CTS results in decreased functional performance of the hand, there seems to be a large void in the research addressing this topic. Despite the absence of such research, employers report worker absenteeism, productivity losses, and potential safety problems related to CTS in the industrial setting.

There is a lack of literature on the WEST, which has been used to determine sensibility loss in the hand. However, much literature exists about its predecessor, the Semmes-Weinstein Monofilament test. These two tests have been shown to give the same results when used to determine sensibility loss.

Although there is little research on the Jebsen-Taylor Hand Function Test, it has been used to assess functional performance of the hand. In their original research, Jebsen et al (1969) standardized this test and proved it to be valid and reliable.
CHAPTER 3
METHODS

Study Design

The research approach used in this study is a descriptive correlational design, in which the nature of the relationship between sensibility loss and functional performance in CTS patients is described. This study is defined as descriptive because its purpose is to explore the relationship among these two phenomena (Portney and Watkins, 1993). In this study the researchers will not assign subjects to experimental or control groups, nor will they control the independent or dependent variables. This research is further defined as correlational because it involves the “systematic investigation of relationships among two or more variables” (Portney and Watkins, 1993, p. 242).

The independent variable of this study is the amount of sensibility deficit present in the hand as determined by the WEST. The dependent variable is performance on the Jebsen-Taylor Hand Function Test.

Design Limitations

Due to the nature of this study design, some limitations exist. This correlational study illustrates characteristics of the subjects that are beyond the control of the researchers. Therefore, the results obtained are limited in their interpretation because of the potential bias that exists in the data (Portney and Watkins, 1993). Another potential limitation of this study design is the inability of correlational research to establish a cause and effect relationship between the variables. Despite these possible limitations, this
design is optimal for this study in order to determine the relationship between sensibility loss in the hand and functional performance in CTS patients. The researchers were not looking for a cause and effect relationship between the data, rather they were exploring the nature of the relationship between the two variables of the study.

Research Site

This study was conducted with the cooperation of West Michigan Hand Center and Blodgett Upper Extremity Rehabilitation, associated with Blodgett Memorial Medical Center, in Grand Rapids, Michigan. Testing took place in the therapeutic area of Blodgett Upper Extremity Rehabilitation.

Subjects

Upon approval from the Grand Valley State University and Blodgett Memorial Medical Center Human Subject Review Committees, thirteen participants (23 hands), including seven males and six females, ranging in age from 26-77 years, were recruited. Hand surgeons from the West Michigan Hand Center and hand therapists employed at Blodgett Upper Extremity Rehabilitation referred volunteers for this study based on the pre-established inclusion and exclusion criteria. An attempt was made to arrange testing times immediately after the subjects' scheduled therapy appointments or following their initial evaluation by the physician. This ensured that the timing was convenient for the subjects and eliminated the need for them to make return visits to the departments for testing. Testing times were scheduled for a duration of 20 - 30 minutes.

Inclusion criteria for this study were: (1) a diagnosis of CTS that is work related as determined by physical exam and/or nerve conduction velocity study and (2) currently receiving conservative treatment for CTS. Exclusion criteria were: (1) previous surgical
CTS release; (2) other hand surgeries on affected hand(s); (3) the presence or history of hypothyroidism or diabetes.

Instrumentation

In this study two standardized tests were utilized. The WEST kit, manufactured by Connecticut Bioinstruments, Inc., was used to determine sensibility thresholds in the hands of the subjects. The WEST provides a measurement of touch recognition thresholds in milligrams of force. To make the testing less time consuming for volunteers, a shorter version of testing was administered, in which the three critical points of median nerve distribution were assessed. Bell-Krotoski et al (1995) described these points as (1) the tip of the thumb, (2) the tip of the index finger, and (3) the proximal index finger.

The Jebsen-Taylor Hand Function Test (JTHFT) was also used in this study to evaluate the functional capabilities of the subjects. Materials used for the administration of this test were provided by the investigators and include a ball-point pen, 8-by-11-inch paper, 3-by-5-inch index cards, pennies, bottle caps, paper clips, kidney beans, a teaspoon, checkers, and No. 303 cans.

Limitations of each test exist. The WEST kit is relatively new and not widely used among clinicians. Many clinicians still employ the SWMF test in evaluation and treatment of patients. Therefore, there is limited research utilizing the WEST. A limitation of the JTHFT is that it was developed almost 30 years ago and has not been used in recent research.
**Validity and Reliability**

The WEST was used in this study because of its high degree of repeatability (Bell-Krotoski, 1987; 1993; 1995; Weinstein, 1993; Al-Quanttan, 1995). To ensure reliability one examiner tested all subjects and an experienced hand therapist was present. In addition, an intrarater reliability study was performed with five normal subjects (Portney and Watkins, 1993). To increase the reliability of the test itself, each testing site on the hand was assessed three times. Once one of the three stimuli was felt, the test was considered positive for that monofilament and there was no need to continue testing with filaments of greater force (Bell-Krotoski et al, 1995). Bell-Krotoski et al (1995) profess "there is absolutely no evidence to support the concept that detection threshold can be changed if the filaments are applied more than once" (p.160).

The JFHFT was used in this study because this test has been proven to be a reliable and valid assessment tool (Fess, 1986). Via test-retest data, Jebsen et al. (1969) demonstrated an absence of practice effect, which is an improvement in test times from simply practice rather than an improvement from gain of function. All subtests, performed with dominant and non-dominant hands, failed to reach the significance of p<0.05, which supports the absence of practice effect.

In Jebsen's study, each subtest was proven to be reliable over time through a test-retest study of a variety of patients with hand disabilities. The results of this study demonstrated statistical significance at the p<0.01 level. These patients were also assessed for presence of a practice effect. The means of their scores on the test-retest study were compared in a t-test. There was no significant difference at the p<0.05 level, therefore, there was no practice effect. Using the same subjects, the researchers
investigated whether the subtests could be used to discriminate between levels of disability. There was a wide distribution of scores among the patients with various hand disorders.

Stern (1992) conducted a study on normal subjects on the stability of the JTHFT. She found strong test-retest reliability in five of the seven subtests. The writing and simulated feeding, however, were not so strong. Stern asserts that this may be due to a practice effect from refining the subjects' grip styles of the pen and spoon required to perform this test. Stern suggests that these two subtests be used cautiously as the sole measurement of functional improvement. In patients with hand disability, however, it is still necessary to test using these subtests as a part of functional assessment.

Each test was administered by one examiner and an intrarater reliability study was performed prior to collecting research data. Ten normal subjects, five for each test, were recruited for this intrarater reliability study and were tested on three consecutive days, for a total of three trials each.

**Procedures**

Each participant read and signed an informed consent form as approved by the Grand Valley State University Human Subjects Review Board (Appendix A). Participants were then asked to complete a brief Patient History Form (Appendix B). After completing the Patient History Form, subjects performed both the sensibility test and the functional test in random order.

Subjects underwent sensibility testing in the involved and uninvolved hand(s). Each subject was seated in a 20 inch-high chair, facing the examiner with his/her extremity(s) supported on a 30 ½ inch-high table with elbow partially flexed and
supinated, and shoulder in slight flexion. The dorsum of the subjects’ hands were placed in putty to ensure finger extension and full exposure of the testing surface as well as to decrease any proprioceptive input. A blindfold was used to occlude the subjects’ vision while the test was performed. Subjects’ hands were examined for any areas of callus, abrasion, scars or other blemishes. The appearance of any of these was documented on the Data Collection Sheet (Appendix C).

The subjects’ normal cutaneous sensation was assessed on the forearm using Filament #3 of the WEST. Subjects were instructed to respond when the stimulus was felt by saying “Yes”. The median nerve distribution of the affected hand(s) was then assessed at three separate points to determine the sensibility threshold. Beginning with Filament #1, the monofilaments were pressed against the skin at a 90 degree angle until they bowed. The monofilaments were slowly applied to the skin in 1.5 seconds, held in place for 1.5 seconds, and removed in 1.5 seconds. Each monofilament was applied three times at each testing site. If there was no response after three applications to an area, testing of that site was postponed and was resumed with the next larger filament after other testing sites were assessed. If subjects did not respond to the first filament, then subsequent filaments were applied in the same manner until the stimulus was perceived. The results were recorded on the Data Collection Sheet (Appendix C).

The subjects also performed the JTHFT. The subjects performed each of the seven subtests, and the length of time taken to perform each subtest was recorded. The test was administered twice, once using the right hand and once using the left hand. The subtests was administered at a table of 30 1/2 inch-height
with the subject sitting in a chair of 20 inch-height. The standardized procedures
and instructions according to Jebsen, et al. are as follows:

Subtest 1: Writing
The subjects were given a ball-point pen and four 8-by-11-inch sheets of paper fastened to a clip board. The first sentence to be copied was “Whales live in the blue ocean”. The second sentence to be copied was “John saw the red truck coming”. The first sentence was copied with the subjects’ left hand and the second sentence was copied with his/her right hand. These sentences were typed in all capital letters and centered on 5-by-8-inch index card. The card was presented with the typed side faced down on the table. The card was turned over by the examiner with an immediate command to begin. The subtest was timed from the word “GO” until the pen was lifted from the page at the end of the sentence.

The subjects were given the following instructions: “Do you require glasses for reading? If so, put them on. Take this pen in your left hand and arrange everything so that it is comfortable for you to write with this hand. On the other side of this card (indicate) is a sentence. When I turn the card over and say ‘Go,’ write the sentence as quickly and clearly as you can using your left hand. Write, do not print. Do you understand? Ready? Go.”

After subjects completed Subtest 1 with the left hand, they were given the following instructions: “Now repeat the same thing, only this time using your right hand. I’ve given you a different sentence. Are you ready? Go.”

Subtest 2: Card Turning (Simulated Page Turning)
Five 3-by-5-inch index cards were placed in a horizontal row two inches apart on the table in front of the subject. Each card was oriented vertically, 5 inches from the front edge of the table. This distance was indicated on the side edge of the table. Timing was from the word “GO” until the last card was turned over. No accuracy of placement after turning was necessary.

Subjects were given the following instructions: “Place your left hand on the table, please. When I say ‘Go,’ use your left hand to turn these cards over one at a time as quickly as you can, beginning with the one to your extreme right. You may turn them over in any way that you wish and they need not be in a neat pattern when you finish. Do you understand? Ready? Go.”

After subjects completed Subtest 2 using the left hand, they were given the following instructions: “Now do the same thing with your right hand beginning with this one (card on the extreme left). Ready? Go.”

Subtest 3: Small Common Objects
An empty 1-pound coffee can was placed directly in front of the subject, 5 inches from the front edge of the table. Two 1-inch paper clips, two plastic bottle caps, and two United States pennies were placed in a horizontal row to the left of the can. The paper clips were to extreme left and the pennies were nearest to the can. The objects were 2 inches apart. Timing was from the word “GO” until the sound of the last object striking the inside of the can was heard.

Subjects were given the following instructions: “Place your left hand on the table, please. When I say ‘Go,’ use your left hand to pick up these objects one at a time and place them in the can as fast as you can beginning with paper clips on the extreme left. Do you understand? Ready? Go.”

After subjects completed Subtest 3 with the left hand, they were given the following instructions: “Now do the same thing with your right hand beginning here (paperclip on extreme right). Ready? Go.”

Subtest 4: Simulated Feeding

Five kidney beans were placed on a board on a table in front of the subject 5 inches from the front edge of the table. The beans were oriented to the left of center, parallel and touching the upright of the board 2 inches apart. An empty 1-pound coffee can was placed centrally in front of the board. A regular teaspoon was provided. Timing was from the word “GO” until the last bean was heard hitting the bottom of the can.

Subjects were given the following instructions: “Take the teaspoon in your left hand, please. When I say ‘Go,’ use your left hand to pick up these beans one at a time with the teaspoon and place them in the can as fast as you can beginning with the bean on the extreme left. Do you understand? Ready? Go.”

After the subjects completed Subtest 4 with the left hand, they were given the following instructions: “Now do the same thing with your right hand beginning here (bean on extreme right). Ready? Go.”

Subtest 5: Checkers

Four standard sized (1-1/4 inch diameter) plastic checkers were placed in front of and touching a board on a table in front of the subject, 5 inches from the front edge of the table. Checkers were oriented 2 on each side of the center in a 0000 configuration. Timing was from the word “GO” until the fourth checker made contact with the third checker. The fourth checker need not stay in place.

Subjects were given the following instructions: “Place your left hand on the table, please. When I say ‘Go,’ use your left hand to stack these checkers on the board in front of you as fast as you can, one on top of the other. You may begin with any checker. Do you understand? Ready? Go.”
After the subject completed Subtest 5 with the left hand, they were given the following instructions: “Now do the same thing with your right hand. Ready? Go.”

Subtest 6: Large Light Objects
Five empty No. 303 cans were placed in front of a board on a table in front of the subject 5 inches from the front edge of the table. The cans were spaced 2 inches apart with the open end of the can facing down. Timing was from the word “GO” until the fifth can was released.
Subjects were given the following instructions: “Place your left hand on the table, please. When I say ‘Go,’ use your left hand to stand these cans on the board in front of you. Begin with the can on the extreme left. Do you understand? Ready? Go.”
After the subjects completed Subtest 6 with the left hand, they were given the following instructions: “Now do the same thing with your right hand beginning here (can on extreme right). Ready? Go.”

Subtest 7: Large Heavy Objects
Five full (1-pound) No. 303 cans were placed in front of a board on a table in front of the subject 5 inches from the front edge of the table. The cans were spaced 2 inches apart. Timing was from the word “GO” until the fifth can was released.
Subjects were given the following instructions: “Now do the same thing with these heavier cans. Place your left hand on the table. When I say ‘Go,’ use your left hand to stand these cans on the board as fast as you can. Begin with the can on the extreme left. Do you understand? Ready? Go.”
After the subjects completed Subtest 7 with the left hand, they were given the following instructions: “Now do the same thing with your right hand beginning here (can on extreme right). Ready? Go.”

The procedures and instructions for each of the seven subtests were taken directly from Jebsen et al. (1969) with the exceptions that in the Small Common Objects subtest plastic bottle caps were substituted for “regular-sized” bottle caps and in the Checkers subtest plastic checkers were substituted for “wooden” checkers. A possible limitation of using this test with CTS patients is that the affected hand may not be the subject’s dominant hand. In this study, this was found to affect Subtests 1 and 4, which involve writing and simulated feeding. Therefore, the performance on these subtests may reflect
variability in the subtest itself rather than a clear measurement of the subjects’ functional ability (Stern, 1992).

Testing was complete when each subject was evaluated using the WEST and completed the JTHFT. Results of both tests were documented on the Data Collection Sheet for each subject.

**Data Analysis**

For the intrarater reliability test, a multivariate analysis of variance (MANOVA) was performed using p-values and the Wilks’ lambda. For the research data, the Pearson product-moment correlation coefficient was determined between the results of both tests.
CHAPTER 4
RESULTS

Prior to initiation of data collection, an intrarater reliability study for each test was performed using normal subjects. Data collected from this study was analyzed using the StatGraphics Plus, Version 3.1, computer program and a multivariate analysis of variance (MANOVA) was performed on the data. The p-values and Wilks’ lambda were identified across three trials for each test and including all subjects. P-values less than 0.05 indicate a significant relationship at the 95% or higher confidence level.

Table 1 displays the results of the intrarater reliability study. For data collected using the right hand on the JTHFT, the Wilks’ lambda was determined to be 0.06 and p=0.61. For data collected using the left hand on this same test, the Wilks’ lambda was determined to be 0.06 and p=0.63. For data collected on the right and left hands combined using the WEST, the Wilks’ lambda was determined to be 0.11 and p=0.51. These results show that each examiner demonstrated little variability in measuring her respective test across the three trials.

<table>
<thead>
<tr>
<th>Test</th>
<th>Wilks’ ( \lambda ) Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jebsen-Taylor Hand Function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test-Right Hand</td>
<td>0.06</td>
<td>0.61</td>
</tr>
<tr>
<td>Jebsen-Taylor Hand Function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test-Left Hand</td>
<td>0.06</td>
<td>0.63</td>
</tr>
<tr>
<td>WEST-Right and Left Hands Combined</td>
<td>0.11</td>
<td>0.51</td>
</tr>
</tbody>
</table>
Two types of research data were collected in this study: (1) performance times on the JTHFT, measured in seconds and (2) sensibility threshold at three locations on the hand as identified by the WEST, determined to be in one of five categories (Appendices D and E). Using the Pearson product-moment correlation coefficient, the data obtained in this study was analyzed separately for subjects whose dominant hands were affected and those whose non-dominant hands were affected, with no regard to age or sex. The mean times and standard deviations for performance on the JTHFT and their correlations to the sensibility results determined by the WEST are shown in Tables 2 and 3. Level of significance for correlations was determined to be \( r \geq |0.60| \).

Table 2 displays data for the 12 subjects in this study whose dominant hands were affected. The most notable correlations were determined to be \( r = 0.56 \) between the distal index point of the WEST and the Writing subtest of the JTHFT, \( r = -0.72 \) between the volar thumb point and the Large Light Objects subtest and \( r = -0.59 \) between the proximal index point and the Large Light Objects subtest. No significant correlations were determined between the volar thumb, distal index, and proximal index point of the WEST and the Card Turning, Small Common Objects, Simulated Feeding, Checkers, and Large Heavy Objects subtests of the JTHFT. In addition, no significant correlation was determined between the volar thumb and proximal index points and the Writing subtest nor between the distal index point and the Large Light Objects subtest.

Table 3 displays data for the 11 subjects in this study whose non-dominant hands were affected. No significant correlations were determined between any of the points tested with the WEST and any of the JTHFT subtests.
### Table 2
Mean Times, Standard Deviations, and Correlations of Subjects with Dominant Hand Affected

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Mean Performance Time and SD (seconds)</th>
<th>Volar Thumb Correlation (r)</th>
<th>Distal Index Correlation (r)</th>
<th>Proximal Index Correlation (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Writing</td>
<td>14.16 ± 4.04</td>
<td>-0.14</td>
<td>0.56</td>
<td>0.23</td>
</tr>
<tr>
<td>2-Card Turning</td>
<td>6.38 ± 3.03</td>
<td>-0.15</td>
<td>0.26</td>
<td>-0.03</td>
</tr>
<tr>
<td>3-Small Common Objects</td>
<td>7.69 ± 1.71</td>
<td>-0.39</td>
<td>0.01</td>
<td>-0.27</td>
</tr>
<tr>
<td>4-Simulated Feeding</td>
<td>8.32 ± 1.59</td>
<td>-0.21</td>
<td>0.14</td>
<td>-0.16</td>
</tr>
<tr>
<td>5-Checkers</td>
<td>5.25 ± 1.28</td>
<td>-0.41</td>
<td>-0.11</td>
<td>-0.26</td>
</tr>
<tr>
<td>6-Large Light Objects</td>
<td>4.20 ± 0.91</td>
<td>-0.72</td>
<td>-0.45</td>
<td>-0.59</td>
</tr>
<tr>
<td>7-Large Heavy Objects</td>
<td>4.38 ± 1.14</td>
<td>-0.45</td>
<td>0.02</td>
<td>-0.41</td>
</tr>
</tbody>
</table>

### Table 3
Mean Times, Standard Deviations and Correlations of Subjects with Non-Dominant Hand Affected

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Mean Performance Time and SD (seconds)</th>
<th>Volar Thumb Correlation (r)</th>
<th>Distal Index Correlation (r)</th>
<th>Proximal Index Correlation (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Writing</td>
<td>23.51 ± 6.37</td>
<td>-0.15</td>
<td>0.26</td>
<td>0.19</td>
</tr>
<tr>
<td>2-Card Turning</td>
<td>7.01 ± 3.06</td>
<td>-0.01</td>
<td>0.22</td>
<td>0.39</td>
</tr>
<tr>
<td>3-Small Common Objects</td>
<td>8.10 ± 1.70</td>
<td>-0.08</td>
<td>0.04</td>
<td>0.21</td>
</tr>
<tr>
<td>4-Simulated Feeding</td>
<td>9.71 ± 2.21</td>
<td>0.09</td>
<td>0.26</td>
<td>0.48</td>
</tr>
<tr>
<td>5-Checkers</td>
<td>6.00 ± 1.96</td>
<td>-0.08</td>
<td>-0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>6-Large Light Objects</td>
<td>4.56 ± 0.91</td>
<td>0.01</td>
<td>0.01</td>
<td>0.31</td>
</tr>
<tr>
<td>7-Large Heavy Objects</td>
<td>4.67 ± 1.24</td>
<td>-0.14</td>
<td>-0.05</td>
<td>0.21</td>
</tr>
</tbody>
</table>
CHAPTER 5
DISCUSSION

Discussion of Findings

The descriptive correlational research design used in this study failed to show a significant correlation between sensibility loss and functional performance in non-surgical CTS patients. Although some small correlations were shown between the JTHFT and the WEST in subjects whose dominant hands were affected, no correlations were determined between the results of the two tests in subjects whose non-dominant hands were affected.

One possible explanation for the findings of this study is that the subjects varied greatly in the length of time they had been experiencing CTS symptoms. This may have affected the results of this study because those subjects who had been experiencing symptoms for a longer period of time may have developed compensation strategies to produce functional movements. When performing gross motor tasks like those required in the JTHFT, these subjects may use movements at proximal joints of the upper extremity, which position the hand for function, to compensate for reduced function of the affected wrist and hand (Jebsen et al.). This compensation may be evident during the JTHFT since this test does not discriminate performance between large and small muscle groups (Jebsen et al.). Therefore, despite the sensibility threshold determined by the WEST for these subjects, this development of compensation techniques may have caused them to perform better than expected on the JTHFT.
In addition to compensating with proximal musculature for motor performance, some subjects may have become dependent on vision to compensate for loss of sensibility. Bell-Krotoski et al. (1993) state that "the sense of vision can sometimes substitute for some feedback, but only minimally" (p. 122). This supports the theory that vision may be able to compensate for sensibility loss completely in mild cases. In this clinical trial, those subjects whose sensibility was only minimally affected, as measured by the WEST, may have performed better than expected on the Jebsen-Taylor Hand Function Test due to visual compensation.

Another possible explanation for the findings of this study is that many of the subjects were involved in manual or hand-intensive labor, which caused their hands to be more callused than normal. The presence of these calluses may have been a disadvantage to the subjects in that they may have been unable to perceive the smaller filaments of the WEST. This, in turn, would have given an inaccurate measurement of their sensibility threshold when evaluated with the WEST (Weinstein and Weinstein, 1996). Furthermore, Weinstein and Weinstein (1996) state "the discovery of a minimally elevated threshold [in CTS] will not reveal whether the nerves are compromised or whether the skin was thickened" (p. 1). Therefore, with an inaccurate measurement of the sensibility threshold, it was speculated that the subjects would demonstrate an increased performance time on the JTHFT, which was not always demonstrated.

Both the development of compensation techniques affecting performance time on the JTHFT and the presence of callused skin affecting perceived sensibility threshold using the WEST are factors that may have affected the lack of significant correlations in
this clinical trial. If either test was not giving an accurate measurement, no correlations could be determined between hand function and loss of sensibility in the subjects.

Another factor that may have affected the findings in this study is that abnormal sensibility using the monofilaments of the WEST has not been clearly defined. Although monofilament #1 (2.83 g) was defined as "normal" in this study, Bowen, Griefer, and Jones (1990) state that a threshold higher than 2.83 was observed in 8% of right hands and 13% of left hands in a small sample of subjects without any hand abnormalities. Therefore, some subjects in this study may have actually had a higher than normal sensibility threshold despite having CTS, which may have been interpreted as loss of sensibility when measured with the WEST. With this interpretation, these subjects would have been expected to show increased performance times on the JTHFT, which was not always demonstrated.

The negative correlations established in this study (Tables 2 and 3) were not consistent with the hypothesis that there is a positive correlation between sensibility threshold as demonstrated by the WEST and hand function as demonstrated by performance on the Jebsen-Taylor Hand Function Test in the hands of non-surgical CTS patients. The determination of these negative correlations is likely due to the small sample size used in this study, and further research with a larger sample size is needed to better test this hypothesis. Further, a decrease in sensibility acuity was not determined to cause an increase in gross hand function in this study, which may be due to the development of compensation techniques in the proximal musculature and/or visual...
compensation in some subjects as previously discussed. This may also provide an explanation for the negative correlations found in this clinical trial.

Limitations

A major limitation of this study was its small sample size, which was affected by many factors. One such factor was that the hand clinic from which the subjects were recruited did not see many non-surgical CTS patients. Most of the CTS patients seen at this clinic underwent surgical CTS releases, which excluded them as candidates for this study according to the predetermined exclusion criteria. Another factor which affected the sample size was that the hand surgeons that were requested to select appropriate subjects for this study according to the inclusion and exclusion criteria were sometimes inconsistent in referring patients to the researchers. For example, they sometimes forgot to recruit subjects for the study before they left the office. Time constraints of the subjects was also a factor which lead to a small sample size. Subjects often had to wait long periods of time to be seen by the physician and didn’t have extra time to volunteer for the study at the time of their appointment. This was especially an issue for subjects that were receiving Worker’s Compensation for work-related injuries. These subjects were allotted a specific amount of time for paid physician visits, after which they were expected to return to work. The combination of these factors permitted no extra time to volunteer for the study.

The nature of the tests used in this study also presented some limitations. Differences in the cognitive levels of the subjects were found to affect performance on the JTHFT. For example, subjects were required to comprehend and follow specific instructions. In addition, the subjects were specifically required to read and write in order
to perform the Writing subtest, which was stated to be at the third grade reading level (Jebsen et al.). In this study, one subject was unable to read or write, therefore, was unable to perform this subtest.

The nature of the WEST also presented a limitation. Although the literature asserts that there is less slippage of the monofilaments with this test as compared to the original Semmes-Weinstein Monofilaments, the researchers still found there to be some amount of slippage, especially in subjects with callused skin (Weinstein, 1993). This may have affected the measurement of sensibility threshold. Although an ideal sensibility acuity assessment tool is objective, sensitive and specific and is able to detect early stages of hand dysfunction, the WEST may not be the best way to assess sensibility in all situations, i.e. when heavy calluses are present on the skin (Coutu-Wakulczyk, Brammer, and Piercy, 1997).

**Application to Practice**

Contrary to general clinical practice assumption, the results of this study show that hand function and sensibility are not related in the hands of patients with non-surgical CTS. Even though the hypothesis was not supported, the data represents useful information. The data support the need for clinical research to uphold or reject assumptions made by clinicians, upon which the practices of physical and occupational therapy are based. Both professions work on the basic assumption that there is a relationship between sensibility loss and hand function in CTS patients, which has not been supported by research. Working on this assumption may not be the best utilization of time and money in clinical practice. Therefore, there is a definite need to support such basic clinical assumptions with research.
Conclusions

Despite the small sample size, the lack of correlation between sensibility loss in CTS patients and hand function as determined in this clinical trial is significant. This finding amplifies the need for research to support clinical assumptions such as that examined in this study. Studies with a larger sample size and/or more specific inclusion/exclusion criteria might demonstrate a relationship between sensibility and hand function. For example, inclusion/exclusion criteria that distinguish between males and females, subjects of different ages, cognitive levels of subjects, and the presence of other conditions that may mimic symptoms of CTS. In addition, the employment of a tool which tests the utilization of fine motor tasks better than those represented in the JTHFT may be more sensitive to measuring hand function. Furthermore, such a tool may minimize the effect of proximal joint compensation on the measurement of hand function.
References


APPENDIX A
Informed Consent Form

I understand that this is a study of the relationship between sensibility loss and functional performance in industrial workers with carpal tunnel syndrome and that the knowledge gained is expected to help physical and occupational therapists objectively document this relationship and increase early detection of nerve injury in such patients.

I also understand that:

1. I understand that I will be one of approximately 30 participants in this study.

2. Participation in this study will involve completion of a Patient History questionnaire, and the testing of both sensation and function of my hands by a physical therapist or student physical therapist.

3. That I have been selected for participation because I am employed in a factory/industrial setting and I am currently receiving treatment for carpal tunnel syndrome.

4. It is not anticipated that this study will lead to physical or emotional risk to me.

5. My participation in this study will be kept strictly confidential and the data will be coded so that identification of individual participants will not be possible.

6. A summary of the results will be made available to me upon my request.

I acknowledge that:

"I have been given an opportunity to ask questions regarding this research study and that these questions have been answered to my satisfaction."

"In giving my consent, I understand that my participation in this study is voluntary and that I may withdraw at any time by calling Paul Huizinga at the Grand Valley State University Human Subject Review Board at (616) 895-2281, or Bethany Navarre or Elizabeth Ware at the Grand Valley State University Physical Therapy Department at (616) 895-3356, without penalty or loss of any benefits to which I may be entitled."

"My participation in this study is voluntary and that no compensation is being offered or is available for my participation."
"The investigators, Bethany Navarre and Elizabeth Ware, have my permission to release the information obtained in this study to scientific literature. I understand that I will not be identified by name."

"I have been given the phone numbers of Bethany Navarre and Elizabeth Ware so that I may contact them at any time if I have questions."

"I acknowledge that I have read and understand the above information, and that I agree to participate in this study."

_________________________  __________________________  
Participant  Investigator

_________________________  __________________________  
Date  Date

____ I am interested in receiving a summary of the study results.
Address:
APPENDIX B
PATIENT HISTORY FORM

1. Which hand do you use most at work?   R   L

2. How long have you had your symptoms?   __________________________

3. What is the nature of your symptoms?
   pain ___  clumsiness ___
   numbness ___  burning ___
   tingling ___  loss of feeling ___
   aching ___  other _________

4. Have you ever had a nerve conduction velocity test to confirm the diagnosis of CTS?  
   Yes ___  No ___

5. How long have you been receiving treatment for your current symptoms?  __________

6. What kind of treatment have you received?
   cortisone injection(s) ___  splinting ___  other _________
   iontophoresis ___  exercise ___
   ultrasound ___  vitamin B6 pills (dosage) ___
   Comments:  __________________________________________________________
               __________________________________________________________

7. Have you ever had carpal tunnel syndrome or experienced similar symptoms?   
   Yes ___  No ___

8. Does your job include:
   repetition ___  vibration ___
   forceful gripping ___  exposure to extremes of temperature: cold   hot
   awkward wrist positioning ___

9. How long have you been at your job?  __________
APPENDIX C
DATA COLLECTION SHEET

Date of Testing: ______________
Participant Identification Number: ________
DOB: ______________
Affected Hand (Circle one):  R  L  Both

Jebsen-Taylor Hand Function Test Results (in seconds):

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Card Turning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Common Objects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simulated Feeding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Checkers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Light Objects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Heavy Objects</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Weinstein Enhanced Sensory Test Results:
C=callus
A=abrasion
S=scar
B=blemish

Site Filament Number

<table>
<thead>
<tr>
<th>Site</th>
<th>Filament Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volar Thumb (Point I)</td>
<td>1 (0.07g)  2 (0.2g)  3 (2g)  4 (4g)  5 (200g)</td>
</tr>
<tr>
<td>Distal Index (Point II)</td>
<td></td>
</tr>
<tr>
<td>Proximal Index (Point III)</td>
<td></td>
</tr>
</tbody>
</table>

*Record result for each filament. 0 (zero) if no response, ✓ (check mark) for response

Site Filament Number

<table>
<thead>
<tr>
<th>Site</th>
<th>Filament Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volar Thumb (Point I)</td>
<td>1 (0.07g)  2 (0.2g)  3 (2g)  4 (4g)  5 (200g)</td>
</tr>
<tr>
<td>Distal Index (Point II)</td>
<td></td>
</tr>
<tr>
<td>Proximal Index (Point III)</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX D
JTHFT DATA
(in seconds)

RIGHT HAND

<table>
<thead>
<tr>
<th>ID</th>
<th>AGE</th>
<th>G</th>
<th>DH</th>
<th>AH</th>
<th>W</th>
<th>CT</th>
<th>SCO</th>
<th>SF</th>
<th>C</th>
<th>LLO</th>
<th>LHO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>10.69</td>
<td>4.56</td>
<td>6.03</td>
<td>7.19</td>
<td>3.72</td>
<td>3.09</td>
<td>3.25</td>
</tr>
<tr>
<td>2</td>
<td>51</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>9.9</td>
<td>10.69</td>
<td>6.84</td>
<td>7.5</td>
<td>5.82</td>
<td>4.25</td>
<td>3.34</td>
</tr>
<tr>
<td>3</td>
<td>51</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>22.43</td>
<td>7.31</td>
<td>11.53</td>
<td>11.87</td>
<td>6.18</td>
<td>4.18</td>
<td>4.38</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>12.75</td>
<td>4.53</td>
<td>8.53</td>
<td>8.32</td>
<td>7.47</td>
<td>6.47</td>
<td>5.69</td>
</tr>
<tr>
<td>5</td>
<td>45</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>6.94</td>
<td>8.25</td>
<td>9</td>
<td>4.54</td>
<td>4.16</td>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>10.28</td>
<td>4.41</td>
<td>6.72</td>
<td>6.56</td>
<td>5.44</td>
<td>3.78</td>
<td>3.53</td>
</tr>
<tr>
<td>7</td>
<td>37</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>13.28</td>
<td>7.03</td>
<td>7.12</td>
<td>10.03</td>
<td>4.81</td>
<td>4.38</td>
<td>4.81</td>
</tr>
<tr>
<td>8</td>
<td>34</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>19.06</td>
<td>13.55</td>
<td>9.9</td>
<td>9.78</td>
<td>7.09</td>
<td>5.07</td>
<td>6.94</td>
</tr>
<tr>
<td>9</td>
<td>39</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>16.93</td>
<td>5.75</td>
<td>6.34</td>
<td>7.91</td>
<td>5.6</td>
<td>4.47</td>
<td>5.22</td>
</tr>
<tr>
<td>10</td>
<td>77</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>13.34</td>
<td>7.72</td>
<td>8.09</td>
<td>9.34</td>
<td>6.56</td>
<td>6.19</td>
<td>6.78</td>
</tr>
<tr>
<td>11</td>
<td>50</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>15.47</td>
<td>4.34</td>
<td>7.25</td>
<td>6.4</td>
<td>3.94</td>
<td>3.62</td>
<td>3.62</td>
</tr>
<tr>
<td>12</td>
<td>50</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>10.47</td>
<td>3.84</td>
<td>8.25</td>
<td>7.72</td>
<td>3.41</td>
<td>3.66</td>
<td>4.53</td>
</tr>
<tr>
<td>13</td>
<td>26</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>14.5</td>
<td>3.56</td>
<td>5.56</td>
<td>7.59</td>
<td>4.94</td>
<td>3.22</td>
<td>3.31</td>
</tr>
</tbody>
</table>

LEFT HAND

<table>
<thead>
<tr>
<th>ID</th>
<th>W</th>
<th>CT</th>
<th>SCO</th>
<th>SF</th>
<th>C</th>
<th>LLO</th>
<th>LHO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22.16</td>
<td>6.84</td>
<td>7.53</td>
<td>7.28</td>
<td>3.41</td>
<td>3.88</td>
<td>3.5</td>
</tr>
<tr>
<td>2</td>
<td>21.38</td>
<td>5.34</td>
<td>7.38</td>
<td>9.66</td>
<td>5.28</td>
<td>3.84</td>
<td>3.78</td>
</tr>
<tr>
<td>3</td>
<td>29.6</td>
<td>7.19</td>
<td>8.94</td>
<td>10.75</td>
<td>8.69</td>
<td>4.44</td>
<td>4.16</td>
</tr>
<tr>
<td>4</td>
<td>19.75</td>
<td>6.29</td>
<td>8.75</td>
<td>9.87</td>
<td>5.62</td>
<td>5.09</td>
<td>5.66</td>
</tr>
<tr>
<td>5</td>
<td>7.41</td>
<td>8.94</td>
<td>11.09</td>
<td>5.65</td>
<td>4.75</td>
<td>4.62</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>15.97</td>
<td>5.19</td>
<td>6.66</td>
<td>7.69</td>
<td>4.97</td>
<td>3.6</td>
<td>3.47</td>
</tr>
<tr>
<td>7</td>
<td>18.94</td>
<td>7.87</td>
<td>6.84</td>
<td>11.84</td>
<td>3.72</td>
<td>4.69</td>
<td>4.63</td>
</tr>
<tr>
<td>8</td>
<td>38.25</td>
<td>14.91</td>
<td>11.82</td>
<td>13.87</td>
<td>8.04</td>
<td>6.13</td>
<td>7.31</td>
</tr>
<tr>
<td>9</td>
<td>30.21</td>
<td>5.53</td>
<td>8.47</td>
<td>7.6</td>
<td>9.28</td>
<td>4.41</td>
<td>4.54</td>
</tr>
<tr>
<td>10</td>
<td>23.59</td>
<td>9.34</td>
<td>9.96</td>
<td>11.87</td>
<td>9.06</td>
<td>6.09</td>
<td>6.18</td>
</tr>
<tr>
<td>11</td>
<td>34</td>
<td>6.85</td>
<td>8.22</td>
<td>8.03</td>
<td>5.22</td>
<td>3.85</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>21.22</td>
<td>4.66</td>
<td>6.34</td>
<td>7.59</td>
<td>5.5</td>
<td>4.15</td>
<td>4.22</td>
</tr>
<tr>
<td>13</td>
<td>23.59</td>
<td>3.78</td>
<td>6.41</td>
<td>8.43</td>
<td>5.5</td>
<td>3.5</td>
<td>3.47</td>
</tr>
</tbody>
</table>

KEY: ID=Identification Number, G=Gender (0=male, 1=female), DH=Dominant Hand (0=right, 1=left), AH=Affected Hand (0=right, 1=left, 2=both), W=Writing, CT=Card Turning, SCO=Small Common Objects, SF=Simulated Feeding, C=Checkers, LLO=Large Light Objects, LHO=Large Heavy Objects.
# APPENDIX E

## WEST DATA

<table>
<thead>
<tr>
<th>ID</th>
<th>R: VT</th>
<th>R: DI</th>
<th>R: PI</th>
<th>L: VT</th>
<th>L: DI</th>
<th>L: PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

**KEY:** ID=Identification Number, R=Right hand, L=Left hand, VT=Volar thumb, DI=DISTAL INDEX, PI=Proximal index; 1=Normal sensibility; 2=Reduced tactile sensation; 3=Reduced protective sensation; 4=Loss of protective sensation; 5=Residual sensation (Al-Qattan, 1995).