A Trend Analysis of Occupational Therapy Treatment Outcomes Following Carpal Tunnel Syndrome Surgery

Richard G. Cooper
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A TREND ANALYSIS OF OCCUPATIONAL THERAPY TREATMENT OUTCOMES FOLLOWING CARPAL TUNNEL SYNDROME SURGERY

by

Richard G. Cooper

A Dissertation
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Doctor of Education
Department of Educational Leadership

Western Michigan University
Kalamazoo, Michigan
December 1990

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A TREND ANALYSIS OF OCCUPATIONAL THERAPY TREATMENT OUTCOMES FOLLOWING CARPAL TUNNEL SYNDROME SURGERY

Richard G. Cooper, Ed.D.
Western Michigan University, 1990

A trend analysis of treatment outcomes was completed for a single group of subjects who participated in a staged occupational therapy rehabilitation program following carpal tunnel surgery. In addition, the enabler skills of range of motion and muscle strength were compared with the outcome skills of motor function and occupational performance. Thirty-one subjects participated. Data were collected before surgery, and three months, six months, and nine months after surgery.

The findings from this study indicated that: (a) differences in range of motion, gross grasp, motor function, and occupational performance occurred in linear trends; and (b) increases in enabler skills were accompanied by increases in motor function and occupational performance. It was concluded that differences in enabler skills, motor function, and occupational performance occurred in linear trends after participation in a staged occupational therapy program following carpal tunnel surgery.
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A trend analysis of occupational therapy treatment outcomes following carpal tunnel syndrome surgery

Cooper, Richard Gene, Ed.D.
Western Michigan University, 1990

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Last, but not least, my deepest love, gratitude, thanks, and appreciation are extended to my wife and fellow therapist, Roslyn, for her support, sacrifice, and encouragement in completing this study.

This project is submitted in the memory of my mentor and friend, Dr. Elissa Gatlin, who asked that I finish our work.

Richard G. Cooper
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CHAPTER I

THE PROBLEM

Establishing the Research Question

Healthcare in the United States has grown into a complex industry with hospitals in the United States providing treatment for 35 million admissions in 1986 (American Hospital Association, 1987, p. 2). The allied health professions are part of the healthcare industry with 100% of 6,290 reporting hospitals maintaining a department of nursing, 86% maintaining physical therapy services, 84% maintaining respiratory therapy services, 49% maintaining speech pathology services, 35% maintaining recreation therapy services, and 50% maintaining occupational therapy services (American Hospital Association, 1987, pp. 208-210). Healthcare providers and consumers have accepted the historic growth in the healthcare industry. However, healthcare providers and consumers are now questioning their support for continued growth in the healthcare industry. Providers and consumers are seeking more scientific study of provided treatment services. The forces of healthcare regulations, fiscal accountability, and competition are also moving the healthcare industry away from the use of professional tenacity and authority to the use of more scientific methods of establishing growth and change. Therefore, a problem facing the healthcare industry has been the need for producing scientific study of treatment services to support the healthcare services.

The growth of occupational therapy has paralleled that of the healthcare industry. Growth in occupational therapy services has been facilitated by historical
environmental factors including decentralization of psychiatric services from state institutions to the community mental health system; decentralization of services for the developmentally disabled from state institutions to local school systems; demographic changes toward an older population, and advances in medical technology. Healthcare providers and consumers have accepted the historic growth of occupational therapy services. Healthcare providers and consumers are questioning their support of continued growth of occupational therapy services. The forces of healthcare regulations, fiscal accountability, and competition are also moving occupational therapy from the use of professional tenacity and authority toward the use of scientific methods of establishing growth and change. Therefore, a problem facing the profession of occupational therapy has been the need for scientific study of services to support occupational therapy services.

The American Occupational Therapy Association (AOTA) (1986) has supported the need for demonstrated effectiveness of treatment services through a published professional report. The report stated “there seems to be little question on the part of therapists, physicians, employers, and consumers that occupational therapy services are relevant. However, the evidence supporting the value of our service is limited to a handful of outcome studies and minimal basic research” (AOTA, 1986, p. 9). The report stated “the profession must facilitate acceptance of new concepts in healthcare and the measurement of treatment outcomes” (AOTA, 1986, p. 3). The report went on to state that “there is a need for substantiation of the effectiveness of treatment and a clearer definition of the theoretical basis of our practice” (AOTA, 1986, p. 2). Pedretti (1985) supported the need to study treatment theory by stating that “although the concept of biomechanical treatment has long been used in occupational therapy, occupational therapists apply the biomechanics perhaps more intuitively than scientifically. There is a great need for the study and analysis of
the scientific application of biomechanical principles to therapeutic activities” (Pedretti, 1985, p. 3). The profession of occupational therapy has accepted the need for more study of the effectiveness of theory based treatment in all areas of practice.

Carpal tunnel syndrome rehabilitation has been a growing practice area within occupational therapy. Armstrong (1986) described this growth by stating “the overall incidence rate and prevalence of carpal tunnel syndrome is unknown; however, reports from individual work sites suggest that they approach epidemic proportions and are a major cause of lost work in some settings” (Armstrong, 1986, p. 553). Business Week (January 30, 1989) stated:

The Bureau of Labor Statistics reports that cases of nerve conditions, such as carpal tunnel syndrome, have almost doubled for 1987 to 73,000 cases making repetitive motor injuries the fastest growing occupational injury. The National Institute of Occupational Safety and Health (NIOSH) estimates that more than 5 million people, or 4% of the work force, suffer from motion injuries resulting in 30% of all workers compensation claims. The American Academy of Orthopedic Surgeons estimates lost earnings and expenses for medical and treatment costs for motion injuries at more than $27 billion annually (Mallory & Bradford, 1989, p. 92).

Considerable pressure has been upon the healthcare industry to identify effective treatments for carpal tunnel syndrome. Spence (1985) described these pressures by stating “the fiscal impact of hand and upper extremity injuries has drawn the attention of employers, safety officials, and insurers. These groups have turned to the medical community to help minimize costs” (Spence, 1985, p. 10).

Current treatment for carpal tunnel syndrome includes physician directed primary care coupled with occupational therapy rehabilitation services. Occupational therapy treatment programs have been established to provide post-surgical rehabilitation for the carpal tunnel syndrome patient. Effective occupational therapy treatment for post-surgical carpal tunnel syndrome should demonstrate increases in (a) range of motion and muscle strength; (b) increases in motor function; (c) increases
in the occupational performance tasks of work, self-maintenance, leisure, play, and rest; (d) increases in return to work rates; and (e) decreases in recidivism. A problem facing occupational therapy has been the study of the effect of post-surgical rehabilitation services on carpal tunnel syndrome.

There has been a need for scientific study in the healthcare industry and the profession of occupational therapy. Carpal tunnel syndrome has been a practice area of occupational therapy and a concern to healthcare consumers. Therefore, it was appropriate to address the research question: Is the use of a post-surgical occupational therapy program effective in the treatment of post-surgical carpal tunnel syndrome as measured by treatment outcomes of range of motion, muscle strength, motor performance, occupational performance, recidivism, and return to work rates?

**Operational Definitions**

The following operational definitions were utilized in the study of occupational therapy treatment outcomes for post-surgical carpal tunnel syndrome.

**Carpal Tunnel Syndrome**

Carpal tunnel syndrome was the compression neuropathy of the median nerve at the wrist which produced progressive atrophy of the thenar muscles in the median nerve distribution of the hand. This compression caused motor and sensory changes in the involved hand. Symptomology included paresthesia, loss of range of motion, loss of muscle strength, decreases in motor function, and decreases in the ability to complete occupational performance tasks.
Motor Function

Motor function was the gross and fine motor coordination of the arm, hand, and fingers. Motor function was measured on the Purdue Pegboard (Tiffin & Asher, 1948) using the subtest scores of right + left + both and assembly.

Muscle Strength

Muscle strength was the force produced by voluntary muscle contraction. Muscle strength for the involved extremity was measured in pounds on a dynamometer or pinch meter as described in Occupational Therapy for Physical Dysfunction (Trombly, 1983). Measures of muscle strength included lateral pinch, 3-jaw pinch, and gross grasp.

Occupational Performance

Occupational performance was the ability of the individual to accomplish the tasks required by his or her life roles, and has been related to his or her developmental stage. Occupational performance tasks include: (a) self-maintenance, (b) work, (c) leisure, (d) play, (e) rest, and (f) employment. An individual was said to be independent in occupational performance when he was able to complete the tasks he deemed important in each category.

Self-Maintenance

Self-maintenance included the tasks related to feeding, hygiene, dressing, grooming, mobility and object manipulation.
**Work**

Work included the tasks related to family management, school, childcare, home management, and home maintenance.

**Leisure/Play**

Leisure/play included the tasks related to games, sports, hobbies, and social activities.

**Rest**

Rest included the tasks related to rest periods and sleep.

**Employment**

Employment included the tasks required at the employment site during work hours.

Occupational Performance was measured through self-report on the *Activities of Daily Living Form For Carpal Tunnel Syndrome* developed by the researcher (Appendix B). The form provides a self-report on a seven point Likert scale which measures the ability to complete each of the five categories of occupational performance tasks.

**Occupational Therapy Treatment Program**

A six staged treatment program was developed for the rehabilitation of patients following surgery for carpal tunnel syndrome (Appendix C). The treatment program was based upon the biomechanical approach to occupational performance treatment theory. The treatment program was provided through the satellite occupational therapy program of Borgess Medical Center, Kalamazoo, Michigan.
Range of Motion

Range of motion was active movement around the axis of a joint. Range of motion for the involved extremity was measured in degrees of movement through the use of a manual goniometer according to professional standards as described in *Occupational Therapy for Physical Dysfunction* (Trombly, 1983). Measures of range of motion included wrist flexion, wrist extension, ulnar deviation, radial deviation, and thumb opposition.

Recidivism

Recidivism was a decrease in the outcome measures. Recidivism occurred if the subject: (a) decreased in measures of range of motion, muscle strength, coordination, or occupational performance; (b) was placed on medical leave; or (c) required additional surgery. Recidivism was measured by the proportion of subjects who experienced decreases in outcome measures.

Return to Work Rate

Return to work occurred on the date the physician gave on the return to work prescription. The return to work rate was determined as the number of weeks from the surgical procedures to that given on the return to work prescription.

Research Objectives

The objectives of this study were two. The first research objective was to determine the effectiveness of occupational therapy treatment for post surgical carpal tunnel syndrome through a study, across time, of treatment outcomes. The study included subjects who were referred to the formalized post-surgical occupational
therapy rehabilitation program. Treatment outcomes included: (a) the motor enabler skills of range of motion, muscle strength, and fine motor coordination; (b) the ability to complete occupational performance tasks; (c) return to work rates; and (d) recidivism.

The second research objective was to provide information on the biomechanical approach for the occupational performance treatment theory. Information on the biomechanical approach was gathered through the treatment outcomes from the post surgical carpal tunnel syndrome rehabilitation program.

Summary of the Problem

The evolution of the allied health professions has produced a complex healthcare industry. In the past, the allied health professions have utilized tenacity and authority as methods for gaining consumer support for growth of professional services. Consumers and providers are questioning their support of growth in the healthcare industry. A problem faced by the healthcare industry has been the need to demonstrate effectiveness of treatment services through more scientific methods. The growth of occupational therapy parallels that of the healthcare industry. Occupational therapy has been under the same pressures to demonstrate the effectiveness of treatment services. The need for the study of treatment effectiveness has been supported by the American Occupational Therapy Association through published professional documents.

Rehabilitation for post-surgical carpal tunnel syndrome represents a new treatment service provided by occupational therapy. Effective occupational therapy treatment for carpal tunnel syndrome should demonstrate: (a) increases in range of motion and muscle strength; (b) increases in fine-motor coordination; (c) increases in the occupational performance areas of work, self-maintenance, leisure, play, and rest;
(d) decreases in the time for return to work; and (e) decreases in recidivism. If consumers and providers are to support the continued use of occupational therapy with post-surgical carpal tunnel syndrome then the study of the effectiveness of such treatment should be completed.

The study addressed the research question: Is the use of post-surgical occupational therapy effective in the treatment of carpal tunnel syndrome as measured by treatment outcomes of range of motion, muscle strength, motor performance, occupational performance, recidivism, and return to work rates? The study addressed the question through a quasi-experimental, modified time-series design. The study also provided information on the biomechanical approach for the occupational performance treatment theory.

The results of the study are of benefit to occupational therapy, healthcare providers, and healthcare consumers by producing a more scientific study of occupational therapy treatment outcomes for post-surgical carpal tunnel syndrome and treatment theory.

Assumptions of the Study

The review of medical literature identified standard surgical procedures which are used with carpal tunnel syndrome. This study made the assumption that the skill of the individual surgeon in using standard surgical procedure was not an independent variable.

The literature documented that carpal tunnel syndrome was a progressive neurological dysfunction in which the severity of symptoms increase over time (Armstrong, Castelli, Evans, & Diaz-Perez, 1984; Halpern, 1986; Phalen, 1966; and Posch & Marcotte, 1976). The study made the assumption that if additional pre-
surgery observations were feasible they would demonstrate a downward trend (slope) in function with the lowest point of the slope occurring immediately prior to surgery.

Limitations of the Study

A control group was not feasible for the study. Therefore, the study was limited to a single group design. The subjects for the study self-selected themselves into the study group through their choice of physician. This eliminated the possibility for random selection of the sample. Generalizations of research findings were limited to the sample. The modified time-series design included one pre-treatment (baseline) observation and multiple post-treatment observations. Current medical practice provides very limited periods of time between the identification of appropriate candidates for carpal tunnel syndrome surgery and the scheduling of surgical procedures. This practice limited the study to one baseline measurement and resulted in a modification of the time-series design.

Longitudinal study of treatment outcomes most accurately tests the effectiveness of treatment. The study provided for data collection on the experimental group through a nine month time-line. While the testing schedule provided a level of long-term study, the study was limited to a nine month post-surgery study of treatment outcomes and recidivism.

Strengths of the Study

The literature review yielded a number of ex post facto, single group, pretest-post-test design studies of post-surgical carpal tunnel syndrome treatments. The study was to be a prospective study using a modified time-series design with multiple post-test observations. The study "was a more powerful design as these additional measurements enable the researcher to rule out maturation and testing effects as
influences on shifts in the measurements” (Borg & Gall, 1979, p. 562). The modified time-series design provided a measure of control of factors affecting internal validity including maturation, testing effect, regression, selection, mortality, and possibly instrumentation; but did not control for history (Campbell & Stanley, 1966, p. 40).

The majority of the studies identified in the literature compared measurements of range of motion, manual muscle testing, and gross grasp. The study used measurements of fine-motor performance and measurements of daily living skills in addition to the measurements of range of motion, manual muscle testing, and gross grasp.

Many previous studies obtained the post-test observations within three months of the surgical procedures. The study provided a measure of long-term treatment effects through the three, six, and nine month post-treatment observations.

One experienced certified therapist made all observations and measurements for the study. The use of one rater reduced variances produced by the use of multiple raters.

The study provided information on the bio-mechanical approach to the occupational performance treatment theory. The study also provided information on a new instrument for measuring the occupational performance of carpal tunnel syndrome clients.
CHAPTER II

REVIEW OF SELECTED LITERATURE

Introduction

Literature relating to carpal tunnel syndrome, treatment of carpal tunnel syndrome and related disorders, and scientific studies of cumulative trauma and carpal tunnel syndrome was reviewed. The literature from medicine, orthopedic medicine, occupational medicine, occupational therapy, vocational rehabilitation, nursing, physical therapy, and allied health was reviewed. The review was assisted by the staff and facilities of Western Michigan University, Kalamazoo, MI; Borgess Medical Center, Kalamazoo, MI; The Upjohn Corporation, Portage, MI; and the Medical Library of the University of Michigan, Ann Arbor, MI.

The literature review provided: (a) a definition of carpal tunnel syndrome, (b) descriptions of current treatment for carpal tunnel syndrome, (c) definition of occupational therapy, (d) descriptions of occupational therapy treatment of carpal tunnel syndrome, (e) an occupational therapy treatment theory for use with carpal tunnel syndrome, study of the effectiveness of treatment, and (f) study of the biomechanical approach to the occupational performance treatment theory. The literature review demonstrated the need for scientific study of the effectiveness of occupational therapy treatment with carpal tunnel syndrome and of the biomechanical approach to the occupational performance treatment theory.
A Scenario for Carpal Tunnel Syndrome

Spence (1987) provided a client scenario when carpal tunnel syndrome was the pathology. The scenario exemplified the personal, medical, and fiscal problems in providing effective treatment for this disability.

Our injured employee, Sally, is a highly motivated employee who has been doing the same type of highly repetitive work for several years. She is starting to notice some tingling and numbness at work, with pain in her hand during the evening. Sally informs her manager. He doubts that the problem has anything to do with her job, since “nobody else has had the problem.” Also, “Sally has been doing the same work for years”. He does, however, agree to send her to the plant physician.

The physician performs various tests and diagnoses Sally’s problem as Carpal Tunnel Syndrome (CTS). The physician prescribes a brace and recommends the nebulous “light work” assignment. The physician wants to cure Sally; but recognizes that every time she returns to work, she is aggravating the condition even when he prescribes “light work”. Sally’s employer wants to get her back to work quickly, but knows she can not do her regular job while wearing a brace. He doesn’t think there’s any ‘light work’ available for Sally, since the union contract does not allow this type of special job assignment.

The plant’s industrial engineer believes that Sally is already performing light work because the pieces she is handling weigh only a few ounces, even though she may be handling several hundred such pieces an hour. The plant manager is more disturbed when he reviews the insurance company’s computerized loss run which is now estimating that Sally’s claim is going to cost over $5,000 in indemnity payments, plus medical payments. The claim supervisor wants to get her back to work as quickly and economically as possible. He may have had some experience with carpal tunnel syndrome and is convinced that surgery is the only solution available. He realizes that the costs may grow rapidly into five figures if an operation, rehabilitation, and resulting time off work are involved. Typically this has resulted in payments to injured employees of over $40,000 plus an additional 10% for medical bills.

The real increase in cost will emerge if the surgery doesn’t relieve Sally’s symptoms, and she never returns to work. The “lifetime reserving process” can escalate the cost of Sally’s CTS claim into six figures. Naturally, this will have a substantial effect on the employer’s insurance or self-insurance program. The major problem now is that Sally has tried returning to work several times, all unsuccessfully, and she is now looking at the possibility of wrist surgery.
At this point, one may wonder how Sally's experience might be ameliorated. Probably, the missing key was the lack of an experienced health professional, occupational therapist, or ergonomic engineer who is familiar with this type of case. Physicians and Workers' Compensation laws encourage the use of occupational therapists after traumatic injuries have occurred. In Sally's case, the therapist should have been involved before major medical procedures are contemplated. Unfortunately, this may be contrary to conventional medical practice and claims handling procedures (Spence, 1987, pp 2-9).

There is considerable pressure upon the healthcare industry to identify effective treatments for carpal tunnel syndrome as described in the scenario. Spence (1987) described this pressure by stating:

> the fiscal impact of hand and upper extremity injuries has drawn the attention of employers, safety officials, and insurers. These groups have turned to the medical community to help minimize costs. Physicians specializing in the management of upper extremity injuries have been asked to provide cost-effective treatment, to identify causes of injuries, and to return the worker as rapidly as possible to the workplace. Upper extremity cumulative trauma disorder was not recognized, until recently, as a serious problem. Consequently, relatively little Workers' Compensation cost information is available, but I believe that the cost already has exceeded other cumulative trauma disorders which have required major capital expenditures by industry. This problem is being attacked on a broad front so that there is finally hope for success (Spence, 1987, p. 10).

Effective treatment of carpal tunnel syndrome has been defined through this scenario as producing a decrease in symptomology, producing a rapid return to work, halting the recidivism cycle, and being cost-effective.
Carpal Tunnel Syndrome

History

The history of carpal tunnel syndrome has been documented by Phalen (1966) and Posch and Marcotte (1976).

In 1854 Paget discussed compression of the median nerve at the wrist secondary to trauma. In 1913, Marie and Foix, at the autopsy of a patient with advanced atrophy of the thenar muscles but no history of injury, demonstrated neuromata in both median nerves just proximal to the transverse carpal ligament. They were the first to recommend decompression of the median nerve by sectioning the transverse carpal ligament in order to prevent paralysis of the thenar muscles. Moersch, in 1938, also recommended section of the transverse carpal ligament in a patient with bilateral median neuritis, but no operation was performed. In 1946, Cannon and Love reported on thirty-eight cases of tardy median nerve palsy, nine of which were treated by section of the transverse carpal ligament. Three of these nine patients had no definite history of antecedent compression of the median nerve in the carpal tunnel. Six of the patients were treated successfully by sectioning the transverse carpal ligament (Phalen, 1966, p.211).

Carpal tunnel syndrome was first recognized by Sir James Paget in 1865. Abbott and Saunders discussed the problem in fractures of the radius in 1936. According to Bruner, in 1930 Learmonth, was one of the first surgeons to correct the carpal tunnel syndrome with section of the transverse carpal ligament. Moersch described median thenar neuritis in 1938. Sachary, in 1945 described a thenar palsy due to compression of the median nerve in the carpal tunnel. Cannon and Love, in 1946 reported on 36 patients. In 1953, Kraemer reported a series of 40 cases with a diagnosis of acroparesis in which the transverse carpal ligament was sectioned. Of these, 37 patients found prompt relief. Brain discussed spontaneous compression of both median nerves in the carpal canal in 1947 (Posch & Marcotte, 1976, p. 25).

Carpal tunnel syndrome is often classified under the category of cumulative trauma. Cumulative trauma is recognized as a long term traumatic process through which repetitive micro-traumas occur over time. Armstrong (1986) presented the historical relationship between carpal tunnel syndrome and cumulative trauma.

Although he did not use the term cumulative trauma, Ramazini was the first to describe the concept over 200 years ago as he described the harvest of diseases reaped by certain workers from the crafts and trades. All of the profit that they get is fatal injury to their health,
mostly from two causes. The first and most potent is the harmful character of the materials they handle. The second, I ascribe to certain violent and irregular motions and unnatural postures of the body, by reason of which, the natural structure of the vital machine is so impaired that serious diseases gradually develop therefrom.

The terms “repetitive trauma disorders” and “cumulative trauma disorders” are used because these conditions develop over periods of weeks, months, and years as a result of repeated action. Cumulative trauma disorders are those of the soft tissues due to repeated exertions and movements of the body. Carpal tunnel syndrome and tendonitis are cited as typical examples. Upper extremity cumulative trauma disorders of the tendons and nerves are major causes of lost time and workers’ compensation in many hand intensive industries (Armstrong, 1986, p. 553).

Medical Definition

A medical definition of the carpal tunnel and carpal tunnel syndrome was presented by Bannister (1978), Halpern (1986) and Phalen (1966).

Carpal tunnel syndrome is the name now commonly applied to compression neuropathy of the median nerve at the wrist. Carpal tunnel syndrome is the most common cause of progressive atrophy of the thenar muscles in the median nerve distribution in the hand. The median nerve is easily compressed by any condition that increases the volume of the structures within the carpal tunnel. Even a slight swelling of the synovial sheath of the flexor tendons may be sufficient to force the median nerve up against the firm, inelastic changes in the structures supplied by the distal portion of the nerve (Phalen, 1966, p. 211).

The carpal tunnel is a small canal in the wrist through which passes the median nerve as it travels into the palm of the hand and the nine tendons for flexing the digits. The bottom of the canal is formed by the carpal bones and the ligaments which connect them. The canal is lined by synovium, a slippery tissue that furnishes lubrication and enables the tendons to glide through the canal. Because the boundaries of the canal are quite rigid, any condition that causes swelling leads to increased pressure on all of the contents of the canal. In addition, the actual size of the canal may be reduced when the bones are fractured or when spurs press on the contents leading to increased pressure on the nerve and tendons. This increased pressure leads to compromise of the function of the nerve. The most common cause of increased pressure is inflammation of the synovium which may result for arthritic conditions or overuse and mechanical stress.

Carpal tunnel syndrome is a condition that results when excessive pressure is placed on the median nerve as it crosses the wrist. The
disorder is quite common and is found in a surprising number of varied conditions. Many women develop carpal tunnel syndrome during pregnancy. Others may develop the syndrome in the course of employment and may have to permanently change their line of work to achieve resolution of their problem (Halpem, 1986, p. 2).

The median nerve is formed by the union of two heads from the inner and outer cords of the brachial plexus. In the forearm, the median nerve supplies the following muscles: pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum superficialis, flexor pollicis longus, flexor digitorum profundus, and the pronator quadratus. In the hand, the median nerve supplies two radial lumbricals, opponens pollicis, abductor pollicis brevis, and the outer head of the flexor pollicis brevis. Sometimes it supplies the first dorsal interosseous.

Trauma may involve the median nerve at any point in its course, and a complete interruption above the elbow will cause paralysis of the muscles mentioned. In medical neurology, the only common lesion is compression of the median nerve in the carpal tunnel which is described as Carpal Tunnel Syndrome (Bannister, 1978, p. 356).

Carpal tunnel syndrome is a dysfunction produced by compression of the median nerve in the carpal tunnel. The compression is related to the swelling of tissues surrounding the nerve as it passes across the wrist. The swelling may be caused by trauma to the wrist, secondarily to conditions such as pregnancy or arthritis, through anomalies such as additional muscles in the hand, and inflammation of the synovial tissues. Symptoms produced by this compression include weakness of the specific muscles involved, altered sensation, pain, and decrease of hand coordination.

**Symptomology**

Carpal tunnel syndrome is produced by a compression of the median nerve as it crosses the wrist through the carpal tunnel. Symptomology related to the syndrome included: (a) muscle weakness, (b) altered sensation, (c) pain, and (d) decreased coordination. The symptomology is isolated to the muscles, structures, and cutaneous areas innervated by the distal component of the median nerve.
Posch and Marcotte (1976) examined a total of 990 patients (1,201 involved hands). They reported “in distribution by sex, carpal tunnel syndrome is more common among females than among males, a ratio of 60 to 40%. The predominant age for a carpal tunnel syndrome is in the 30-50 year age group for both sexes. The right hand is usually involved more the the left” (Posch & Marcotte, 1976, p. 25).

Phalens' study of 439 patients (654 involved hands) reported “67% were female with the majority being in 40 and 60 year age group” (Phalen, 1966, p. 212).

Phalen (1966) described a typical history of the symptomology for carpal tunnel syndrome as:

Progressive weakness and clumsiness in the hands associated with hyphesthesia and tingling in the distribution of the median nerve distal to the wrist joint. Although mild symptoms have been present for many years, the more severe symptoms may have developed quite recently. The increase is often associated with a sudden change to more strenuous manual labor. The symptoms are usually bilateral and are worse in the dominant hand.

Pain at night, often severe enough to prevent sleep is a frequent complaint. Although pain may be referred to the forearm, elbow, or shoulder, there are never any subjective or objective sensory changes proximal to the wrist joint. A sensory disturbance in the distribution of the median nerve distal to the wrist joint is the most constant clinical finding. Numbness and tingling in the hand is usually aggravated by sustained grasp. Thenar atrophy almost always is preceded by hypesthesia in the median distribution for many months or years. Many patients note weakness and clumsiness in their thumbs, but are unaware of the thenar-muscle atrophy until the physician shows it to them (Phalen, 1966, pp. 212 & 213).

Posch and Marcotte (1976) supported the pattern of symptomology described by Phalen (1966) when they stated that “the patients’ main complaints were numbness, tingling, and nocturnal aggravation” (Posch & Marcotte, 1976, p. 25).

Posch and Marcotte (1976) also noted that symptomology may include a dryness of the skin. Many of his 439 carpal tunnel patients demonstrated an associated history of injury somewhere in the upper extremity, arthritis, hypertension, menopausal symptoms, diabetes, or amyloid disease.
Bannister (1978) described the sensory losses associated with carpal tunnel syndrome as "the appreciation of light touch and tactile discrimination are impaired, and there is also impairment of appreciation of pain, heat, cold, and pin-prick sometimes causing an unpleasant diffuse tingling sensation" (Bannister, 1978, p. 357). Bannister related a decrease in coordination as "the weakness of opposition of the thumb adds to the clumsiness of the hand" (Bannister, 1978, p. 357).

Halpem (1986) described the effects of occupational stress on the presence of carpal tunnel symptomology.

In early and mild cases, the symptoms may be minimal and intermittent. In severe cases, the pain may be unremitting and the weakness dramatic, making even the most simple tasks impossible. Night pain is accompanied by an aching in the hand with strenuous use during the day, and tingling or numbness in the thumb and index finger. When the condition is exacerbated by an occupational stress, individuals commonly report improvement over the weekend and while on vacation (Halpem, 1986, p. 6).

While the specific symptomology of carpal tunnel syndrome may vary between individuals, there is a commonality of progressive muscle weakness, paresthesia, night pain, and a decreasing coordination of the involved hand. The symptoms may be related to stressful activity or be associated with other conditions including pregnancy, arthritis, and employment.

Etiology

Carpal tunnel syndrome limits the effective use of the involved hand. The syndrome results from compression of the median nerve which innervates the thenar component of the hand. Phalen (1966) and Posch and Marcotte (1976) described the etiology as:

Carpal tunnel syndrome is the name now commonly applied to compression neuropathy of the median nerve at the wrist. The median nerve is easily compressed by any condition that increases the volume of the structures within the carpal tunnel. Even a slight swelling of the
synovial sheath of the flexor tendons may be sufficient to force the median nerve against the firm, inelastic transverse carpal ligament, causing motor and sensory changes in the structures supplied by the distal portion of the nerve (Phalen, 1966, p. 211).

The etiology of this syndrome is any condition that will narrow the diameter of the carpal canal or carpal tunnel. Swelling of flexor tendons from tenosynovitis, fractures of the wrist, ganglion cysts, tumors of many types, aberrant arteries, aberrant muscles, gout, arthritis, acute infections, swelling of the tissues from myxoedema, and edema from pregnancy all have been present as possible causes of this syndrome (Posch & Marcotte, 1976, p. 26).

While the pathological process of carpal tunnel syndrome is not fully known, spontaneous and traumatic etiologies have been identified.

**Spontaneous Etiology**

Spontaneous carpal tunnel syndrome is produced by pressure on the median nerve which arises in association with other systemic conditions. These conditions may be time-limited, such as pregnancy, or long term, such as rheumatoid arthritis. Bannister (1978) described the spontaneous etiology.

The pathogenesis of spontaneous compression of the median nerve in the carpal tunnel is not completely understood. The condition occurs principally in middle-aged women, and has been thought to be secondary to swelling of the synovial sheaths. It occasionally occurs during pregnancy, and in rheumatoid arthritis, myxoedema, and acromegaly. The spontaneous compression is frequently bilateral, but often begins in one hand some months or longer before it starts in the other (Bannister, 1978, p. 357).

The symptomology of spontaneous carpal tunnel syndrome may be alleviated when the primary condition is time-limited and is terminated. This is seen in spontaneous carpal tunnel syndrome related to pregnancy. However, the nerve compression may produce permanent symptomology if the primary condition is not time-limited as seen in rheumatoid arthritis. A high percentage of spontaneous cases are middle aged women who were not employed outside of the home.
Traumatic Etiology

Traumatic carpal tunnel syndrome may also be caused by a sudden trauma, such as breaking of the wrist, or by small traumas over a long period of time. The occurrence of small trauma, over time, has been described as cumulative trauma. Halpem (1986) described the trauma etiology.

A carpal tunnel syndrome may result from direct trauma to the median nerve in the wrist or may be associated with many other diseases. The condition can be related to fractures, abnormal lumbrical muscles present in the canal, and tumors or other growths. A growing number of individuals develop pressure on the median nerve in association with their employment, often as part of what has come to be called "cumulative trauma disorder" or "overuse syndrome." While the problem most commonly develops at work, such activities as knitting and crocheting can produce similar effects. The problem develops in a predisposed individual in response to activities that tend to be repetitive, overstrenuous, and place the wrist in abnormal postures. Direct pressure on the palm, particularly if forceful, can lead to nerve damage. Certain factors have been found to increase the likelihood of developing a nerve compression syndrome. These include: repetitive tasks, placement of the wrist in stressful postures, excessive force requirements, vibration, exposure to cold, inappropriate gripping surfaces, and excessive direct pressure on the palm (Halpem, 1986, p. 3).

While there are historical descriptions of cumulative trauma as early as 1850, it has been since the 1970s that the occurrence of industrial related carpal tunnel syndrome has reached an epidemic level. This epidemic is described by Armstrong (1986).

The overall incidence rate and prevalence of cumulative trauma disorders is unknown; however, reports from individual work sites suggest that they approach epidemic proportions and are a major cause of lost work in some settings. There are reasons to believe that the actual incidence rate of cumulative trauma disorders is considerably higher than those based on studies of workers’ compensation reports. Cumulative trauma disorders develop gradually over periods of weeks, months, and years; they cannot be related to a specific event like an accident. Many of the symptoms of cumulative trauma disorders (including pain, stiffness, and numbness) result from naturally occurring chronic diseases. Cumulative trauma disorders are a major health problem in some work settings. Reported occupational risk factors include: repetitive and forceful exertion, mechanical stresses, certain postures, vibration, and low temperature. Although
there are no standards for excessively repetitive or forceful work, common sense dictates that these tasks be minimized to the extent possible, especially in situations where cumulative trauma disorders have been reported (Armstrong, 1986, pp. 553-54).

The recent recognition of occupational induced carpal tunnel syndrome represents a new treatment population which has received wide attention. That attention has been gathered through the past five to ten years. Armstrong, Radwin, Hansen, and Kennedy (1986) were the first investigators of cumulative trauma. Their article Repetitive Trauma Disorders: Job Evaluation and Design and Armstrong’s article Ergonomic and Cumulative Trauma Disorders (1986) provided the descriptors for the four major etiological factors relating to occupational cumulative trauma. Armstrong (1986) described posture as the first of the major etiologies of occupational cumulative trauma.

Posture probably is the most frequently cited risk factor of occupational cumulative trauma disorders. Movements of the wrist, flexion-extension, and radial-ulnar deviation cause the tendons to be displaced past and against the adjacent anatomic surfaces. Flexing the wrist causes the median nerve to be compressed between the finger flexor tendons and the flexor retinaculum, causing the nerve to be stretched around the tendons. Examples of these postures are seen in the use of hand tools, keyboards, and in assembly and packing operations (Armstrong, 1986, p. 559).

Armstrong (1986) described repetitiveness of work as the second of the major etiological factors for cumulative trauma.

Repetitiveness of work is one of the most commonly cited risk factors of carpal tunnel syndrome. Although frequently mentioned, this problem is seldom defined or measured. Engineers and managers tend to think of repetitiveness in terms of work quantities. Work quantities are expressed in terms of the time to complete a task or a set of tasks; this quantity is referred to as “standard time”. Although the number of movements generally increases with the standard time, repetitiveness increases only if all of the movements are the same, that is, if they involve the same joints and muscle groups. Various schemes have been proposed for describing jobs in terms of movements, including reach, grasp, move, position, and release, as well as acts, such as inspect, hold, and rest (Armstrong, 1986 p. 554).
Armstrong (1986) described force as a third major etiological factor for cumulative trauma.

Force is another frequently cited factor of carpal tunnel syndrome. Engineers tend to think in terms of workplace attributes including weight, friction, handle size, and shape. The amount of force exerted by fingers to hold an object is proportional to the force causing it to slip out of the hand and inversely proportional to the object’s slipperiness. Slipperiness is related to the material properties of the handle and the moistness of the skin. Thus, more force will be required to grasp something with a dry hand than a moist hand. The amount of force exerted by the muscles on the tendons and fingers is related to the posture of the hand (Armstrong, 1986, p. 555).

The last major factor which Armstrong (1986) described as an etiology of cumulative trauma is mechanical stress.

Another factor is the mechanical stress produced by contact with hard sharp edges of objects that are held in the hand. The human hand is very strong. Exertion of this force results in reaction forces that are transmitted through the skin of the hand to the underlying tendons. Compression of the digital nerves is produced by tools such as scissors that rub on the sides of the fingers (Armstrong, 1986, p. 557).

Industrialization has introduced many repetitive and stressful work characteristics which are now being recognized as etiological factors in occupational cumulative trauma. One major diagnostic entity which represents occupational cumulative trauma is carpal tunnel syndrome.

**Summary of Etiology**

Carpal tunnel syndrome is produced by compression on the median nerve. This pressure can be produced by a variety of conditions which may be classified as spontaneous or traumatic. Small traumas, over time, may produce a cumulative trauma which represents an increasing cause of carpal tunnel syndrome. Herrick and Herrick (1987) provided an excellent summary of the etiology of the syndrome.

Although it was described in the 19th century the condition is still often overlooked, in spite of considerable increased prevalence now,
which appears to parallel the rise of industrialization. The increasing incidence of carpal tunnel syndrome is considered to be primarily due to the increased abnormal use of the hand in vocational and avocational settings that require repetitive wrist and finger motion. In the workplace, the syndrome affects workers whose occupation involves deviation of the wrist from the straight position and/or use of great force with the hand. Repeated relatively low forceful movements of the flexor tendons through the carpal tunnel may lead to tenosynovitis and thereby to carpal tunnel syndrome. Many tests have been devised to try to clinically diagnose carpal tunnel syndrome; they include the wrist flexion test, the nerve percussion test, the two-point discrimination test, and electrodiagnostic studies. It is often important to objectively determine the presence of carpal tunnel syndrome, or one of the other upper extremity compressive neuropathies, especially if the physician might face the necessity of advising the patient to change a hobby, modify a job significantly, participate in an intensive therapy program, or even consider the possibility of surgical intervention (Herrick & Herrick, 1987, p. 943).

Diagnostic Procedures

"The diagnosis of a carpal tunnel syndrome may be apparent from the description of the symptoms" (Halpern, 1986, p. 7). The symptomology of carpal tunnel syndrome includes motor and sensory changes relating to the distribution of the distal component of the median nerve. "The diagnosis of carpal tunnel syndrome must be considered in any patient who has hypesthesia or paresthesia in the distribution of the median nerve in the hand or in any patient who has weakness or paralysis of the abductor pollicis brevis or opponens pollicis" (Phalen, 1966, p. 212).

The specific diagnostic examination of the upper extremity for carpal tunnel syndrome includes the evaluation of motor and sensory function; specific tests including the Phalen test, Tinel's sign, and electrodiagnostic test; evaluation of range of motion of the wrist; and evaluation for dryness of the skin within the involved area. These evaluations are standard diagnostic procedure and are well documented (Halpern, 1986; Herrick & Herrick, 1987; Phalen, 1966; and Posch & Marcotte, 1976).
Diagnostic Procedures for Motor Function

The absence of normal muscle power may be evaluated through manual muscle testing procedures. The specific muscles tested include the abductor pollicis brevis, opponens pollicis, and flexor pollicis brevis. Functional motor testing evaluates the power produced by several muscles working together in a normal motion. Functional motor testing for pinch strength, wrist flexion and extension, and gross grasp is completed. The hand is also evaluated for atrophy of the thenar eminence. Posch and Marcotte (1976) observed atrophy of the opponens pollicis, abductor pollicis brevis, and flexor pollicis brevis in 261 (41%) of the hands included in that study (Posch & Marcotte, 1976, p. 27). Phalen (1966) described the abductor pollicis brevis as the muscle most often initially involved in this syndrome, with weakness in this muscle being an early sign of median-nerve compression (Phalen, 1966, p. 213).

Diagnostic Procedures for Sensory Functioning

The absence of normal sensation may be evaluated through manual sensory evaluations. The sensation to normal touch, pinprick, two point discrimination, and hypesthesia is typically evaluated. Hypesthesia was demonstrated in 517 hands (79%) studied by Posch and Marcotte (1976). “The hypesthesia may be minimum, usually in the long finger; but the patient will readily point out the portion of the hand in which paresthesia and numbness occur after strenuous use of the hand” (Posch & Marcotte, 1976, p. 26).

The Phalen Maneuver

In performing the Phalen Maneuver the patient is asked to hold the forearms vertically and to allow both hands to drop into complete flexion at the wrist for one
minute. "In this position the median nerve is squeezed between the proximal edge of the carpal ligament and the flexor tendon. Maintaining this position for a long time eventually causes numbness and tingling over the distribution of the median nerve" (Phalen, 1966, p. 214). In a positive test, the numbness and tingling occur after a short time of maintaining the flexed position.

**Tinel’s Sign**

Tinel’s sign is used to evaluate the degree of compression of the median nerve against the carpal ligaments. If the Tinel’s sign is positive, a tingling sensation radiating out into the hand is produced by light percussion over the median nerve at the wrist. It has been demonstrated to be a valuable sign in the diagnosis of carpal tunnel syndrome. In a study by Posch and Marcotte (1976), 73% of the hands demonstrated a positive Tinel’s sign (Posch & Marcotte, 1976, p. 26).

**Electrodiagnostic Evaluation**

Electrodiagnostic procedures may be helpful when the diagnosis is in doubt. Conduction time for the motor fibers of the median nerve is determined by stimulating the nerve with a bipolar electrode at the proximal flexion crease of the wrist, and recording the time required for the appearance of the muscle action potential of the opponens pollicis. “Johnson and associates found a mean delay of 8.4 milliseconds for carpal tunnel clients” (Phalen, 1966, p. 215). “Well over 90% of patients with carpal tunnel syndrome will have an abnormal nerve conduction velocity study” (Halpern, 1986, p. 12).
Range of Motion Evaluation

"Decreased muscle strength and normal sensation may lead to contractures or abnormal resting positions resulting in loss of range of motion within the joints of the wrist and hand. In assessing the hand and wrist, the ability of the individual to move the extremity through a normal range of motion is evaluated" (Halpern, 1986, p. 9).

Testing the Dryness of Skin

"Dryness over the thumb and first 2.5 fingers leads one rather readily to the diagnosis of carpal tunnel syndrome" (Posch & Marcotte, 1976, p. 25). The dryness over this area is related to sympathetic function which is decreased by the compression of the median nerve.

The physician utilizes all, or the majority, of these diagnostic tests to establish the presence of carpal tunnel syndrome. Once the diagnosis is established, treatment through primary care and rehabilitation may begin. The treatment of carpal tunnel syndrome falls into the categories of conservative and surgical.

Treatment of Carpal Tunnel Syndrome

Physician Primary Care

The physician directs the treatment procedures utilized with the patient who has been diagnosed as having carpal tunnel syndrome. The procedures currently utilized in that treatment are classified as conservative (non-surgical) and surgical. Within both of these classifications, the physician may prescribe secondary care such as exercise programs, splints, educational programs, or rehabilitation programs. These secondary care procedures are implemented by occupational therapists, physical therapists, or rehabilitation specialists.
Conservative Treatment

Conservative treatment procedures are used for both spontaneous and traumatic carpal tunnel syndrome. The conservative treatment procedures include rest of the hand, splinting, diuretics, and injections of hydrocortisone acetate into the carpal tunnel (Bannister, 1978; Herrick & Herrick, 1986; Phalen, 1966; and Posch & Marcotte, 1976).

The treatment of a carpal tunnel syndrome must be tailored to each patient's individual problem and needs. Conservative treatment options include: splinting, nonsteroidal anti-inflammatory medication, corticosteroid injection, job modification, occupational therapy, short arm casting, and control of inciting disease. If the condition is the result of an occupational stress, changing jobs may resolve the problem (Halpern, 1986, p. 13).

If the symptomology continues after conservative methods are utilized and the physician believes the syndrome is related to occupational trauma, then job changes are recommended (Halpern, 1986, p. 13). "It is obvious that resting the hands or change of occupation is indicated for the patient who has had a recent onset of symptoms after an unusual amount of manual labor" (Phalen, 1966, p. 221). Physicians perceive job changes as conservative treatment.

Spontaneous carpal tunnel syndrome tends to be receptive to conservative treatment although surgery may be required if relapses occur. "Spontaneous compression symptoms improvement may result from rest or immobilization of the hand, diurectics, and the injection of hydrocortisone acetate into the carpal tunnel. Relapse may follow the resumption of activity at which point surgery is advisable" (Bannister, 1978, p. 358).

Conservative treatment procedures may be effective for many patients of carpal tunnel syndrome. Phalen (1966) reported that conservative treatments were effective with 60 percent of the 654 hands included in that study (Phalen, 1966, p. 221). Posch and Marcotte (1976) reported that 520 of 1201 hands in that study
responded to conservative treatment. The response to conservative treatment measures is additional confirmation of the diagnosis of carpal tunnel syndrome. “The prompt relief after injection of a steroid into the carpal tunnel gives additional support to the diagnosis of carpal-tunnel syndrome” (Phalen, 1966, p. 222). If there is no response to conservative treatment or the symptoms reappear upon return to normal activity, then surgical procedures may be required. “Other than in exceptional cases, surgery is undertaken only when conservative measures have failed to relieve the problem” (Halpem, 1986, p. 16).

Surgical Treatment

The surgical procedures for carpal tunnel involves the division of the flexor retinaculum or transverse carpal ligament (Bannister, 1978; Halpem, 1986; Herrick & Herrick, 1986; Phalen, 1966; and Posch & Marcotte, 1976). “Surgical division of the flexor retinaculum gives rapid relief from the acroparaesthesiae, and, if the condition has not been left too long, full sensory recovery may be expected in the course of six to twelve months with a high degree of recovery of muscular power” (Bannister, 1978, p. 358). Halpem provided a description of the surgical procedures.

A small, curved incision is made directly over the carpal tunnel. The transverse carpal ligament is carefully cut allowing the contents of the canal to expand. The median nerve is identified and carefully visualized through the entire canal to insure that all pressure inducing tissue is removed. In cases where extensive fibrosis, or scar, is present, the tissue enclosing the nerve is removed. The synovium in the canal may also be excised from around the nerve and from around the tendons. The canal is further explored to insure that no aberrant tissue, such as an extra muscle or tumor, is present. Any areas of bleeding are controlled and the wound is sewn closed. Following the surgery, a bulky dressing is applied and kept in place for approximately one week. The stitches are removed in seven to ten days and a gentle exercise program is begun (Halpem, 1986, p. 17).
The studies of Herrick and Herrick (1987) and Phalen (1966), Posch and Marcotte (1976) indicated that the surgical procedures can provide relief from the symptomology of carpal tunnel syndrome. However, not all surgical procedures are successful. Phalen (1966) described the prognosis of surgical success by stating "there was no correlation between the duration of symptoms and the post-operative disappearance of atrophy. No firm prognosis in regard to the return of the thenar muscle power is possible" (Phalen, 1966, p. 226). Many of the patients who do not receive relief from the symptomology are those that must return to a work situation that requires continuation of the etiological stresses that activated the symptomology.

While surgical release of the carpal tunnel may completely relieve the symptoms, there are a substantial number of patients who will never be able to return to a task that precipitated the compressive neuropathy originally. For some individuals, to attempt to return to certain tasks may cause a recurrence of the carpal tunnel syndrome and lead to permanent disability (Halpern, 1986, p. 18).

It is important to recognize that the tasks referred to in these discussions are not solely employment situations. Many who have return of symptomology are homemakers, with young children.

The primary care provided by physicians includes conservative and surgical procedures. The physician also may include secondary providers in the treatment procedures. The increase in carpal tunnel syndrome through cumulative trauma at the employment site has brought new attention to the use of secondary providers in treatment of carpal tunnel syndrome, especially in post-surgical rehabilitation.

If an individual is to return to light activities, this can usually be accomplished in a few weeks after surgery. If, on the other hand, he is to return to strenuous and repetitive functions, many months may be required for adequate recovery. An occupational therapist is vital for treating the individual who wishes to return to such vigorous activity, as the recovery must be gradual and guided if a recurrence is to be avoided.

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be able to return to a task that precipitated the compressive neuropathy originally. For some individuals, the attempt to return to certain tasks may cause a recurrence of the carpal tunnel syndrome and lead to permanent disability (Halpern, 1986, p. 13).

This recent recognition of the occupational therapist as an additional postsurgical rehabilitation treatment has brought new treatment programming into the field of occupational therapy.

**Occupational Therapy**

**Definition of Occupational Therapy**

The profession of occupational therapy has a history beginning in the early twentieth-century. "According to history the term occupational therapy was first coined by George Barton of Chicago around 1912 when he was attempting to treat an arthritic condition by the use of occupational methods" (Bear-Lehman, 1986, p. 3). From the treatment of the mentally ill the profession evolved to include the treatment of the physically disabled during World War I. "Early work-related programs, referred to as workshops, flourished in the 1920s" (Bear-Lehman, 1986, p. 3; Jacobs, 1985, p. 3). Today, the profession of occupational therapy is utilized in the treatment of a broad range of psychosocial, physical, and developmental dysfunctions. The treatment settings for occupational therapy include hospitals, mental health agencies, schools, industry, and home health care. The occupational therapist is employed in both public and private sectors of the healthcare delivery system. Throughout this evolution, the profession has continued to function within its founding concept "that human beings have an occupational nature, that is, it is natural for humans to be engaged in activity, and the process of being occupied contributes to the health and well being of the organism" (Pedretti, 1985, p. 3).
Due to diverse treatment populations, defining the profession has been a difficult task. The American Occupational Therapy Association has officially adopted the definition that occupational therapy is "the art and science of directing man's participation in selected tasks to restore, reinforce and enhance performance, facilitate learning of those skills and functions essential for adaptation and productivity, diminish or correct pathology, and to promote and maintain health. The fundamental concern of occupational therapy is the development and maintenance of capacity throughout the life span. And, to perform with satisfaction to self and others, those tasks and roles essential to productive living and to the mastery of self and the environment" (AOTA, 1972, p. 204).

Occupational therapy treatment centers on providing the patient with opportunities to master tasks and roles. The occupational therapy treatment process has been delineated by The American Occupational Therapy Association as:

- evaluating the client to determine an individual's activity goals, their capacity to plan and perform purposeful activities, and their ability to meet the functional demands of the environment. Based on this evaluation, the occupational therapist designs activity experiences that offer the client opportunities for effective action. These activities are purposeful in that they assist and build upon the individuals abilities and lead to the achievement of personal goals" (Hinojosa, 1983, p. 805).

Through the treatment process, the patient "(a) explores the nature of his or her interest, needs, capacities, and limitations; (b) develops or refines motor, perceptual, and cognitive skills; and (c) learns a variety of interpersonal and social attitudes and behaviors that are sufficient for coping with life tasks and assuming appropriate roles that aid in mastering elements of the environment" (Evans, 1987, p. 628).

The ability of the occupational therapist to provide legitimate treatment in arenas with varying philosophical and scientific foundations lies in the definition of
occupation. "Occupation is defined as the active or doing process of a person engaged in goal-directed, intrinsically gratifying, and culturally appropriate activity. The founders and early pioneers in occupational therapy conceptualized occupation as an essential part of human nature that is manifested by active participation in self-maintenance, work, leisure, play and rest" (Meyer, 1977, p. 630). This definition of occupation identifies the major individual life tasks as self-maintenance, work, and play-leisure. Self-maintenance includes feeding, hygiene, dressing, grooming, mobility, and object manipulation. Work activities include school, home, family management, and employment. Play and leisure activities are games, sports, hobbies, and social activities" (AOTA, 1974, p. 12).

From this definition of occupation, the boundaries of a professional domain of practice have been described as

encompassing the use of occupation: (a) in a variety of therapeutic situations for the purpose of promoting a person’s ability to influence his or her own state of health; (b) with people of all age groups having occupational performance dysfunction resulting from illness, trauma, deprivation, stress, or developmental insults; and (c) for the purpose of preventing occupational performance dysfunction and for remediating, habituating, and maintaining occupational performance skills of self-maintenance, work, leisure and play (Evans, 1987, p. 628).

"The concept of occupation, then includes all of the occupational performance skills included in self-care, work, and play/leisure. Since the occupational performance skills, by their very nature, are purposeful and meaningful, they serve as appropriate treatment modalities within the domain of occupational therapy" (Pedretti, 1985, pp. 2-3).

**Occupational Therapy Treatment Programs for Carpal Tunnel Syndrome**

Occupational therapy has maintained a role in the diagnostic process and conservative treatment procedures of carpal tunnel syndrome. The role of the
occupational therapist in the diagnostic process involved: (a) the measurement of muscle strength of the involved muscles through manual muscle testing; (b) measurement of functional power through the testing of such motions as grasp, pinch, and wrist flexion-extension; (c) measurement of active range of motion of the joints of the involved extremity; and (d) sensory evaluations of the involved extremity. The role of the occupational therapist in the provision of conservative treatment included: (a) the construction and modification of splints, (b) implementation of exercise programs to increase range of motion and strengthen muscle power, (c) education of the client toward correct body mechanics, and (d) modification of the job tasks which initiated the stress on the median nerve.

Bear-Lehman (1986) described the role of the occupational therapist.

The occupational therapist’s unique blend of expertise in occupational performance, body mechanics, and ability to teach both joint protection and work simplification principles is of great value to an industrial program. In addition, the occupational therapist can use knowledge of anatomy, physiology, the disease and injury process to identify the right activities and exercise procedures to increase a worker’s strength and endurance, and to minimize the effect of work postures and patterns (Bear-Lehman, 1986, p. 7).

Bear-Lehman (1986) identified the increased role of occupational therapy in the treatment of hand dysfunction by surveying the members of the American Society of Hand Therapy. “The study indicated a strong resurgence of work evaluation in the occupational therapy hand clinics, as well as, identifiable relationships between upper extremity injuries and the occupational tasks that seem to produce them” (Bear-Lehman, 1986, p. 5).

While no studies of the effectiveness of the occupational therapy role in carpal tunnel syndrome or occupational cumulative trauma were found in the professional literature, there have been some program descriptions published. The R. L. Petzoldt Hand Surgery and Rehabilitation Center of San Jose, CA provided a program which
is typical for industrial rehabilitation programs. The program contains four components including assessment, acute phase treatment, reconditioning/work hardening, and return to work/work capacity testing. The following description was provided by Walker (1985).

**Assessments**

A baseline of function for the patient is established through a history of symptoms, range of motion, sensory, strength, pain, Phalen test, Semmes-Weinstein monofilament test, and two-point discrimination.

**Phase I: Acute Phase Treatment**

The acute phase treatment is characterized by dynamic rest, and incorporates the use of rigid splints, gentle active and passive exercises to promote healing without adhesions, and therapy modalities to reduce inflammation.

**Phase II: Reconditioning/Work Hardening**

This phase is characterized by a decrease in pain, with pain only present at the ends of active range of motion; residual scar tissue; and loss of endurance and strength. Treatment is characterized by increased stretching and resistance to motion. Sequencing includes warm-up activities followed by partial range isotonics or partial force isometrics. The next step is to perform full arc of motion against resistance, including motions which involve several joints. This is effected through the use of the Baltimore Therapeutic Work Simulator.

**Phase III: Return to Work/Work Capacity Testing**

During this phase, three major activities occur: (1) Job analysis, (2) work capacity testing, and (3) recommendations for work modification and/or restrictions. These include: The Texas Rehabilitation Institute Battery of Hand Function, the Minnesota Rate of Manipulation Test, the Purdue Peg Board, the Crawford Small Parts Test, and the Bennet Hand Tool Test (Walker, 1985, pp. 150-152).

Professional literature relating to the treatment of dysfunctions such as carpal tunnel syndrome has identified a need for rehabilitation services in the conservative and post-surgical phases of treatment (Armstrong, 1986; Halpern, 1986; Herrick & Herrick, 1986; Posch & Marcotte, 1976; and Spence, 1987). The literature of
occupational therapy provides program descriptions for treatment of carpal tunnel syndrome, but provides no studies of the effectiveness of such treatment.

The Occupational Performance Theory of Treatment

Occupational therapy has been defined in terms of activity, participation, performance, and occupation. Occupational therapy treatment provides directed participation in tasks designed to restore, reinforce, and enhance performance. Occupation has been defined as performing appropriate self-maintenance, work, play, and leisure tasks. From the definition of occupation several treatment theories have been described. One theory described in the literature is occupational performance. Occupational performance has been defined by the profession as:

The individual's ability to accomplish the tasks required by his or her roles and is related to his or her developmental stage. Occupational performance tasks include self-care, work, play, and leisure. The occupational performance task of self-maintenance includes feeding, hygiene, dressing, grooming, mobility, and object manipulation. The occupational performance task of work activities includes school, home, family management, and employment. The occupational performance task of play and leisure includes games, sports, hobbies, and social activities (AOTA, 1974, p. 12).

To accomplish the occupational performance tasks of self-maintenance, work, play, and leisure the individual must possess enabling skills, or performance components. "Performance components are the learned developmental patterns of behavior which are the substructure (enablers) of the individual's occupational performance" (AOTA, 1974, p. 12). "The performance components (enablers) include (1) sensory-integrative functioning, (2) motor functioning, (3) social functioning, (4) psychological functioning, and (5) cognitive functioning" (Pedretti, 1985, p. 1).

Occupational therapists provide organized experiences which enable the client to accomplish their occupational performance tasks. The boundaries of the domain of
practice “encompass the use of occupation with people of all age groups having occupational performance dysfunction resulting from illness, trauma, deprivation, stress, or developmental insults; and for the purpose of preventing occupational performance dysfunction and for remediating, habituating, and maintaining occupational performance skills for self-maintenance, work, leisure and play” (Evans, 1987, p. 628).

Within the context of occupational performance, the “procedures that prepare the client for occupational performance, but are preliminary to the use of the performance skills, are the concern of occupational therapy” (Ayers, 1958, p. 300). Rogers (1982) described the relationship between the performance components and the performance skills.

In this frame of reference, the concerns of occupational therapy are the performance skills (self-care, work, and play/leisure) and the performance components that enable performance skills. When working on a performance component, it is essential that the methods be directed ultimately to the client’s ability to master performance skills since functional independence is a core concept of occupational therapy theory and the goal of the occupational therapy process (Rogers, 1982, p. 709).

Therefore, treatment centers on developing performance components which in turn enable mastery of performance skills. The goal of treatment is the development of those performance skills needed, or desired, by the patient.

The occupational performance theory is based upon the five enabling performance components which include: (1) sensory-integrative functioning, (2) motor functioning, (3) social functioning, (4) psychological functioning, and (5) cognitive functioning. The performance component to be addressed in the treatment of carpal tunnel syndrome is motor functioning. “The motor component refers to joint motion, muscle strength and tone, functional use of the limbs and body, and gross and fine motor skills” (Pedretti, 1985, p. 2). “In order to ensure success, the
patient must have the prerequisite strength, mobility, endurance, balance, and coordination required by each task before it is attempted. The therapist attempts to increase the patient’s motor capabilities through the use of the biomechanical approach” (Trombly, 1983, p. 125). “Examples of enabling activities in the biomechanical occupational therapy treatment approach are repetitive practice of a particular motor pattern, exercise for muscle strengthening, or balance training. It is important that occupational therapists plan the treatment so that performance skills are an ultimate outcome of enabling activities” (Pedretti, 1985, p. 2). The principles and methods of the biomechanical approach were described by Trombly (1983).

The principles and methods of the biomechanical approach to treatment are appropriate for patients who have problems that directly affect range of motion (ROM), strength, and endurance but have an intact central nervous system (CNS). Therefore, these clients possess control of isolated movement and specific movement patterns, although there is weakness, low endurance, or joint limitation. Examples of such disabilities are orthopedic dysfunction such as rheumatoid arthritis, fractures, hand trauma, lower motor neuron disorders (such as peripheral nerve injuries), and primary muscle diseases (Trombly, 1983, p. 124).

The treatment process for the biomechanical approach to increasing motor function was described by Pedretti.

The biomechanical approach includes those techniques of evaluation and treatment that use the application of forces to the body and employ principles of physics to select and direct those forces appropriately. Some examples are joint measurement, muscles strength testing, therapeutic activity, therapeutic exercise, and orthotics. Methods of evaluation and treatment that can be included in the biomechanical approach are primarily directed at restoration of motor function. Therefore, this approach addresses the motor performance component in the occupational performance frame of reference. Many of the techniques and modalities that can be considered “enabling methods”, such as exercise, splints, and kinetic activities are biomechanical in nature (Pedretti, 1985, p. 4).

The occupational performance theory relates the ability of an individual to perform the life tasks of work, leisure, and self-care to the adequacy of the performance components (enablers). These enablers include sensory-integrative
functioning, motor functioning, social functioning, psychological functioning, and cognitive functioning. Individuals who suffer a loss in the motor functioning enabler will experience decreased levels of occupational performance. Losses in the motor functioning component will be demonstrated through decreased strength of involved muscles and decreased range of motion of involved joints. Evaluations will not identify losses of central nervous system functions including: (a) sensory-integrative functioning, (b) cognitive functioning, (c) social functioning, or (d) psychological functioning.

Carpal tunnel syndrome matches the criteria for motor functioning component loss. The syndrome is produced by a compression of a peripheral nerve (median) and does not affect the function of the central nervous system. The syndrome affects the range of motion, strength, and endurance of the patient. While atrophy of specific muscles occurs, there is no loss of isolated muscle movement. It is appropriate for treatment programs directed toward increasing the motor functioning component to incorporate the biomechanical treatment approach. Within occupational performance theory, occupational therapy treatment programs for carpal tunnel syndrome may utilize the biomechanical approach to increase the client’s motor functioning as an enabler to occupational performance. Such treatment programs should incorporate repetitive activities which strengthen the involved muscles and the range of motion of involved joints. Treatment outcomes would include: (a) strength of the muscles, (b) active range of motion of the joints, and (c) endurance as indicators of the performance components. Measurement of coordination and performance measures for work, leisure, and self-care would be indicators of successful occupational performance.
Studies of Occupational Therapy Treatment Effectiveness
With Carpal Tunnel Syndrome

Reviews of the orthopedic medicine, rehabilitation, allied health, and occupational therapy literature demonstrate limited scientific research on treatment outcomes. The review of the literature provided few descriptions of treatment programs for cumulative trauma, and none for carpal tunnel syndrome. The program descriptions provide information needed to initiate services. The treatment outcomes reported in program descriptions are summaries of positive treatment outcomes which support the implementation of the treatment program.

The limited study of allied health services, including occupational therapy, may be related to at least five factors. The first factor is an inability to gain access to client data from healthcare providers (hospitals and clinics) for scientific study. Many providers feel that such access will place them in a competitive situation with other providers. The ethics of confidentiality for client files also affect the availability of data for scientific study. The second factor relates to the nature of the provider institutions which wish to maintain the "secrets of the trade." With the trend toward for-profit service delivery, providers are less willing to allow data on programs and treatment outcomes to become part of the professional literature. The third factor is the ethical factor of random client selection for the provision of healthcare services within the provider agency. It is difficult to justify such research procedures when providing treatment to the general population. The fourth factor is the isolation of independent treatment variables which will effect a change in the pathology of the disabling entity. Most disease entities have over-lapping variables which cloud research data. The fifth factor is the lack of data collection planning at the implementation stage of new rehabilitation programs. This often results in treatment outcome data being collected on an ex post facto basis with a lack in consistency in
the types of data collected. While program descriptions are available from the professional literature, there remains limited scientific research on the effectiveness of allied healthcare treatment, including occupational therapy.

Study of the Occupational Performance Treatment Theory

Review of the literature did not reveal any studies which related to the biomechanical approach to occupational performance. As Pedretti (1985) stated, “although the concept of biomechanical treatment has long been used in occupational therapy, occupational therapists apply the biomechanics more intuitively than scientifically. There is a great need for the study and analysis of a more scientific application of biomechanical principles to therapeutic activities” (Pedretti, 1985, p. 4). There were published studies of the occupational performance theory relating to the sensory-integrative, psychological functioning, and cognitive functioning performance component. However, these studies relate to dysfunctions of the central nervous system.

Summary of the Review of Literature

The literature review documented the definition of occupational therapy, described carpal tunnel syndrome as a functional disease, and documented the primary care treatment procedures currently utilized with carpal tunnel syndrome.

The literature documented that rehabilitation services provided by occupational therapy are becoming a treatment option for carpal tunnel syndrome in both the conservative and post-surgical procedures (Armstrong, Castelli, Evans, & Diaz-Perez, 1986; Halpern, 1986; Herrick & Herrick, 1986; and Spence, 1986).

The literature established a treatment theory for those rehabilitation services provided by occupational therapy. The theory states that the ability of an individual to
complete the occupational performance tasks of work, leisure, and self-care is based upon the development of the motor functioning enablers. The occupational performance treatment theory supported the development of the motor functioning enablers through the use of the biomechanical approach (Pedretti, 1985).

The literature documented that outcomes for occupational therapy treatment using the occupational performance theory include the measurement of active range of motion; strength of the involved muscles; power of functional movements; coordination; and the ability to perform the tasks of work, leisure, and self-care.

The review documented few program descriptions for occupational therapy treatment of carpal tunnel syndrome, documented few studies testing the biomechanical approach to occupational performance, and documented no studies testing the effectiveness of occupational therapy treatment with carpal tunnel syndrome. Therefore, it was appropriate to study the effectiveness of an occupational therapy treatment program based on the biomechanical approach to occupational performance on carpal tunnel syndrome.
CHAPTER III

DESIGN AND METHODOLOGY

Introduction

The literature review supported the need for continued study of occupational therapy programs which are used with carpal tunnel syndrome clients. The literature review also supported the need for study of the biomechanical approach to the occupational performance treatment theory of occupational therapy. Based on the literature, the study addressed the research question: Is the use of a post-surgical occupational therapy rehabilitation program effective in the treatment of carpal tunnel syndrome as measured by the treatment outcomes of range of motion, muscle strength, motor performance, occupational performance, recidivism, and return to work rates? The study also addressed the research question: Are the treatment outcomes of a post-surgical occupational therapy rehabilitation program for the treatment of carpal tunnel syndrome consistent with the bio-mechanical approach to occupational performance treatment theory?

The study collected data on the treatment outcomes for one group of carpal tunnel syndrome clients who had completed a post-surgical occupational therapy rehabilitation program. The subjects interrupted employment for surgery. Data were collected through a modified time-series design (Campbell & Stanley, 1966, p. 37; and Kerlinger, 1973, p. 343). The modified time-series design was implemented as described by Borg and Gall (1979) and diagramed in Figure 1.

In the time-series design a single group of subjects is measured at periodic intervals. The experimental treatment is administered
between two of these time intervals. The effect of the experimental treatment, if any, is indicated by a discrepancy in the measurements before and after its appearance. The use of additional measurements makes the time-series design more powerful than the pretest-posttest design. The time-series design is quite useful when forming a control group is not feasible and when subjects can be measured periodically with the same instrument. It seems particularly appropriate for field research (Borg & Gall, 1979, pp. 562-564).

\[ O_1 \ X \ O_2 \ O_3 \ O_4 \]

\( X \) the experimental treatment of surgery followed by the occupational therapy rehabilitation program.

\( O_1 \) baseline measurement taken prior to surgery.

\( O_2 \) measurement taken at three months post surgery.

\( O_3 \) measurement taken at six months post surgery.

\( O_4 \) measurement taken at nine months post surgery.

Figure 1. Study Design: a Modified Time-Series.

The subjects received occupational therapy treatment built upon the biomechanical approach for increasing occupational performance. Measures of treatment outcomes included active range of motion, muscle strength, motor function, level of occupational performance, return to work rate, and recidivism. The treatment outcomes were also used to study the biomechanical approach to the occupational performance treatment theory.
Research Questions and Research Hypotheses

Research Question 1

Is there a difference between the outcome measurements, across time, for subjects with carpal tunnel syndrome who have received occupational therapy rehabilitation after surgery?

If the treatment is effective, the subjects should demonstrate an increase in the measurement of function and then maintain that increase over time.

Research Hypothesis 1

A difference will be found when comparing the outcomes, across time, for subjects with carpal tunnel syndrome who have received a staged occupational therapy rehabilitation program following surgery as measured by range of motion, muscle strength, motor performance, occupational performance, and recidivism.

Research Question 2

Are the treatment outcomes of the staged occupational therapy rehabilitation program for post surgical carpal tunnel syndrome consistent with the bio-mechanical approach to the occupational performance treatment theory?

The biomechanical approach to the occupational performance treatment theory suggested that range of motion and muscle strength are precursors to both motor function and the ability to complete occupational performance tasks. The theory suggested that increases in range of motion and muscle strength result in an increase in motor performance and an increase in the ability to complete occupational performance tasks.
Research Hypothesis 2

Changes in the enabler skills of range of motion and muscle strength will result in similar changes in motor function and occupational performance.

The Experimental Treatment

The experimental treatment was a six staged occupational therapy program developed for rehabilitation of patients following surgery for carpal tunnel syndrome (Appendix A). The rehabilitation was provided through the satellite occupational therapy program of Borgess Medical Center, Kalamazoo, MI located at Kalamazoo Orthopedic Surgery, P.C., Kalamazoo, MI.

The treatment program included structured clinic sessions and a home exercise program. The treatment program was built upon the biomechanical approach to occupational performance theory. The treatment program was designed to facilitate increases in range of motion and muscle strength as enablers to motor coordination. Increased motor function should maximize the client's functioning in the occupational performance areas of work, self-maintenance, play, leisure, and rest. Clients progressed through the program at their own pace, advancing to the next stage after successfully meeting specific criteria. The occupational therapy treatment program has been provided to post-surgical carpal tunnel syndrome clients since 1987.

Dependent Variables

The dependent variables included: (a) range of motion of the involved hand, (b) muscle strength of the involved hand, (c) motor function, (d) occupational performance, (e) return to work rate, and (f) recidivism. The dependent variables were measured prior to surgery, three months post surgery, six months post surgery, and nine months post surgery.
Range of Motion

Range of motion was defined as active movement around the axis of a joint. Range of motion for the involved extremity was measured in degrees of movement through the use of a manual goniometer according to professional standards as described in Occupational Therapy for Physical Dysfunction (Trombly, 1983). Measures of range of motion included: (a) wrist flexion (Trombly, 1983, p. 144), see Figures 2 and 3; (b) wrist extension (Trombly, 1983, p. 145), see Figures 4 and 5; (c) ulnar deviation (Trombly, 1983, p. 146), see Figures 6 and 7; (d) radial deviation (Trombly, 1983, p. 147), see Figures 8 and 9; and (e) thumb opposition (Trombly, 1983, p. 156). Thumb opposition was the ability to touch the base of the the fifth digit with the distal tip of the the thumb and was recorded as within normal limits (WNL). The inability to touch the base of the fifth digit was recorded as not within normal limits (NWNL).

Figure 2. Wrist Flexion: Starting Position (from Trombly, 1983, p. 144).
Figure 3. Wrist Flexion: Ending Position (from Trombly, 1983, p. 144).

Figure 4. Wrist Extension: Starting Position (from Trombly, 1983, p. 145).

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Figure 5. Wrist Extension: Ending Position (from Trombly, 1983, p. 145).

Figure 6. Ulnar Deviation: Starting Position (from Trombly, 1983, p. 146).
Figure 7. Ulnar Deviation: Ending Position (from Trombly, 1983, p. 146).

Figure 8. Radial Deviation: Starting Position (from Trombly, 1983, p. 147).

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Figure 9. Radial Deviation: Ending Position (from Trombly, 1983, p. 147).

Muscle Strength

Muscle strength was the force produced by voluntary muscle contraction. Muscle strength for the involved extremity was measured in pounds of force produced through the contraction as measured on a dynamometer or pinch meter as described in *Occupational Therapy for Physical Dysfunction* (Trombly, 1983, pp. 226-227). Measures of muscle strength included lateral pinch, Figure 10; 3-jaw pinch, Figure 11; and gross grasp, Figure 12.

Figure 11. 3-Jaw Pinch: Manual Measurement (from Trombly, 1983, p. 227).
Motor Function

Motor function was the gross and fine motor coordination of the arm, hand, and fingers or hand dexterity. Motor function was measured on the Purdue Pegboard (Tiffin & Asher, 1948) using the subtest scores of right + left + both and assembly.

The Instructions and Normative Data for Model 32020 Purdue Pegboard Lafayette Instrument Company (1982) states that "Two types of activity are measured, one involving gross movement of the hands, fingers, and arms and the other involving fingertip dexterity" (p. 2). The Purdue Pegboard provides five separate sets of scores of including: (1) right hand, (2) left hand, (3) both hands, (4) right + left + both, and (5) assembly. The right hand score and left hand scores should have been most affected by involved hand differences caused by the non-random selection procedure. Therefore, only the right + left + both score and the assembly score were used in making the comparisons.
The Purdue Pegboard was originally normed for males and females. "The male norm group was composed of 865 industrial applicants, 481 college men, and 1958 veterans. The female norm group was composed of 4138 industrial applicants and 392 college women" (Lafayette Instrument Company, 1982, p. 8). Additionally, "Means and standard deviations on the 5 categories were gathered from 340 candidates for vocational rehabilitation ranging in age from 16 to 58 by Hamm and Curtis in 1980. The means fell significantly (p less than .05) below the means of the original norms" (Lafayette Instrument Company, 1982, p. 5).

Validity studies were reported in the instrument manual as:

Two trial intercorrelation scores for 760 airmen were gathered by Fleshman and Ellison (1962). Although low enough to warrant the use of each sub-test as a potential predictor, the common factor called finger dexterity caused the authors to conclude that each of the placement tests measured ability to make rapid, skillful, controlled manipulative movements of small objects where the fingers are primarily involved (Lafayette Instrument Company, 1982, p. 4).

The Purdue Pegboard was validated against a sample of 80 referred patients independently diagnosed by clinical neurological examination, electroencephalography, and radiographic procedures by Costa, et. al (1963). A cross validation sample was subsequently run on 65 consecutive admissions (Lafayette Instrument Company, 1982, p. 4).

Reliability studies were reported in the instrument manual as:

Test-retest reliabilities for single-trial scores recorded in the first edition of the Purdue Pegboard Manual ranged from .60 to .76. According to the Spearman-Brown formula, estimated reliabilities for the three trial scores range from .82 to .91 (Lafayette Instrument Company, 1982, p. 4).

**Occupational Performance**

Occupational performance was the ability to accomplish the tasks required by individual roles and is related to personal developmental stages. Occupational performance tasks included the categories of self-maintenance, work, leisure, play,
rest, and employment. The specific tasks related to each of the categories are different for each individual and each socio-economic group.

The professional standard for measurement of occupational performance has been self-report of the ability to complete tasks related to each of the categories. The literature revealed no formal or standardized evaluation form for measurement of occupational performance for individuals with lower motor neuron dysfunction. The Scales of Independent Behavior (Bruininks, Woodcock, Weatherman, & Hill, 1984) was a normed measure of enabler skills and the occupational performance. Unfortunately, the scale was constructed for use with central nervous system dysfunctions and was inappropriate for use with a lower motor neuron dysfunction, such as carpal tunnel syndrome. Therefore, a self-report measure of occupational performance was developed for use in the study. The Activities of Daily Living Form For Carpal Tunnel Syndrome (Appendix B) was constructed by the author to provide a self-reported measurement of occupational performance for lower motor neuron dysfunctions. The form provided a measure of the ability to complete the five categories of occupational performance tasks. The self-report was based upon a seven point Likert scale. The form was reviewed for content validity by an expert panel of occupational therapists. The form was pilot tested with twelve carpal tunnel syndrome clients for readability and scoring.

Return to Work Rate

The return to work rate was the number of weeks from the surgical procedure to the return to work date given by the physician on the return to work prescription. The return to work rate was reported as descriptive data.
Recidivism was reported as the proportion of subjects who experienced return of symptomology or decreases in the performance of occupational tasks, placed on medical leave, or required additional surgery.

Subjects and Sample Selection

Subjects

The subjects were employed adults who interrupted employment for carpal tunnel surgery. The diagnosis of carpal tunnel syndrome was made by the attending physician. The subjects included males and females from the Southwest Michigan geographic area.

Subject Selection

Potential subjects were identified from existing and incoming caseloads of Kalamazoo Orthopedic Surgery P.C., Kalamazoo, MI. Potential subjects were screened by the attending physicians for appropriateness for inclusion in the study. Subjects with secondary risk factors including arthritis, diabetes, or heart conditions were excluded from the study. Potential subjects were recruited for the study through the approved informed consent procedure (Appendix C).

Data Collection Instruments

Data were collected through the use of two data collection forms. The Data Collection Sheet (Appendix B) was used for recording data related to subject demographics, employment information, diagnosis, surgery date, and treatment outcome data. The treatment outcome data included range of motion, muscle testing,
and Purdue Pegboard scores. The Occupational Performance Scale for Carpal Tunnel Syndrome (Appendix B) was used for recording symptomology and occupational performance. The form included six sections. The first section provided a self-report on symptomology related to carpal tunnel syndrome through a seven point Likert scale, and a timeline for symptomology occurrence. The remaining five sections provided self-report on the ability to complete the occupational performance tasks of employment, work, self-maintenance, leisure, and rest on a seven point Likert scale with a timeline for task occurrence.

Human Subject Review

The research protocol and informed consent forms (Appendix C) were submitted for review and monitoring to the Human Subjects Institutional Review Board of Western Michigan University and the Human Research and Clinical Investigation Committee of Borgess Medical Center. The research protocol and informed consent forms received approval from both institutions.

General Research Procedures

Timelines

The study occurred from October 15, 1988 to April 15, 1990 with four data collection sessions scheduled for the subjects (Figure 1). Subjects were added to the study as they became available until the target number (20-30) was reached. The timeline allowed subjects to be added to the study from October 15, 1988 until August 1, 1989. All subjects were tested prior to surgery, three months post surgery, six months post surgery, and nine months post surgery.
A meeting between the investigator and the orthopedic physicians who identified potential subjects was scheduled. During that meeting, a letter from the investigator was provided to the physicians for distribution to potential subjects. The occupational therapist selected to calculate the subjects was oriented to the testing procedures and the data collection forms. The data collection forms were held separately from the client medical files, and the informed consent forms were held by the investigator.

Data Collection Procedures

The treatment outcome data were recorded during the four testing sessions for each subject. Each testing session required forty minutes. Data were collected prior to treatment, three months post treatment, six months post treatment, and nine months post treatment. The testing was completed by an experienced Certified Occupational Therapist. The data were recorded on the Data Collection Sheet and the Occupational Performance Scale for Carpal Tunnel Syndrome (Appendix B). These records were held separate from the medical records and coded by number only. Research testing was terminated at signs of fatigue, pain, or edema. The attending physician was notified when such symptomology was exhibited. Subjects were contacted as closely as possible to the three month, six month, and nine month post surgery dates. The testing occurred at Kalamazoo Orthopedic Surgery, P.C., Kalamazoo, MI.
Statistical Analysis

Definitions

Data were collected on a single sample of post-surgical carpal tunnel syndrome clients in a modified time-series design. The sample was selected from the clients of Kalamazoo Orthopedic Surgery, P.C., Kalamazoo, MI. Selection of subjects was not completed by random selection methods, but by self-selection through physician choice. The study included one observation prior to surgery and three observations after surgery.

The statistical methods used were appropriate for interval level data gathered in a repeated measurements design with a non-random, dependent sample.

Measurements as Interval Data

Data collected on the dependent variables fit the definition of interval data as provided by Hinkle, Wiersma, and Jurs (1979):

1. Data categories are mutually exclusive.
2. Data categories have a logical order.
3. Data categories are scaled according to the amount of the characteristic they possess.
4. Equal differences in the characteristic are represented by equal differences in the numbers assigned to the categories (Hinkle, Wiersma, & Jurs, 1979, p. 8).

Statistical Analysis of Dependent Samples

The use of statistical analysis for measurements from dependent samples was addressed by Hinkle, Wiersma, and Jurs (1979):

One of the assumptions made in true experimental design is that through the random assignment of the subjects to the two conditions, the two groups are equivalent at the beginning of the experiment (independent). An alternative procedure would be to have the subjects act as their own controls, and to study them under both treatment conditions. If the control situation is the absence of any kind of
treatment, all of the subjects are pretested to provide data for the control condition. Then all subjects are tested after the administering of the experimental treatment. Such data are correlated data since, in the repeated measures approach, a subject scoring high under one condition would tend to score relatively high under the second condition as well. That is the scores for each subject are not independent. The scores under one condition are dependent upon the scores in the other condition. Thus we have dependent samples for testing the hypothesis (Hinkle, Wiersma, & Jurs, 1979, pp. 211-212).

Statistical Analysis of Non-Random Samples

The statistical analysis of measurements from non-random samples was appropriate as described by Hinkle, Wiersma, and Jurs (1979).

We have stated that the logic of inferential statistics involves selecting a random sample from the population, taking measurement on that sample, and then, by using probability theory drawing inferences about the population.

However, it is often difficult to select a random sample of subjects for participation or assignment. In these situations, statistical inferences can be used to compare the results of groups receiving different experimental treatments. The extent to which the results generalize to populations depends on a logical analysis (Hinkle, Wiersma, & Jurs, 1979, pp. 199-200).

The discussion supported the use of statistical analysis of measurements from non-random samples for determining differences.

Time-Series Design

The study followed a modified time-series design as described by Borg and Gall (1979):

In the time-series design a single group of subjects is measured at periodic intervals. The experimental treatment is administered between two of these time intervals. The effect of the experimental treatment, if any, is indicated by a discrepancy in the measurements before and after its appearance. The use of additional measurements makes the time-series design more powerful than the pretest-posttest design. The time-series design is quite useful when forming a control group is not feasible and when subjects can be measured periodically with the same instrument. It seems particularly appropriate for field research.
Unlike other experimental designs, the time-series design does not yield data that are amenable to straightforward statistical analysis. The proper analysis of time-series data depends on the particular pattern of findings obtained. Generally, analysis of variance or a trend analysis is used to determine the statistical significance of time-series data (Borg & Gall, 1979, pp. 562-564).

A descriptive analysis of the collected data was completed through graphs of the mean scores for each treatment outcome. The descriptive analysis determined the pattern of findings. The descriptive analysis included the assumption that the symptomologies increased, over time, prior to surgery. The assumption provides that if additional observations were made prior to treatment, the measurements would demonstrate a downward slope. The descriptive analysis was followed by an ANOVA, if appropriate to the pattern of findings.

Assumptions Underlying the Analysis of Variance

Hinkle, Wiersma, and Jurs (1979) described the assumptions underlying the analysis of variance as:

1. The observations are random and independent samples from the populations.
2. Measurement of the dependent variable is at least an interval scale.
3. The populations from which the samples are selected are normally distributed.
4. The variances of the populations are equal (Hinkle, Wiersma, & Jurs, 1979, pp. 260-261).

The authors described the consequence of violating the assumptions as “ANOVA is robust with respect to the violations of the assumptions except in the case of unequal variances with unequal sample sizes” (Hinkle, Wiersma, & Jurs, 1979, p. 262). The discussion supported the use of the ANOVA for the time-series design with dependent samples and interval data.
Analysis for Research Hypothesis 1

Null Hypothesis 1: No difference will be found when comparing the treatment outcomes, across time, for subjects with carpal tunnel syndrome who have received a staged occupational therapy rehabilitation program following surgery as measured by range of motion, muscle strength, motor performance, and occupational performance.

The data related to the research hypothesis were analyzed on the basis of a modified time-series quasi-experimental design. Measurements of the dependent variables were collected through the four scheduled observations (Figure 1). A descriptive analysis of the means for treatment outcomes was completed to determine the pattern of findings. A repeated measures ANOVA was completed if appropriate. The confidence interval for the ANOVA was set at .05. Trend analysis and Tukey post hoc multiple comparison were completed if the null was rejected.

Analysis for Research Hypothesis 2

Hypothesis 2: Changes in the enabler skills of range of motion and muscle strength will result in changes in motor function and occupational performance.

The biomechanical approach to the occupational performance treatment theory suggested that range of motion and muscle strength are precursors to both motor function and the ability to complete occupational performance tasks. The theory suggested that increases in range of motion and muscle strength would result in increases in motor performance and the ability to complete occupational performance tasks.
Descriptive Statistics

Descriptive statistics were used to summarize data for the demographic characteristics of gender, age, hand dominance, involved hand, job titles, availability of light duty, and return to work rates. Descriptive statistics were used to summarize symptomology, and recidivism rates. Relationships were sought between recidivism rates and demographic factors of gender, age, hand dominance, involved hand, and job title.
CHAPTER IV

DATA ANALYSIS AND FINDINGS

Data Collection Procedures

Data were collected on 31 subjects who had interrupted employment for carpal tunnel surgery. All subjects participated in an occupational therapy rehabilitation program following surgery. The study occurred from October 15, 1988 to April 15, 1990. The data were collected in a modified time-series design with equal intervals between the four measures (Figure 1) which were taken before surgery and 3 months, 6 months, and 9 months after surgery. The study provided data on the demographic characteristics of the subjects and on the dependent variables of range of motion, muscle strength, motor performance, occupational performance, return to work rates, and recidivism. The study was designed to document the long-term postsurgical recovery process for carpal tunnel syndrome and to test two research hypotheses: (1) A difference will be found when comparing outcomes, across time, for subjects with carpal tunnel syndrome who have received a staged occupational therapy rehabilitation program following surgery, and (2) Changes in the enabler skills of range of motion and muscle strength will result in changes in motor function and occupational performance. The data were entered and analyzed through the SPSS-X program on the VAX-VMS system of Western Michigan University.
Data Analysis

Research Hypothesis 1

Data on the dependent variables of range of motion, muscle strength, motor performance, and occupational performance were collected to address the research hypothesis: a difference will be found when comparing the outcomes, across time, for subjects with carpal tunnel syndrome who have received a staged occupational therapy rehabilitation program following surgery. Means for the dependent variables at each of the four test points were calculated and were summarized in Table 1. Line graphs of the means for each dependent variable were completed to determine the pattern of findings. A repeated measure ANOVA was completed on each of the dependent variables which demonstrated an appropriate pattern of findings. A confidence interval of .05 was set for the ANOVA to reject the null hypothesis. If the null hypotheses was rejected, a trend analysis was completed for the dependent variable. A Tukey Post Hoc analysis was then completed to determine where the differences occured for each dependent variable.

Range of Motion

Range of motion was measured in degrees of active motion for wrist flexion, wrist extension, ulnar deviation, and radial deviation. The means for range of motion were summarized in Table 1. Active range of motion increased for each test period for wrist flexion, ulnar deviation, and radial deviation. Wrist extension increased from the baseline to 3 months, then fell at 6 months, and rose again at 9 months.
# Table 1

Mean Performance Scores for Whole Group

<table>
<thead>
<tr>
<th>Performance</th>
<th>Baseline</th>
<th>3 Months</th>
<th>6 Months</th>
<th>9 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range of Motion (in degrees)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist flexion</td>
<td>60.45</td>
<td>64.07</td>
<td>66.67</td>
<td>67.41</td>
</tr>
<tr>
<td>Wrist extension</td>
<td>64.58</td>
<td>67.83</td>
<td>67.17</td>
<td>69.48</td>
</tr>
<tr>
<td>Ulnar deviation</td>
<td>40.97</td>
<td>46.17</td>
<td>48.67</td>
<td>50.00</td>
</tr>
<tr>
<td>Radial deviation</td>
<td>26.87</td>
<td>31.00</td>
<td>32.33</td>
<td>36.52</td>
</tr>
<tr>
<td><strong>Strength (in pounds)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross grasp</td>
<td>52.89</td>
<td>59.16</td>
<td>71.12</td>
<td>75.48</td>
</tr>
<tr>
<td>Lateral pinch</td>
<td>15.95</td>
<td>16.74</td>
<td>17.53</td>
<td>18.03</td>
</tr>
<tr>
<td>3 Jaw chuck</td>
<td>13.47</td>
<td>14.72</td>
<td>15.33</td>
<td>15.49</td>
</tr>
<tr>
<td><strong>Purdue peg board (#of pegs)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R+L+B assembly</td>
<td>36.59</td>
<td>38.97</td>
<td>40.03</td>
<td>40.07</td>
</tr>
<tr>
<td><strong>Occupational performance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>employment</td>
<td>3.32</td>
<td>5.21</td>
<td>5.46</td>
<td>6.06</td>
</tr>
<tr>
<td>work</td>
<td>4.48</td>
<td>5.52</td>
<td>6.16</td>
<td>6.32</td>
</tr>
<tr>
<td>self-care</td>
<td>5.06</td>
<td>6.45</td>
<td>6.42</td>
<td>6.39</td>
</tr>
<tr>
<td>leisure</td>
<td>3.61</td>
<td>5.64</td>
<td>6.27</td>
<td>6.39</td>
</tr>
<tr>
<td>rest</td>
<td>3.84</td>
<td>6.36</td>
<td>6.42</td>
<td>6.42</td>
</tr>
<tr>
<td><strong>Thumb opposition</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># within normal limits</td>
<td>27</td>
<td>25</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td># not within normal limits</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

**Wrist Flexion.** A line graph of the means for degrees of active wrist flexion at the baseline (60.45), 3 months (64.07), 6 months (66.67), and 9 months (67.41) was constructed. The line graph demonstrated a positive slope pattern (Figure 13). The pattern of findings warranted further analysis.
Figure 13. Graph of the Means for Wrist Flexion.

A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA were significant at a level of p<.003 and allowed for the rejection of the null hypothesis for wrist flexion (Table 2). As the null hypothesis was rejected, a trend analysis was completed. The trend analysis supported the presence of a linear relationship at the p<.003 level (Table 2). A Tukey post hoc analysis was completed and identified significant differences (p<.05) between the baseline and 6 month mean, and between the baseline and 9 month mean (Table 2).

The findings for wrist flexion demonstrated a positive slope to the line graph of outcomes. The findings supported the rejection of the null hypothesis for wrist extension. The trend analysis indicated a linear nature in the outcomes. Significant differences existed between the baseline and the 6 month mean, and the baseline and the 9 month mean.
Table 2
Summary of Data Analysis for Wrist Flexion

<table>
<thead>
<tr>
<th>ANOVA for Repeated Measures</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within</td>
<td>81</td>
<td>70.71</td>
<td>5.06</td>
<td>.003*</td>
</tr>
<tr>
<td>Trial</td>
<td>3</td>
<td>357.55</td>
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<td></td>
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</table>

<table>
<thead>
<tr>
<th>Trend Analysis</th>
<th>df (1,27)</th>
<th>df (3,81)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>df</td>
</tr>
<tr>
<td>Linear</td>
<td>930.86</td>
<td>88.85</td>
</tr>
<tr>
<td>Quadratic</td>
<td>128.57</td>
<td>97.96</td>
</tr>
<tr>
<td>Cubic</td>
<td>13.21</td>
<td>25.34</td>
</tr>
</tbody>
</table>

Tukey Post Hoc Analysis

<table>
<thead>
<tr>
<th>df (3,81)</th>
<th>B</th>
<th>3</th>
<th>6</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>3.62</td>
<td>6.22*</td>
<td>6.96*</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>-</td>
<td>2.60</td>
<td>3.34</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>.74</td>
</tr>
</tbody>
</table>

* Significant at the .05 level

**Wrist Extension**. A line graph of the means for degrees of active wrist flexion at the baseline (64.58), 3 months (67.83), 6 months (67.17), and 9 months (69.48) was constructed. The line graph demonstrated a positive slope with a slight decline between 3 and 6 months (Figure 14). The pattern of findings warranted further analysis.

A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA were significant at a level of p<.003 and allowed for the rejection of the null hypothesis for wrist extension (Table 3). As the null hypothesis was rejected, a trend analysis was completed. The trend analysis supported the presence of a linear relationship at the p<.004 level (Table 3). A Tukey post hoc
analysis was completed and identified significant differences ($p<.05$) between the baseline and 9 month mean for wrist extension (Table 3).

The findings for wrist extension demonstrated a positive slope to the line graph of outcomes with a slight decline between 3 and 6 months. The findings supported the rejection of the null hypothesis for wrist extension. The trend analysis indicated linear nature in the outcomes. Significant differences existed between the baseline and 9 month mean.

**Ulnar Deviation.** A line graph of the means for degrees of active ulnar deviation at the baseline (40.97), 3 months (46.17), 6 months (48.67), and 9 months (50.00) was constructed. The line graph demonstrated a positive slope (Figure 15). The pattern of findings warranted further analysis.

A repeated measure ANOVA was completed with a confidence interval of $.05$. The results of the ANOVA were significant at a level of $p<.000$ and allowed for the rejection of the null hypothesis for ulnar deviation (Table 4). As the null hypothesis was rejected, a trend analysis was completed. The trend analysis supported the presence of a linear relationship at the $p<.000$ level (Table 4). A Tukey post hoc analysis was completed and identified significant differences ($p<.05$) between the baseline and 3 month mean, the baseline and 6 month mean, and the baseline and 9 month mean (Table 4).

The findings for ulnar deviation demonstrated a positive slope to the line graph of outcomes. The findings supported the rejection of the null hypothesis for ulnar deviation. The trend analysis indicated a linear nature in the outcomes. Significant differences were identified between the baseline and 3 month mean, the baseline and 6 month mean, and the baseline and 9 month mean.
Radial Deviation. A line graph of the means for degrees of active radial deviation at the baseline (26.87), 3 months (31.00), 6 months (32.33), and 9 months (36.52) was constructed. The line graph demonstrated a positive slope (Figure 16). The pattern of findings warranted further analysis.

A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA were significant at a level of p<.000 and allowed for the rejection of the null hypothesis for radial deviation (Table 5). As the null hypothesis was rejected, a trend analysis was completed. The trend analysis supported the presence of both a linear relationship at the p<.004 level and a quadratic relationship at the p<.000 level (Table 5). A Tukey post hoc analysis was completed and identified significant differences (p<.05) between the baseline and 3 month mean, the baseline and 6 month mean, the baseline and 9 month mean, the 3 month and 9 month mean, and between the 6 month and 9 month mean (Table 5).
Table 3
Summary of Data Analysis for Wrist Extension

ANOVA for Repeated Measures

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within</td>
<td>81</td>
<td>36.94</td>
<td>5.60</td>
<td>.002*</td>
</tr>
<tr>
<td>Trial</td>
<td>3</td>
<td>206.88</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Trend Analysis

<table>
<thead>
<tr>
<th></th>
<th>df (1,27)</th>
<th>MS_H</th>
<th>MSE</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td></td>
<td>471.78</td>
<td>47.00</td>
<td>10.04</td>
<td>.004*</td>
</tr>
<tr>
<td>Quadratic</td>
<td></td>
<td>85.75</td>
<td>44.04</td>
<td>1.95</td>
<td>.174</td>
</tr>
<tr>
<td>Cubic</td>
<td></td>
<td>63.11</td>
<td>19.74</td>
<td>3.19</td>
<td>.085</td>
</tr>
</tbody>
</table>

* p<.05

Tukey Post Hoc Analysis

<table>
<thead>
<tr>
<th></th>
<th>df (3,81)</th>
<th>cv (.05) = 4.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>3.25</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*p<.05

* Significant at the .05 level

The findings for radial deviation demonstrated a positive slope to the line graph of outcomes. The findings supported the rejection of the null hypothesis for radial deviation. The trend analysis indicated both a linear and quadratic nature in the outcomes. Significant differences existed between the baseline and 3 month mean, the baseline and 6 month mean, the baseline and 9 month mean, the 3 month and 9 month mean, and between the 6 month and 9 month mean.

**Thumb Opposition.** Thumb opposition was measured in a dicotomy of "within normal limits" or "not within normal limits." A bar graph of the outcomes was completed (Figure 17). At the baseline, 27 subjects were "within normal limits"
and 4 were "not within normal limits." The number of subjects "within normal limits" decreased to 25 at three months. One subject experienced too much pain to attempt the test. The number of subjects "within normal limits" increased to 28 at six months. At 9 months, only one subject was "not within normal limits." The results made further analysis inappropriate. The data supported the finding that a proportion of the subjects had decreases in thumb opposition due to carpal tunnel syndrome, and that most subjects returned to within normal limits at 6 months post-surgery.

**Muscle Strength**

Strength was measured in pounds for gross grasp, lateral pinch, and 3-jaw pinch. The means for gross grasp, lateral pinch, and 3-jaw pinch increased for all measures from the baseline through 9 months. The means for gross grasp increased from 52.89 pounds at the baseline to 75.48 pounds at 9 months. The largest increase (11.96 pounds) occurred between 3 and 6 months. Lateral pinch strength and 3-jaw pinch strength increased through each testing, although by less than one pound per testing period.

**Gross Grasp.** A line graph of the means for pounds of gross grasp at the baseline (52.89), 3 months (59.16), 6 months (71.12), and 9 months (75.48) was constructed. The line graph demonstrated a positive slope (Figure 18). The pattern of findings warranted further analysis.

A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA were significant at a level of $p<.000$ and allowed for the rejection of the null hypothesis for gross grasp (Table 6). As the null hypothesis was rejected, a trend analysis was completed. The trend analysis supported the presence of both a linear relationship and a cubic relationship (Table 6). A Tukey post hoc
analysis was completed and identified significant differences (p<.05) between the baseline and 6 month mean, the baseline and 9 month mean, the 3 month and 6 month mean, and the 3 month and 9 month mean (Table 6).

![Graph of the Means for Ulnar Deviation.](image)

**Figure 15.** Graph of the Means for Ulnar Deviation.

The findings for gross grasp demonstrated a positive slope to the line graph of outcomes. The findings supported the rejection of the null hypothesis for gross grasp. The trend analysis indicated both a linear and cubic nature in the outcomes. A Tukey post hoc analysis was completed and identified significant differences existed between the baseline and 6 month mean, the baseline and 9 month mean, the 3 month and 6 month mean, and the 3 month and 9 month mean.

**Lateral Pinch.** A line graph of the means for pounds of lateral pinch at the baseline (15.95), 3 months (16.74), 6 months (17.53), and 9 months (18.03) was constructed. The line graph demonstrated a positive slope (Figure 19). The pattern of findings warranted further analysis.
A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA approached the confidence level ($p<.055$), but did not meet the criterion for rejection of the null hypothesis (Table 7). As the null hypothesis was not rejected, no further analysis was completed for lateral pinch.

Table 4
Summary of Data Analysis for Ulnar Deviation

<table>
<thead>
<tr>
<th>ANOVA for Repeated Measures</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within</td>
<td>81</td>
<td>49.54</td>
<td>9.50</td>
<td>.000*</td>
</tr>
<tr>
<td>Trial</td>
<td>3</td>
<td>490.83</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trend Analysis df (1,27)</th>
<th>MSH</th>
<th>MSE</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>1260.00</td>
<td>40.93</td>
<td>30.79</td>
<td>.000*</td>
</tr>
<tr>
<td>Quadratic</td>
<td>150.89</td>
<td>87.00</td>
<td>1.73</td>
<td>.199</td>
</tr>
<tr>
<td>Cubic</td>
<td>1.61</td>
<td>20.68</td>
<td>.08</td>
<td>.783</td>
</tr>
</tbody>
</table>

* $p<.05$

Tukey Post Hoc Analysis df (3,81)

<table>
<thead>
<tr>
<th>B</th>
<th>3</th>
<th>6</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>5.20*</td>
<td>7.70*</td>
<td>9.03*</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>2.50</td>
<td>3.83</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
<td>1.33</td>
</tr>
</tbody>
</table>

* $p<.05$

The findings for lateral pinch demonstrated a positive slope to the line graph of outcomes. However, the null hypothesis could not be rejected for lateral pinch.
3-Jaw Pinch. A line graph of the means for pounds of 3-jaw pinch at the baseline (13.47), 3 months (14.72), 6 months (15.33), and 9 months (15.49) was completed and demonstrated a positive slope (Figure 20). The pattern of findings warranted further analysis.

A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA did not meet the criterion for rejection of the null hypothesis (Table 8). As the null hypothesis was not rejected, no further analysis for 3-jaw pinch was completed.

The findings for 3-jaw pinch demonstrated a positive slope to the line graph of outcomes. However, the null hypothesis could not be rejected for 3-jaw pinch.
Table 5

Summary of Data Analysis For Radial Deviation

<table>
<thead>
<tr>
<th>ANOVA for Repeated Measures</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial</td>
<td>81</td>
<td>26.88</td>
<td>9.28</td>
<td>.000*</td>
</tr>
</tbody>
</table>

| Trend Analysis              | df (1,27) | MSH | MSE | F   | p   |
|-----------------------------|           |     |     |     |     |
| Linear                      | 321.03     | 32.57 | 9.86 | .004* |
| Quadratic                   | 424.32     | 27.01 | 15.71 | .000* |
| Cubic                       | 3.15       | 21.06 | .15  | .702 |

| *p<.05                      |           |     |     |     |     |

| Tukey Post Hoc Analysis     | df (3,81) | cv (.05) = 3.63 |     |     |     |
|-----------------------------|           |                  |     |     |     |
| B                           | 3          | 6                | 9   |     |     |
| 3                           | -          | 4.13*            | 5.46* | 9.65* |
| 6                           | -          | -                | 1.33 | 5.52* |
| 9                           | -          | -                | -    | 4.19* |

| *p<.05                      |           |     |     |     |     |

* Significant at the .05 level

Motor Performance

The Purdue Peg Board (Tiffen & Asher, 1948) was used to measure motor performance. The results are given in the number of pegs placed over time. To eliminate subject differences between hand dominance and the involved hand, only the Right+Left+Both and the Assembly scores were used for analysis. The means for the group increased in both scores for each period from the baseline through 9 months.
Right+Left+Both. A line graph of the mean number of pegs placed for the Right+Left+Both subtest of the Purdue Peg Board at the baseline (36.59), 3 months (38.97), 6 months (40.03), 9 months (40.07) was completed. The line graph demonstrated a positive slope followed by a leveling off (Figure 21). The pattern of findings warranted further analysis.

![Graph of Thumb Opposition](image)

Figure 17. Graph of Thumb Opposition.

A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA were significant at a level of p<.000 and allowed for the rejection of the null hypothesis for Right+Left+Both (Table 9). As the null hypothesis was rejected, a trend analysis was completed. The trend analysis (Table 9) supported the presence of both a linear (p<.000) and a quadratic trend (p<.018). A Tukey post hoc analysis was completed and identified significant differences (p<.05) between the baseline and 3 month mean, baseline and 6 month mean, and baseline and 9 month mean (Table 9).
Figure 18. Graph of the Means for Gross Grasp.

Table 6
Summary of Data Analysis for Gross Grasp

<table>
<thead>
<tr>
<th>ANOVA for Repeated Measures</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
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</thead>
<tbody>
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<td>Within</td>
<td>81</td>
<td>203.79</td>
<td>15.43</td>
<td>.000*</td>
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<tr>
<td>Trial</td>
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<td>3145.02</td>
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</table>

Trend Analysis
df (1,27)

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<th>p</th>
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<tr>
<td>Linear</td>
<td>8718.45</td>
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<td>34.83</td>
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<tr>
<td>Quadratic</td>
<td>3.79</td>
<td>238.75</td>
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<td>.901</td>
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<tr>
<td>Cubic</td>
<td>712.81</td>
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*p<.05

Tukey Post Hoc Analysis
df (3,81)
cv (.05) = 9.98

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<td>6.27</td>
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<td>-</td>
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<td>16.32*</td>
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<td>-</td>
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</table>

*p<.05

* Significant at the .05 level

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Figure 19. Graph of the Means for Lateral Pinch.

Table 7

Summary of Data Analysis for Lateral Pinch

<table>
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<th>ANOVA for Repeated Measures</th>
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<tr>
<td>Trial</td>
<td>3</td>
<td>19.50</td>
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Figure 20. Graph of the Means for 3-Jaw Pinch.
The findings for assembly demonstrated a positive slope to the line graph of outcomes followed by a leveling off. The findings supported the rejection of the null hypothesis for assembly. The trend analysis indicated both a linear and quadratic nature in the outcomes. Significant differences in the means existed between the baseline and 3 month mean, the baseline and 6 month mean, and the baseline and 9 month mean.

**Assembly.** A line graph of the means for the number of pegs placed in the assembly subtest of the Purdue Peg Board at the baseline (32.59), 3 months (33.30),
6 months (34.50), and 9 months (36.93) was constructed. The line graph demonstrated a positive slope (Figure 22). The pattern of findings warranted further analysis.

Table 9
Summary of Data Analysis for Purdue Peg Board (R+L+B)

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<td>Within</td>
<td>81</td>
<td>9.15</td>
<td>12.34</td>
<td>.000*</td>
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<tr>
<td>Trial</td>
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<td></td>
</tr>
<tr>
<td><strong>Trend Analysis</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>df (1,27)</td>
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<td></td>
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<td>Linear</td>
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<td>16.41</td>
<td>18.16</td>
<td>.000*</td>
</tr>
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<td>Quadratic</td>
<td>43.75</td>
<td>6.90</td>
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<td>Cubic</td>
<td>.578</td>
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<td>.133</td>
<td>.71</td>
</tr>
<tr>
<td>*p&lt;.05</td>
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</tr>
</tbody>
</table>

Tukey Post Hoc Analysis

df (3,81)

cv (.05) = 2.16

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<tr>
<td>3</td>
<td>2.38*</td>
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<td>3.48*</td>
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<td>6</td>
<td>1.06</td>
<td>1.10</td>
<td>1.10</td>
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</table>

* Significant at the .05 level

A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA were significant at a level of p<.000 and supported the rejection of the null hypothesis for assembly (Table 10). As the null hypothesis was rejected, a trend analysis was completed. The trend analysis supported the presence of a linear relationship at the p<.000 level (Table 10). A Tukey post hoc analysis was
completed and identified significant differences (p<.05) between the baseline and 9 month mean, and between the 3 month and 9 month mean. (Table 10)

![Graph of the Means for Purdue Peg Board (Assembly).](image)

Figure 22. Graph of the Means for Purdue Peg Board (Assembly).

The findings for assembly demonstrated a positive slope to the line graph of outcomes. The findings supported the rejection of the null hypothesis for assembly. The trend analysis indicated a linear nature in the outcomes. Significant differences existed between the baseline and 9 month mean, and between the 3 month and 9 month mean.
Table 10

Summary Of Data Analysis For Purdue Peg Board (Assembly)

<table>
<thead>
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<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
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<td>Within</td>
<td>81</td>
<td>12.37</td>
<td>11.50</td>
<td>.000*</td>
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<tr>
<td>Trial</td>
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<td>142.24</td>
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<th>MSE</th>
<th>F</th>
<th>p</th>
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<tr>
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<td>32.45</td>
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<td>Quadratic</td>
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<td>32.14</td>
<td>13.42</td>
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<td>.133</td>
</tr>
<tr>
<td>Cubic</td>
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<td>3.46</td>
<td>11.63</td>
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<td>.590</td>
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<td>*p&lt;.05</td>
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</table>

<table>
<thead>
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<th>df (3,81)</th>
<th>CV (.05) = 2.46</th>
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<th>9</th>
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</thead>
<tbody>
<tr>
<td>B</td>
<td></td>
<td></td>
<td>-</td>
<td>.71</td>
<td>1.91</td>
<td>4.34*</td>
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<tr>
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<td>-</td>
<td>1.20</td>
<td>3.63*</td>
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<tr>
<td>6</td>
<td></td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>2.43</td>
</tr>
</tbody>
</table>

* Significant at the .05 level

**Occupational Performance**

Occupational performance was the ability of an individual to complete activities of daily life. The level of occupational performance was determined through self-report on a 7 point Likert Scale. The means for the group increased for all of the occupational performance areas from the baseline through 9 months with the exception of self-care which decreased slightly (.03) between 6 and 9 months and rest which maintained between 6 and 9 months. The greatest increases in the occupational performance scores occurred between the baseline and 3 months.
Employment. A line graph of the means for self reported level of symptomology while performing employment tasks at the baseline (3.32), 3 months (5.21), 6 months (5.46), and 9 months (6.06) was constructed. The line graph demonstrated a positive slope (Figure 23). The pattern of findings warranted further analysis.

A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA were significant at a level of p<.000 and supported the rejection of the null hypothesis for employment (Table 11). As the null hypothesis was rejected, a trend analysis was completed. The trend analysis supported the presence of a linear relationship (p<.000), a quadratic relationship (p<.009), and a cubic relationship (p<.041) (Table 11). A Tukey post hoc analysis was completed and identified significant differences (p<05) between the baseline and 3 month mean, the baseline and 6 month mean, and the baseline and 9 month mean (Table 11).

The findings for employment demonstrated a positive slope to the line graph of outcomes. The findings supported the rejection of the null hypothesis for employment. The trend analysis indicated a linear, a quadratic, and cubic nature in the outcomes. Significant differences existed between the baseline and 3 month mean, the baseline and 6 month mean, and the baseline and 9 month mean.

Work. A line graph for the means of self reported level of symptomology while performing work tasks at the baseline (4.48), 3 months (5.52), 6 months (6.16), and 9 months (6.32) was constructed. The line graph demonstrated a positive slope (Figure 24). The pattern of findings warranted further analysis.
Figure 23. Graph of the Means for Employment.

<table>
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<tr>
<th></th>
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<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANOVA for Repeated Measures</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Trial</td>
<td>90</td>
<td>3.12</td>
<td>12.78</td>
<td>.000*</td>
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<tr>
<td>Trend Analysis</td>
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<td></td>
</tr>
<tr>
<td>df (1,30) Linear</td>
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<td>3.81</td>
<td>22.98</td>
<td>.000*</td>
</tr>
<tr>
<td>Quadratic</td>
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<td>2.90</td>
<td>7.79</td>
<td>.009*</td>
</tr>
<tr>
<td>Cubic</td>
<td>3</td>
<td>3.46</td>
<td>4.57</td>
<td>.041*</td>
</tr>
<tr>
<td>*p&lt;.05</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tukey Post Hoc Analysis</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>df (3,81)</td>
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<td></td>
</tr>
<tr>
<td>cv (.05) = 1.17</td>
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<td>6</td>
<td>9</td>
</tr>
<tr>
<td>B</td>
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<td>2.74*</td>
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<td>.25</td>
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<tr>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>.60</td>
</tr>
</tbody>
</table>

*p<.05

* Significant at the .05 level

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA were significant at a level of p<.000 and supported the rejection of the null hypothesis for work (Table 12). As the null hypothesis was rejected, a trend analysis was completed. The trend analysis (Table 12) supported the presence of both a linear relationship (p<.000) and a quadratic relationship (p<.032). A Tukey post hoc analysis was completed and identified significant differences (p<.05) between the baseline and 3 month mean, the baseline and 6 month mean, and the baseline and 9 month mean (Table 12).

The findings for work demonstrated a positive slope to the line graph of outcomes. The findings supported the rejection of the null hypothesis for work. The trend analysis indicated both a linear and quadratic nature in the outcomes. Significant differences existed between the baseline and 3 month mean, the baseline and 6 month mean, and the baseline and 9 month mean.

Figure 24. Graph of the Means for Work.
Self-Care. A line graph of the means for self-care at the baseline (5.06), 3 months (6.45), 6 months (6.42), and 9 months (6.39) was constructed. The line graph demonstrated a positive slope followed by a slight decline (Figure 25). The pattern of findings warranted further analysis.

Table 12
Summary of Data Analysis for Work

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>df</td>
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<tr>
<td>-----</td>
</tr>
<tr>
<td>Within</td>
</tr>
<tr>
<td>Trial</td>
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</table>

<table>
<thead>
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</thead>
<tbody>
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</tr>
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<td>Linear</td>
</tr>
<tr>
<td>Quadratic</td>
</tr>
<tr>
<td>Cubic</td>
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*p<.05

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<td>df</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>Linear</td>
</tr>
<tr>
<td>Quadratic</td>
</tr>
<tr>
<td>Cubic</td>
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</table>

*p<.05

*p Significant at the .05 level

A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA were significant at a level of p<.000 and supported the rejection of the null hypothesis for self-care (Table 13). A trend analysis was completed (Table 13). The trend analysis supported the presence of both a linear
relationship (p<.006) and a quadratic relationship (p<.000). A Tukey post hoc analysis was completed and identified significant differences (p<.05) between the baseline and 3 month mean, the baseline and 6 month mean, and the baseline and 9 month mean (Table 13).

The findings for self-care demonstrated a positive slope to the line graph of outcomes followed by a slight decline. The findings supported the rejection of the null hypothesis for self-care. The trend analysis indicated both a linear and quadratic nature in the outcomes. Significant differences existed between the baseline and 3 month mean, the baseline and 6 month mean, and the baseline and 9 month mean.

Figure 25. Graph of the Means for Self-Care.

Leisure. A line graph of the means for leisure at the baseline (3.61), 3 months (5.64), 6 months (6.27), and 9 months (6.39) was constructed. The line graph demonstrated a positive slope (Figure 26). The pattern of findings warranted further analysis.
A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA were significant at a level of $p<.000$, and supported the rejection of the null hypothesis for leisure (Table 14). As the null hypothesis was rejected, a trend analysis was completed. The trend analysis (Table 14) supported the presence of both a linear relationship ($p<.000$) and a quadratic relationship ($p<.001$). A Tukey post hoc analysis was completed and identified significant differences ($p<.05$) between the baseline and 3 month mean, the baseline and 6 month mean, and the baseline and 9 month mean (Table 14).
The findings for leisure demonstrated a positive slope to the line graph of outcomes. The findings supported the rejection of the null hypothesis for leisure. The trend analysis indicated both a linear and quadratic nature in the outcomes. Significant differences existed between the baseline and 3 month mean, the baseline and 6 month mean, and the baseline and 9 month mean.

Figure 26. Graph of the Means for Leisure.

**Rest.** A line graph of the means for rest at the baseline (3.84), 3 months (6.36), 6 months (6.42), and 9 months (6.42) was constructed. The line graph demonstrated a positive slope followed by a leveling off (Figure 27). The pattern of findings warranted further analysis.
Table 14

Summary of Data Analysis for Leisure

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<td>2.13</td>
<td>23.77</td>
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<tr>
<td>Trial</td>
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Trend Analysis

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<th>MSE</th>
<th>F</th>
<th>p</th>
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<td>39.58</td>
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<td>1.86</td>
<td>14.57</td>
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<tr>
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* p<.05

Tukey Post Hoc Analysis

df (3,90)
cv (.05) = .97

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<td></td>
<td>-</td>
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<td>2.66*</td>
<td>2.78*</td>
</tr>
<tr>
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<td>.12</td>
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*p<.05

* Significant at the .05 level

A repeated measure ANOVA was completed with a confidence interval of .05. The results of the ANOVA were significant at a level of p<.000 and supported the rejection of the null hypothesis for rest (Table 15). As the null hypothesis was rejected, a trend analysis was completed. The trend analysis (Table 15) supported the presence of a linear relationship (p<.000), a quadratic relationship (p<.000), and a cubic relationship (p<.022). A Tukey post hoc analysis was completed and identified significant differences (p<.05) between the baseline and 3 month mean, the baseline and 6 month mean, and between the baseline and 9 month mean (Table 15).
Figure 27. Graph of the Means for Rest.

Table 15
Summary of Data Analysis for Rest

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<th>MS</th>
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<th>p</th>
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<td>24.44</td>
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<td>50.78</td>
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<td></td>
</tr>
<tr>
<td>Quadratic</td>
<td>49.06</td>
<td>1.64</td>
<td>42.13</td>
<td>.000*</td>
<td></td>
</tr>
<tr>
<td>Cubic</td>
<td>8.83</td>
<td>1.53</td>
<td>5.79</td>
<td>.022*</td>
<td></td>
</tr>
<tr>
<td>*p&lt;.05</td>
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<th>6</th>
<th>9</th>
</tr>
</thead>
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<td>-</td>
<td>2.52*</td>
<td>2.58*</td>
</tr>
<tr>
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<td>-</td>
<td>-</td>
<td>.06</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
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<td>-</td>
</tr>
</tbody>
</table>

*p<.05

* Significant at the .05 level

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The findings for rest demonstrated a positive slope to the line graph of outcomes followed by a leveling off. The findings supported the rejection of the null hypothesis for rest. The trend analysis indicated a linear, a quadratic, and a cubic nature in the outcomes. Significant differences existed between the baseline and 3 month mean, the baseline and 6 month mean, and between baseline and 9 month means.

**Descriptive Analysis of the Outcomes**

Descriptive statistics were gathered and summarized to provide additional information on the demographic characteristics of the group, return to work rates, symptomology, and recidivism.

**Demographic Characteristics**

Data on gender, age, hand dominance, involved hand, job title, and return to work rate were gathered on the group and summarized (Table 16). Comparisons of demographic characteristics were also made between gender and age. The data were dichotomized for analysis of age into "under 40" and "over 40."

The group of 31 included 13 males and 18 females. The mean age of the group was 41.94 years. The right hand was dominant for 29 of the subjects and the left hand was dominant for 2 subjects. The involved hand included 21 right hands with the remaining 10 being the left hand. The majority (17) of the subjects were industrial workers: 9 subjects were machine operators; 4 subjects were assemblers, and 4 subjects were general factory workers. Five of the subjects were clerical or cashiers and only 1 subject was managerial.

Comparison of the demographic data by gender found that there were only slight differences between the mean ages of males (42.2) and females (41.8). The
proportions for hand dominance were similar between males and females. Males
demonstrated a higher proportion of left hand involvement (46.1%) than did females
(22.2%). The majority of males held factory related jobs including machine operator
(7), maintenance (3), and general factory (2). The females held a variety of jobs with
assembler being the most frequent (4).

Comparison of the demographic data by age found that males and females
were nearly equally represented in both age groups. Subjects over 40 demonstrated a
higher proportion of left hand involvement (38.4%) than subjects under 40 (27.7%).
The majority of subjects under 40 held factory related jobs including machine
operator (8) and assembler (2). Subjects over 40 held a variety of jobs with cashier
and general factory jobs being the most frequent (3).

Return to Work Rate

The return to work rate was defined as the number of weeks from the date of
surgery to the date for return to work. The mean return to work rate for the group
was 12.63 weeks (Table 16). The range for return to work varied from two weeks
after surgery to one subject who had not returned to work by the end of the study.
The group return to work rate was bimodal with 5 subjects returning to work in 7
weeks and 5 subjects returning to work in 13 weeks. Four subjects (12.9%) returned
to light duty with the remaining subjects (87.1%) returning to regular work
assignments. Two subjects returned to work and then retired.

The return to work rate was lower for males (11.31 weeks) than females
(13.65 weeks). The lowest mean return to work rate was for subjects over 40 (11.08
weeks) with subjects under 40 having the highest rate (13.67 weeks).
### Table 16
Summary of Demographic Characteristics and Return to Work Rates

<table>
<thead>
<tr>
<th>Group</th>
<th>Gender</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>Number</td>
<td>31</td>
<td>13</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>male</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>female</td>
<td>18</td>
<td>--</td>
</tr>
<tr>
<td>Mean age</td>
<td>41.94</td>
<td>42.2</td>
</tr>
<tr>
<td>Dominant hand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>right</td>
<td>29</td>
<td>13</td>
</tr>
<tr>
<td>left</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Hand involved</td>
<td></td>
<td></td>
</tr>
<tr>
<td>right</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>left</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Job titles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>maintenance</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>machine operator</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>assembler</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>cashier</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>general factory</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>managerial</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>clerical</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>other</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Return to work rate</td>
<td>12.63</td>
<td>11.31</td>
</tr>
<tr>
<td>(in weeks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number not returning to work</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Number returned to light duty</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>
Symptomology

Symptoms experienced by subjects were identified through self-report on a Likert Scale. The scale ranged from 0 being “no symptoms present” to 7 being “high level of symptoms.” Subjects reported the presence of sharp pain, numbness, tingling, aching, swollen feeling, night pain, and need for additional medication. The data on symptomology was summarized (Table 17).

Table 17
Means for Self-Reported Symptomology*

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>3 months</th>
<th>6 months</th>
<th>9 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharp pain</td>
<td>3.13</td>
<td>0.87</td>
<td>0.55</td>
<td>0.04</td>
</tr>
<tr>
<td>Numbness</td>
<td>5.40</td>
<td>0.32</td>
<td>0.21</td>
<td>0.28</td>
</tr>
<tr>
<td>Tingling</td>
<td>4.97</td>
<td>0.45</td>
<td>0.31</td>
<td>0.48</td>
</tr>
<tr>
<td>Aching</td>
<td>5.53</td>
<td>1.39</td>
<td>1.41</td>
<td>1.14</td>
</tr>
<tr>
<td>Swollen feeling</td>
<td>3.87</td>
<td>0.77</td>
<td>1.10</td>
<td>1.07</td>
</tr>
<tr>
<td>Night pain</td>
<td>5.00</td>
<td>0.45</td>
<td>0.28</td>
<td>0.48</td>
</tr>
<tr>
<td>Need for additional</td>
<td>1.87</td>
<td>0.26</td>
<td>0.07</td>
<td>0.10</td>
</tr>
<tr>
<td>medication</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* (0 none - 7 high)

The baseline means ranged from a low of 1.87 for “needing additional medication” to a high of 5.53 for “aching feeling.” The baseline means indicated the presence of a substantial level of symptomology prior to surgery. The subjects reported reduced symptoms 3 months after surgery. The means ranged from 0.26 for “needing additional medication” to 1.39 for “aching feeling.” The decrease in symptomology was maintained at 6 month and 9 month testings with the exception of “swollen feeling” which increased slightly.
Recidivism was defined as the proportion of subjects who declined in performance measures. Recidivism rates were calculated between the baseline and 3 months, between 3 and 6 months, and between 6 and 9 months (Table 18).

The findings for recidivism indicated that a large proportion of recidivism occurred between the baseline and 3 months for radial deviation (41.9%), lateral pinch (48.4%), 3-jaw pinch (38.7%), and assembly (29%). These decreases in performance at 3 months may be attributed to the traumatic effects of the surgical process.

The findings also identified a high rate of recidivism between 6 and 9 months for wrist flexion (32.3%), wrist extension (32.3%), and gross grasp (29%). These findings could not be attributed to the effects of surgery and warranted further analysis for possible predictive characteristics. The demographic characteristics of gender, age, dominant hand, involved hand, and job title were selected as possible predictors of the recidivism found in wrist flexion, wrist extension, and gross grasp.

A chi-square analysis was completed to determine if gender or age were predictors for recidivism for wrist flexion (Table 19 for gender and Table 20 for age), wrist extension (Table 21 for gender and Table 22 for age), and gross grasp (Table 23 for gender and Table 24 for age). The expected frequencies for each cell were determined by the formula: \((\text{frequency in column})(\text{frequency in row}) + n\). The chi-square findings did not support gender or age as predictors of recidivism for wrist flexion, wrist extension, or gross grasp; as none of the characteristics generated a chi-square value that reached the critical value at the .05 level.
Table 18
Recidivism Rates

<table>
<thead>
<tr>
<th>Performance</th>
<th>Baseline-3months</th>
<th>3-6 months</th>
<th>6-9 months</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range of motion</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist flexion</td>
<td>2(6.5%)</td>
<td>1(3.2%)</td>
<td>10(32.3%)</td>
</tr>
<tr>
<td>Wrist extension</td>
<td>5(16.1%)</td>
<td>7(22.6%)</td>
<td>10(32.3%)</td>
</tr>
<tr>
<td>Ulnar deviation</td>
<td>5(16.1%)</td>
<td>7(22.6%)</td>
<td>8(25.8%)</td>
</tr>
<tr>
<td>Radial deviation</td>
<td>13(41.9%)</td>
<td>5(16.1%)</td>
<td>5(16.1%)</td>
</tr>
<tr>
<td>Thumb opposition</td>
<td>1(3.2%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Strength</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross grasp</td>
<td>5(16.1%)</td>
<td>2(6.6%)</td>
<td>9(29%)</td>
</tr>
<tr>
<td>Lateral pinch</td>
<td>15(48.4%)</td>
<td>5(16.1%)</td>
<td>7(22.6%)</td>
</tr>
<tr>
<td>3 jaw chuck</td>
<td>12(38.7%)</td>
<td>7(22.6%)</td>
<td>6(19.4%)</td>
</tr>
<tr>
<td><strong>Purdue peg board</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R+L+B</td>
<td>6(19.4%)</td>
<td>7(22.6%)</td>
<td>4(12.9%)</td>
</tr>
<tr>
<td>Assembly</td>
<td>9(29%)</td>
<td>8(25.6%)</td>
<td>4(12.9%)</td>
</tr>
<tr>
<td><strong>Occupational Performance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td>5(16.1%)</td>
<td>3(9.7%)</td>
<td>3(9.7%)</td>
</tr>
<tr>
<td>Work</td>
<td>2(6.5%)</td>
<td>3(9.7%)</td>
<td>4(12.9%)</td>
</tr>
<tr>
<td>Selfcare</td>
<td>3(9.7%)</td>
<td>3(9.7%)</td>
<td>1(3.2%)</td>
</tr>
<tr>
<td>Leisure</td>
<td>5(16.1%)</td>
<td>6(19.4%)</td>
<td>2(6.5%)</td>
</tr>
<tr>
<td>Rest</td>
<td>1(3.2%)</td>
<td>3(9.7%)</td>
<td>3(9.7%)</td>
</tr>
</tbody>
</table>

*remaining subjects maintained or increased in performance
Table 19
Comparison of Gender on Wrist Flexion Recidivism

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>O</th>
<th>E</th>
<th>O-E</th>
<th>(O-E)^2</th>
<th>(O-E)^2+E</th>
</tr>
</thead>
<tbody>
<tr>
<td>female increased</td>
<td>11</td>
<td>10.5</td>
<td>.5</td>
<td>.25</td>
<td>.024</td>
</tr>
<tr>
<td>female decreased</td>
<td>5</td>
<td>5.5</td>
<td>-.5</td>
<td>.25</td>
<td>.045</td>
</tr>
<tr>
<td>male increased</td>
<td>8</td>
<td>8.5</td>
<td>-.5</td>
<td>.25</td>
<td>.029</td>
</tr>
<tr>
<td>male decreased</td>
<td>5</td>
<td>4.5</td>
<td>.5</td>
<td>.25</td>
<td>.056</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>29</td>
<td>0.0</td>
<td></td>
<td>.154</td>
</tr>
</tbody>
</table>

cv (.05) = 7.815

Table 20
Comparison of Age on Wrist Flexion Recidivism

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>O</th>
<th>E</th>
<th>O-E</th>
<th>(O-E)^2</th>
<th>(O-E)^2+E</th>
</tr>
</thead>
<tbody>
<tr>
<td>under 40 inc.</td>
<td>11</td>
<td>10.5</td>
<td>.5</td>
<td>.25</td>
<td>.024</td>
</tr>
<tr>
<td>under 40 dec.</td>
<td>5</td>
<td>5.5</td>
<td>-.5</td>
<td>.25</td>
<td>.045</td>
</tr>
<tr>
<td>over 40 inc.</td>
<td>8</td>
<td>8.5</td>
<td>-.5</td>
<td>.25</td>
<td>.029</td>
</tr>
<tr>
<td>over 40 dec.</td>
<td>5</td>
<td>4.5</td>
<td>.5</td>
<td>.25</td>
<td>.056</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>29</td>
<td>0.0</td>
<td></td>
<td>.154</td>
</tr>
</tbody>
</table>

cv (.05) = 7.815
Table 21
Comparison of Gender on Wrist Extension Recidivism

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>O</th>
<th>E</th>
<th>O-E</th>
<th>(O-E)^2</th>
<th>(O-E)^2+E</th>
</tr>
</thead>
<tbody>
<tr>
<td>female increased</td>
<td>11</td>
<td>10.5</td>
<td>.5</td>
<td>.25</td>
<td>.024</td>
</tr>
<tr>
<td>female decreased</td>
<td>5</td>
<td>5.5</td>
<td>-.5</td>
<td>.25</td>
<td>.045</td>
</tr>
<tr>
<td>male increased</td>
<td>8</td>
<td>8.5</td>
<td>-.5</td>
<td>.25</td>
<td>.029</td>
</tr>
<tr>
<td>male decreased</td>
<td>5</td>
<td>4.5</td>
<td>.5</td>
<td>.25</td>
<td>.056</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>29</td>
<td>0.0</td>
<td>.154</td>
<td></td>
</tr>
</tbody>
</table>

$cv (.05) = 7.815$

Table 22
Comparison of Age on Wrist Extension Recidivism

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>O</th>
<th>E</th>
<th>O-E</th>
<th>(O-E)^2</th>
<th>(O-E)^2+E</th>
</tr>
</thead>
<tbody>
<tr>
<td>under 40 inc.</td>
<td>11</td>
<td>10.5</td>
<td>.5</td>
<td>.25</td>
<td>.024</td>
</tr>
<tr>
<td>under 40 dec.</td>
<td>5</td>
<td>5.5</td>
<td>-.5</td>
<td>.25</td>
<td>.045</td>
</tr>
<tr>
<td>over 40 inc.</td>
<td>8</td>
<td>8.5</td>
<td>-.5</td>
<td>.25</td>
<td>.029</td>
</tr>
<tr>
<td>over 40 dec.</td>
<td>5</td>
<td>4.5</td>
<td>.5</td>
<td>.25</td>
<td>.056</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>29</td>
<td>0.0</td>
<td>.154</td>
<td></td>
</tr>
</tbody>
</table>

$cv (.05) = 7.815$
Table 23
Comparison of Gender on Gross Grasp Recidivism

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>O</th>
<th>E</th>
<th>O-E</th>
<th>(O-E)^2</th>
<th>(O-E)^2+E</th>
</tr>
</thead>
<tbody>
<tr>
<td>female increased</td>
<td>11</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>female decreased</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>male increased</td>
<td>8</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>male decreased</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>28</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

cv (.05) = 7.815

Table 24
Comparison of Age on Gross Grasp Recidivism

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>O</th>
<th>E</th>
<th>O-E</th>
<th>(O-E)^2</th>
<th>(O-E)^2+E</th>
</tr>
</thead>
<tbody>
<tr>
<td>under 40 inc.</td>
<td>9</td>
<td>11</td>
<td>-2</td>
<td>4</td>
<td>.364</td>
</tr>
<tr>
<td>under 40 dec.</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>.800</td>
</tr>
<tr>
<td>over 40 inc.</td>
<td>11</td>
<td>9</td>
<td>2</td>
<td>4</td>
<td>.444</td>
</tr>
<tr>
<td>over 40 dec.</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>29</td>
<td>0</td>
<td>2.608</td>
<td></td>
</tr>
</tbody>
</table>

cv (.05) = 7.815

A 4X6 contingency table for the frequency of recidivism for hand dominance and involved hand was constructed (Table 25). Row headings included: (a) RR (right hand dominant and right hand involved); (b) RL (right hand dominant and left hand involved); (c) LR (left hand dominant and right hand involved); and (d) LL (left hand dominant and right hand involved). Examination of the contingency table found a high proportion of recidivism for right hand dominant and right hand involved for wrist flexion (44.4%), wrist extension (38.8%), and gross grasp (38.8%). A chi-
square analysis was completed to determine if right hand dominance and involved hand were predictors of recidivism for wrist flexion (Table 26), wrist extension (Table 27), and gross grasp (Table 28). The results of the chi-square were not significant at the .05 level, and did not identify predictors of recidivism.

An 8X6 contingency table for the frequency of recidivism by job title was constructed (Table 29). The contingency table contained several empty cells, therefore a chi-square analysis was not completed. Examination of the contingency table found a high proportion of recidivism for machine operators in gross grasp (44.4%), assemblers in gross grasp (75%), and for “other” in wrist extension (80%). These findings indicate that machine operators and assemblers may experience disproportionate recidivism rates in gross grasp. While the recidivism rate for wrist extension was very high for “others,” this category of jobs contained one subject for 5 different job titles. Another finding was that only cashiers and clerical workers experienced no recidivism in wrist flexion, wrist extension, or gross grasp between 6 and 9 months.

Table 25
Frequency of Recidivism for Hand Dominance and Involved Hand

<table>
<thead>
<tr>
<th></th>
<th>Wrist Flexion</th>
<th></th>
<th>Wrist Extension</th>
<th></th>
<th>Gross Grasp</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR</td>
<td>10</td>
<td>8</td>
<td>11</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>RL</td>
<td>7</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>LR</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LL</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>1</td>
</tr>
</tbody>
</table>
### Table 26
Comparison of Hand Dominance and Involved Hand on Wrist Flexion Recidivism

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>O</th>
<th>E</th>
<th>O-E</th>
<th>(O-E)^2</th>
<th>(O-E)^2+E</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR increase</td>
<td>10</td>
<td>12</td>
<td>-2</td>
<td>4</td>
<td>.333</td>
</tr>
<tr>
<td>RR decrease</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>.666</td>
</tr>
<tr>
<td>RL increase</td>
<td>7</td>
<td>6</td>
<td>-1</td>
<td>1</td>
<td>.167</td>
</tr>
<tr>
<td>RL decrease</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>.333</td>
</tr>
</tbody>
</table>

Total: 27 27 0 1.489

cv (.05) = 7.815

### Table 27
Comparison of Hand Dominance and Involved Hand on Wrist Extension Recidivism

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>O</th>
<th>E</th>
<th>O-E</th>
<th>(O-E)^2</th>
<th>(O-E)^2+E</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR increase</td>
<td>11</td>
<td>10.7</td>
<td>.3</td>
<td>.09</td>
<td>.008</td>
</tr>
<tr>
<td>RR decrease</td>
<td>7</td>
<td>7.3</td>
<td>-.3</td>
<td>.09</td>
<td>.012</td>
</tr>
<tr>
<td>RL increase</td>
<td>6</td>
<td>5.7</td>
<td>.3</td>
<td>.09</td>
<td>.016</td>
</tr>
<tr>
<td>RL decrease</td>
<td>3</td>
<td>3.3</td>
<td>-.3</td>
<td>.09</td>
<td>.027</td>
</tr>
</tbody>
</table>

Total: 27 27 0.0 .063

cv (.05) = 7.815

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Table 28
Comparison of Hand Dominance and Involved Hand on Gross Grasp Recidivism

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>O</th>
<th>E</th>
<th>O-E</th>
<th>(O-E)^2</th>
<th>(O-E)^2×E</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR increase</td>
<td>11</td>
<td>12</td>
<td>-1</td>
<td>1</td>
<td>0.083</td>
</tr>
<tr>
<td>RR decrease</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>0.167</td>
</tr>
<tr>
<td>RL increase</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>0.667</td>
</tr>
<tr>
<td>RL decrease</td>
<td>1</td>
<td>2</td>
<td>-2</td>
<td>4</td>
<td>1.333</td>
</tr>
</tbody>
</table>

\[cv (.05) = 7.815\]

Table 29
The Frequency of Recidivism by Job Title

<table>
<thead>
<tr>
<th></th>
<th>Wrist Flexion</th>
<th>Wrist Extension</th>
<th>Gross Grasp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Machine Oper.</td>
<td>7</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Assembler</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Cashier</td>
<td>3</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Gen. Factory</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Managerial</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Clerical</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Research Hypothesis 2

The second research hypothesis stated that changes in the enabler skills of range of motion and muscle strength will result in changes in motor function and occupational performance.

The occupational therapy rehabilitation program was established on the bio-mechanical treatment theory. The bio-mechanical treatment theory supports the
premise that range of motion and muscle strength are enabler skills. The enabler skills are precursors to coordinated muscle function and occupational performance. The hypothesis would be supported if changes in the enabler skills resulted in similar changes in coordinated motor function and occupational performance.

**Outcomes Over Time**

Examination of the means for the outcome measures for the dependent variables indicated that increases in range of motion and muscle strength occurred from the baseline through 9 months post-surgery. The increases in the enabler skills were accompanied by increases in motor function and occupational performance from the baseline through 9 months post-surgery. The pattern of outcomes provided logical support for the hypothesis.

**Graphic Analysis of Outcomes**

Line graphs of the outcomes for the dependent variables were constructed. The line graphs for all of the dependent variables demonstrated a positive slope for the outcomes. The pattern of results indicated that increases in range of motion and muscle strength were accompanied by increases in motor performance and occupational performance. The line graphs of the outcomes for the dependent variables provided logical support for the research hypothesis.

**Repeated Measure ANOVA**

A repeated measure ANOVA was completed for all of the dependent variables except thumb opposition. Significant differences (p<.05) occurred in the range of motion enablers of wrist flexion, wrist extension, ulnar deviation, and radial deviation; and the muscle strength enabler of gross grasp. Significant differences
also occurred in both tests of motor performance (R+L+B and assembly) and in all of
the occupational performance tasks (employment, work, self-care, leisure, and rest).
These findings provided support for the hypothesis.

The repeated measure ANOVA did not reach a level of significant difference
for lateral pinch and 3 jaw pinch. These findings did not provide support for the
hypothesis.

**Trend Analysis**

A trend analysis was completed for each dependent variable which had
significant differences in the repeated measure ANOVA. The results of the trend
analysis indicated that a linear relationship (p<.05) existed in the outcomes for the
enabler skills (wrist flexion, wrist extension, ulnar deviation, radial deviation, and
gross grasp); the motor function measures (right+left+both and assembly); and
occupational performance tasks (employment, work, self-care, leisure, and rest).
These findings of linear relationships for the outcomes of enabler skills, motor
function, and occupational performance provided support for the hypothesis.

The trend analysis identified a quadratic relationship in the nature of the
outcomes for the motor function measure (right+left+both) and the occupational
performance tasks (employment, work, self-care, leisure, and rest). Radial deviation
was the only enabler skill for which the trend analysis identified a quadratic
relationship. The finding of the quadratic trends support the hypothesis for radial
deviation, but does not support the hypothesis for the remaining enabler skills and the
motor function of assembly.

The trend analysis identified cubic relationships for gross grasp, employment,
and rest. The finding of cubic trends indicates a decline for these measures, and may
predict recidivism.
Recidivism

A level of recidivism was identified for wrist flexion, wrist extension, and gross grasp between 6 and 9 months. The level of recidivism for these enabler skills was not accompanied by a similar rate of recidivism in motor function or occupational performance. These findings do not support the logic of the hypothesis. However, the length of the study may not have allowed a decline in motor function or occupational performance to become evident.

Summary

The hypothesis was supported through the pattern of findings for the outcome means and the line graphs of the outcomes. The hypothesis was supported by the pattern of results for the repeated measure ANOVA with the exception of lateral pinch and 3-jaw pinch. The trend analysis supported the hypothesis in positive linear relationships in the outcomes for the enabler skills, motor functions, and occupational performance tasks. The trend analysis did not support the hypothesis through the finding of quadratic relationships for only one enabler, but with quadratic relationship for right+left+both, employment, work, self-care, and leisure. The findings for recidivism did not support the hypothesis as recidivism occurred in wrist flexion, wrist extension, and gross grasp between 6 and 9 months, but was not accompanied by declines in motor function or occupational performance.
CHAPTER V

RESULTS AND RECOMMENDATIONS

Introduction

There has been considerable pressure upon the healthcare industry to identify effective treatments for carpal tunnel syndrome. Spence (1987) described these pressures by stating "the fiscal impact of hand and upper extremity injuries has drawn the attention of employers, safety officials, and insurers" (Spence, 1987, p. 1). Current treatment for carpal tunnel syndrome included physician directed primary care coupled with rehabilitation services. Occupational therapy treatment programs have been established to provide post-surgical rehabilitation for the carpal tunnel syndrome patient. A problem facing occupational therapy has been the lack of study of the effect of post-surgical rehabilitation services on carpal tunnel syndrome.

The literature review documented a definition of occupational therapy, described carpal tunnel syndrome, and documented the primary care treatment procedures currently utilized with carpal tunnel syndrome. The literature documented that outcomes for occupational therapy treatment include: (a) the measurement of active range of motion; (b) strength of the involved muscles; (c) coordination; and (d) the ability to perform the tasks of work, leisure, and self-care. The literature established a treatment theory for rehabilitation services provided by occupational therapy. The literature documented few program descriptions for occupational therapy treatment of carpal tunnel syndrome, documented few studies testing the biomechanical approach to occupational performance, and documented no studies
testing the effectiveness of occupational therapy treatment with carpal tunnel syndrome. Therefore, it was appropriate to study the effectiveness of an occupational therapy treatment program based upon the biomechanical approach to occupational performance on carpal tunnel syndrome.

A study was designed to collect data on the treatment outcomes for one group of carpal tunnel syndrome clients who had completed a post-surgical occupational therapy rehabilitation program. The study was designed to test two research hypotheses:

1. A difference will be found when comparing the outcomes, across time, for subjects with carpal tunnel syndrome who have received a staged occupational therapy rehabilitation program following surgery, and

2. Changes in the enabler skills of range of motion and muscle strength will result in changes in motor function and occupational performance.

Descriptive statistics were used to summarize demographic characteristics of gender, age, hand dominance, involved hand, job title, availability of light duty, return to work rate, symptomology, and recidivism.

Data were collected through a time-series design (Campbell & Stanley, 1966, p. 37; Kerlinger, 1973, p. 343). The design was modified from Borg and Gall (1979) and diagrammed in Figure 1. The data were collected in four stages with equal intervals which included: before surgery, 3 months, 6 months, and 9 months after surgery. Data were collected on 31 subjects who had interrupted employment for carpal tunnel surgery. All of the subjects participated in an occupational therapy rehabilitation program following surgery. The study occurred from October 15, 1988 to April 15, 1990. The data were entered and analyzed through the SPSS-X program on the VAX-VMS system of Western Michigan University.
Results for Research Hypothesis 1

Data on the dependent variables of range of motion, muscle strength, motor performance, and occupational performance were collected to address the research hypothesis: A difference will be found when comparing outcomes, across time, for subjects with carpal tunnel syndrome who have received a staged occupational therapy rehabilitation program following surgery.

Means for the dependent variables at each of the four test points were calculated and summarized. Line graphs of the means for each dependent variable were completed to determine the pattern of findings.

Visual analysis of the means (Table 1) identified increases in the means for all dependent variables between the baseline and 3 months, except thumb opposition which decreased. The means for all the dependent variables increased between 3 months and 6 months, except for wrist deviation and self-care which both decreased slightly. The means of all dependent variables increased between 6 and 9 months, except for self-care which decreased and rest which remained the same. Graphs of the means were constructed for all dependent variables. Analysis of the graphs demonstrated a continuous positive slope for wrist flexion, ulnar deviation, radial deviation, gross grasp, lateral pinch, 3-jaw pinch, assembly, employment, work, and leisure. The graphs demonstrated a positive slope followed by a leveling off, or stabilizing, for right+left+both and rest. Wrist extension demonstrated a positive slope followed by a slight decrease and then a positive slope. Thumb opposition demonstrated an initial negative slope, followed by a positive slope. The results of the graphing of the outcomes provided support for the positive effects of surgery and the rehabilitation program for this group. The results warranted further empirical analysis.
A repeated measure ANOVA was completed on each of the dependent variables which demonstrated an appropriate pattern of findings. A confidence interval of .05 was set for rejection of the null hypothesis. The outcomes supported the rejection of the null hypothesis ($p < .05$) for wrist flexion, wrist extension, ulnar deviation, radial deviation, gross grasp, right+left+both, assembly, employment, work, self-care, leisure, and rest. The results indicated that there were positive differences between the means for each of these dependent variables. The null hypothesis was not rejected for lateral pinch or 3-jaw pinch. While the graphs of the outcomes for both lateral pinch and 3-jaw pinch indicated a positive slope, the differences were not great enough to reject the null hypothesis. The empirical results of the repeated measure ANOVA indicated positive results for the use of surgery and the rehabilitation program on the dependent variables for which the null was rejected.

A trend analysis was completed for those dependent variables which supported the rejection of the null hypothesis. All of the dependent variables which were tested demonstrated a positive linear trend ($p < .05$). In addition to the linear trend, a quadratic trend was demonstrated for radial deviation, right+left+both, employment, work, self-care, leisure, and rest. A cubic trend was demonstrated for gross grasp, employment, and rest. These results support a positive linear effect for surgery and rehabilitation on the tested variables. The presence of a quadratic and cubic trend support either decreasing effects of the surgery and rehabilitation, over time; or initial effects of recidivism. Additional trend analysis study of a control group, and a longer term study of recidivism would provide additional information.

A Tukey post hoc analysis was completed to identify the differences for those dependent variables which supported the rejection of the null hypothesis. Differences occurred between the baseline and 3 months for ulnar deviation, radial deviation, employment, work, self-care, leisure, and rest. Differences occurred for these
dependent variables plus wrist flexion, gross grasp, and right+left+both occurred between the baseline and 6 months. Difference in the means between the baseline and 9 months occurred for all of the tested dependent variables. Gross grasp and assembly were the only variables which demonstrated a significant difference between 3 months and 6 month, and between 3 months and 9 months. No dependent variables demonstrated a significant difference between 6 months and 9 months. The post hoc results for this group support the positive effects of surgery and rehabilitation. The positive effects continued over nine months with wrist flexion, wrist extension, right+left+both, gross grasp, and assembly increasing to significant differences at six months post surgery. The results also indicated that the effects of surgery and rehabilitation, while positive, were not significant between the 3 months and 9 months except for gross grasp and assembly.

The study documented positive long term effect of surgery and the rehabilitation program on all of the dependent variables. Visual and graphic analysis of the outcomes supported the positive effect for all of the dependent variables. The repeated measure ANOVA supported the presence of differences in the outcomes for all of the dependent variables except thumb opposition, lateral pinch, and 3-jaw pinch. The continued use of surgery and the rehabilitation program was supported by the long term outcomes for this group. Descriptive support was gathered through the graphing of the outcomes. Empirical support was documented through the repeated measure ANOVA, trend analysis, and post hoc analysis. The outcomes lend support for the use of surgery and the rehabilitation program with this population. However, there remains a need for a longer term study with random assignment to treatment and control groups before empirical generalizations to the population can be made.
Results from the Descriptive Analysis of the Outcomes

Descriptive data were gathered and summarized to provide additional information on the demographic characteristics of the group, return to work rate, symptomology, and recidivism. Descriptive analysis was used to summarize the demographic characteristics of gender, age, hand dominance, involved hand, job titles, availability of light duty, return to work rate, symptomology and recidivism rate. Relationships were sought between recidivism rate and the demographic characteristics of gender, age, hand dominance, involved hand, and job title.

Data on gender, age, hand dominance, involved hand, job titles, and return to work rates were gathered on the group and summarized (Table 16). Comparisons of demographic characteristics were also made between gender and age (Table 16). The group of 31 included 13 males and 18 females. The mean age of the group was 41.94 years. The right hand was dominant for 29 of the subjects and the left hand for 2 subjects. The involved hand included 21 right hands with the remaining 10 being the left hand. The majority (17) of the subjects were industrial workers with 9 machine operators, 4 assemblers, and 4 general factory workers. Five of the subjects were clerical workers or cashiers, and only 1 subject was managerial.

Comparison of the demographic data by gender found only a slight difference between the mean ages of males (42.2) and females (41.8). Proportions for hand dominance were similar between males and females. Males demonstrated a higher proportion of left hand involvement (46.1%) than did females (22.2%). The majority of males held factory related jobs including machine operator (7), maintenance (3), and general factory (2). The females held a variety of jobs with assembler being the most frequent.

Comparison of the demographic data by age found that males and females were nearly equally represented in both age groups. The proportions for hand
dominance were similar between both age groups. Subjects over 40 demonstrated a higher proportion of left hand involvement (38.4%) than subjects under 40 (27.7%). The majority of subjects under 40 held factory related jobs including machine operator (8) and assembler (2). Subjects over 40 held a variety of jobs with cashier and general factory jobs being the most frequent (3).

The return to work rate was defined as the number of weeks from the date of surgery to the date that approval to return to work was given. The mean return to work rate for the group was 12.63 weeks (Table 16). Four subjects (12.9%) returned to light duty with the remaining subjects (87.1%) returning to regular work assignments. Two subjects returned to work and then retired. The return to work rate was lower for males (11.31 weeks) than females (13.65 weeks). The lowest mean return to work rate was for subjects over 40 (11.08 weeks) with subjects under 40 having the highest return to work rate (13.67 weeks).

Symptoms experienced by subjects were measured through self-report on a Likert Scale. The baseline means indicated the presence of a substantial level of symptomology prior to surgery. The subjects reported reduced symptoms 3 months after surgery. The decrease in symptomology was maintained at 6 month and 9 month testings with the exception of swollen feeling which increased slightly.

The findings for recidivism indicated that a large proportion of recidivism occurred between the baseline and 3 months for radial deviation (41.9%), lateral pinch (48.4%), 3-jaw pinch (38.7%), and assembly (29%). These decreases in performance at 3 months may be attributed to the traumatic effects of the surgical process. The findings also identified a high rate of recidivism between 6 and 9 months for wrist flexion (32.3%), wrist extension (32.3%), and gross grasp (29%). These findings could not be attributed to the effects of surgery and warranted further analysis for possible predictive characteristics.
The demographic characteristics of gender, age, dominant hand, involved hand, and job title were selected as possible predictors of the recidivism found in wrist flexion, wrist extension, and gross grasp. A chi-square analysis was completed to determine if gender or age were predictors of recidivism. The chi-square findings did not support (p<.05) gender or age as predictors of recidivism. Contingency tables for the frequency of recidivism by hand dominance, involved hand, and job title were constructed. The presence of empty data cells precluded chi-square analysis. Examination of the contingency table for hand dominance and involved hand found a high proportion of recidivism for right hand dominant and right hand involved for wrist flexion (44.4%), wrist extension (38.8%), and gross grasp (38.8%). Examination of the contingency table for job title found a high proportion of recidivism for machine operators in gross grasp (44.4%), assemblers in gross grasp (75%), and for other in wrist extension (80%). These findings indicated that machine operators and assemblers may experience disproportionate recidivism rates in gross grasp. Additionally, cashiers and clerical workers experienced no recidivism in wrist flexion, wrist extension, or gross grasp between 6 and 9 months.

Results for Research Hypothesis 2

Data on the dependent variables were collected to address the research hypothesis: Changes in the enabler skills of range of motion and muscle strength will result in changes in motor function and occupational performance. The hypothesis would be supported if changes in the enabler skills resulted in similar changes in coordinated motor function and occupational performance.

Examination of the means for the outcomes on the dependent variables indicated that increases in range of motion and muscle strength occurred from the baseline through 9 months post-surgery. The increases in the enabler skills were
accompanied by increases in motor function and occupational performance from the baseline through 9 months post-surgery. The pattern of outcomes provided logical support for the hypothesis.

The graphs of outcomes for the dependent variables demonstrated that increases in range of motion and muscle strength were accompanied by increases in motor performance and occupational performance. The graphs of the outcomes for the dependent variables provided support for the research hypothesis.

The result of the repeated measure ANOVA for the dependent variables supported the occurrence of differences (p<.05) in the range of motion enablers of wrist flexion, wrist extension, ulnar deviation, and radial deviation; the muscle strength enabler of gross grasp; the motor performance of R+L+B and assembly; and the occupational performance tasks of employment, work, self-care, leisure, and rest. These findings provided support for the hypothesis. The repeated measure ANOVA did not demonstrate differences for lateral pinch and 3-jaw pinch, and did not support the hypothesis.

A trend analysis was completed for each dependent variable which demonstrated differences through the repeated measure ANOVA. The results of the trend analysis indicated that a linear relationship (p<.05) existed in the outcomes for the enabler skills (wrist flexion, wrist extension, ulnar deviation, radial deviation, and gross grasp); the motor function measures (right+left+both and assembly); and occupational performance tasks (employment, work, self-care, leisure, and rest). The finding of a linear trend for the outcomes of enabler skills, motor function, and occupational performance provided support for the hypothesis.

The hypothesis was supported through the pattern of findings for the outcome means and the line graphs of the outcomes. The hypothesis was supported by the pattern of results for the repeated measure ANOVA with the exception of lateral pinch.
and 3-jaw pinch. The trend analysis supported the hypothesis through positive linear trends in all of the outcomes tested. The results of the study provided a level of logical support for the hypothesis and the premise that the enabler skills are precursors to occupational tasks. The results of the study supported the continued use of the rehabilitation program.

Limitations of the Study

The generalization of the results of the study are limited to the sample. This limitation was imposed by the lack of a control group and the lack of random assignment of subjects to control and treatment groups. The original design of the study did include a control group. That design was discontinued after a number of physicians within the geographic area declined participation in a control and treatment group design. The reluctance to participate in the study seemed to be founded on case-finding competition within the healthcare community. Random selection of subjects to control and rehabilitation treatment groups is an ethical issue and may not be overcome in future field studies.

The outcomes of the study were limited by the 9 month post-surgery design. The outcome data relative to trend analysis and recidivism indicated the appearance of quadratic and cubic trends in performance which warrant further study. Longer term study would provide additional information on trends and recidivism rates. This researcher found that participation of volunteer subjects was tenuous by 6 months. A design incorporating payment to subjects for participation may be successful in limiting mortality of subjects in future studies.
Recommendations for Future Research

Future research is needed to more fully document the long term effects of surgery and rehabilitation on carpal tunnel syndrome. Future studies should utilize an experimental research design and include random assignment of subjects to control and treatment groups. This design would increase the internal validity of the research findings. Future studies should compare the outcomes of orthopedic surgery techniques versus neurosurgery techniques.

Future studies should include data collection beyond 9 months. The results of this study indicate that future studies should be 18-24 months in duration. Studies of that length may provide additional information on outcome trends and recidivism. The prospects of subject mortality in studies of this length may be reduced by the use of payments to the subjects for participation.

Future studies should include data collection from several geographic locations. Such a design would increase the generalizability of outcomes to the population and decrease the effects of localized healthcare politics on the study.

Future studies should consider the substitution of the Minnesota Rate of Manipulation Test (American Guidance Services, 1969) for the Purdue Peg Board (Tiffen & Asher, 1948) as the measure of motor performance. The Purdue Peg Board was chosen for this study for its ability to test fine motor performance in a shortened period of time. While the outcomes for the Purdue provided significant data for the study, the test appeared to be too short in duration to elicit residual carpal tunnel syndrome symptomology. The use of a longer test may provide additional information on recidivism and motor performance outcomes.
Conclusions

The purpose of the study was to document the long term outcomes for patients with carpal tunnel syndrome who had received surgery and an occupational therapy rehabilitation program. The study sought efficacy for the continuation of the rehabilitation program with post-surgical carpal tunnel syndrome patients. The study also sought support for the bio-mechanical treatment theory.

The study documented positive long term outcomes of surgery and the rehabilitation program for a group of 31 subjects. Visual and graphic analysis of the outcomes supported the positive effects for all of the dependent variables. The empirical analysis supported the presence of differences in the outcomes for all of the dependent variables except thumb opposition, lateral pinch, and 3-jaw pinch. Descriptive data provided additional information on the demographic characteristics of the group, return to work rate, symptomology, and recidivism. The results of the study supported the continued use of surgery and the rehabilitation program. However, there remains a need for longer term study with random assignment to control and treatment groups to increase the generalizability of these findings.

The study supported the bio-mechanical treatment theory through the pattern of findings for the outcome means and the line graphs of the outcomes. The treatment theory was supported by the pattern of findings from the empirical analysis with the exception of lateral pinch and 3-jaw pinch. The treatment theory was supported through the positive linear trends in the outcomes for the enabler skills, motor functions, and occupational performance tasks. The outcomes of the study provided support for the premise that enabler skills are precursors to occupational performance tasks. The results of the study supported the continued use of the rehabilitation program.
Appendix A

An Occupational Therapy Treatment Program
for Post Surgery Carpal Tunnel Syndrome
An Occupational Therapy Treatment Program
for Post Surgery Carpal Tunnel Syndrome

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August, 1988
An Occupational Therapy Treatment Program
For Post-Surgery Carpal Tunnel Syndrome

Introduction

The occupational therapy treatment program is based upon the bio-mechanical approach to occupational performance. The bio-mechanical approach bases an individual's ability to perform work, self-care, and leisure activities on the integrity of the "enabling" components of sensory integrative functioning, motor functioning, social functioning, psychological functioning, and cognitive functioning. This treatment program is based upon the position that carpal tunnel syndrome effects the motor functioning enabler only. Therefore, the treatment program is designed to facilitate range of motion, muscle strength, motor endurance, and fine motor coordination for post-surgery carpal tunnel syndrome clients. The treatment is designed to increase motor function which will, in turn, maximize the client's functioning in the occupational performance areas of work, self-care, and leisure.

The six staged occupational therapy treatment program was developed for rehabilitation of patients following surgery for carpal tunnel syndrome. The program includes clinic treatment sessions and a home exercise program. Clients progress through the program at their own pace, advancing to the next stage upon successfully meeting criteria. The treatment program should be implemented by an experienced, Certified, Occupational Therapist (OTR). The program is designed to provide ongoing communication with the client, monitoring of client progress, maintenance of client motivation, early identification of potential problems, analysis of potential risks, and client education.
Criteria and Precautions

The client advances to the next treatment stage when five days have elapsed and the client can complete the activities in the current stage without the presence of sharp pain during exercise; pain which continues one hour past exercise; significant increases in numbness, tingling, aching, pain, and swollen feeling; pain which interferes with sleep; or the need for additional pain medication.

The Six Stages of Treatment

The descriptions of the six stages of treatment provide for a graded activity approach which each stage increasing in muscle strength and endurance. The client should not advance from one stage to the next until the criteria and precautions are met.

Stage One Treatment

The treatment goals for stage one include: the initiating of active range of motion, the reduction of edema, and desensitization of the incision site. This stage is initiated after surgery and before the client is seen by the therapist. The physician directs the client to complete the following activities at home, three times per day with no resistance:

1. Exercises out of water (1-5 repetitions).
2. Range of motion exercises for hand/wrist (1-5 repetitions).
3. Cold application. (10-15 minutes).
Stage Two Treatment

The treatment goals for stage two include: increasing active range of motion, reducing edema, and desensitization of the incision site. The exercises provide no resistance applied. The stage begins after the first treatment session with the therapist. The client is instructed to complete the following activities at home, three times per day, with no resistance:

1. Warm-up exercises in water (5-10 repetitions).
2. Pressure massage (to tolerance).
3. Exercises out of water (5-10 repetitions).
4. Contrast bath or ice application (10-15 minutes).

Stage Three Treatment

The treatment goals for stage three include: increasing tolerance to pressure, increasing strength, increasing endurance, increasing abilities for activities of daily living (ADL), and decreasing sensitivity of the incision site. The activities provide minimal resistance. The client is instructed to complete the following activities at home, three times per day, with minimal resistance.

1. Warm-up exercises in water.
2. Use foam hand exerciser or sponge for squeezing (10-15 repetitions).
3. Pressure massage (to tolerance).
4. Warm-up exercises out of water (#8, 9, 10, 11, 14). Add 1-1.5 pound weights (10-15 repetitions).
5. Putty exercises (5-10 repetitions) or rubber-band exercise (10 repetitions) with one rubber-band.
6. Contrast bath or ice application.
Stage Four Treatment

The treatment goals for stage four include: increasing strength, increasing active range of motion, increasing endurance, and increasing the ability to perform activities of daily living. The activities provide moderate resistance. The client is instructed to complete the following activities at home, three times per day, with moderate resistance:

1. Warm-up exercises in water, using foam sponge (more than 15 repetitions).
2. Pressure massage (to tolerance).
3. Exercises out of water, using 1.5-2 pound weights (15-20 repetitions).
4. Putty exercises (10 or more repetitions of 4-8 exercises).
5. Rubber-band exercise, using 2 rubber-bands (10 or more repetitions).
6. Contrast bath/ice application (as instructed).

Stage Five Treatment

The treatment goals for stage five include: increasing active range of motion, increasing strength, increasing endurance, increasing abilities to perform activities of daily living, and simulation of work requirements. The activities provide sub-maximal resistance. The client is instructed to complete the following activities at home, three times per day, with sub-maximal resistance:

1. Warm-up exercises.
2. Pressure massage.
3. Exercises out of water. Use of 2-3 pound weights (more than 20 repetitions).
4. Putty exercises. No limit on number of exercises (repetitions to fatigue).
5. Hand Helper with 2 or more rubber bands (repetitions to fatigue).
6. Contrast bath/ice application (if needed for relief).
Stage Six Treatment

The goal for stage six is to increase strength and endurance to levels required for work through the use of the Baltimore Therapeutic Equipment (B.T.E.) Work Simulator during clinic treatment sessions. The client will move to stage six during these additional treatment sessions while they are also working on stage five goals at home. The use of the Baltimore Therapeutic Equipment (B.T.E.) Work Simulator allows for the control of resistance to motions made during the use of tools which represent components of work.

Clinic Treatment Sessions

The occupational therapy treatment program begins with the referral from the participating physician. The client is initially seen by the occupational therapist 5-7 days post-surgery, after removal of surgical stitches. The client is seen until return to work. The number of times the client is seen for treatment varies upon individual differences in recovery.

Initial Treatment Session

During the initial therapy session, an evaluation is completed which includes: range of motion of the affected extremity, edema measurements of the hand, sensory exam of the hand, activities of daily living evaluation, and job identification. This information should be included in the treatment records. There is no evaluation of resistive muscle strength during the initial evaluation.

The client receives the treatment protocol for the staged rehabilitation program. The program is explained to the client by the therapist. Particular attention is given to an explanation of the effects of carpal tunnel syndrome on the client's daily functioning, the effects of the surgical procedures performed, the goals for the
treatment, and treatment precautions. The therapist instructs the client in those procedures which they will be completing at home including: edema control, pressure massages, ice packs, and contrast baths.

The therapist observes the hand, wrist, and forearm while moving through gentle active range of motion. If pain is not experienced during this activity, the therapist coaches the client through the warm-up exercises. The warm-ups are completed out-of water, as the stitches have just been removed and the hand should not be placed in water for 24 to 48 hours. The therapist instructs the client to begin the program at stage one after 24 hours have passed from the removal of the stitches. The client is instructed that he/she may move to stage two if he/she meets the criteria from stage one. The initial treatment ends with the scheduling of a second therapy session in three days to one week.

Second Treatment Session

The second session begins with a review of the program and identification of client problems or concerns. The client is directed to perform the prescribed exercises with the therapist providing corrections as needed. If the client indicates that pain or edema is a concern, he/she is instructed to discontinue that exercise or decrease the repetitions used. Grip and pinch strength is evaluated during the second session, if the client can tolerate that activity. The therapist performs pressure message and decongestive massage on the hand as a means of reducing edema. If edema is present, the client is to stress elevated decongestive massage during his/her home activities. If edema and pain are not present, the client begins minimally resistive exercise. Resistive exercise is initiated with the use of contour foam hand exercisers (small, medium, or large to match hand size) and putty (soft or medium density). The client is instructed in the utilization of these materials in his/her home program.
which has now reached stage three. The second session ends with the scheduling of a third treatment session in one week, unless there are problems with edema or pain.

**Third Treatment Session**

The third treatment session follows the pattern established in the second with a review of the program and identification of client problems or concerns. The client is directed to perform the exercises with the therapist correcting as needed. The therapist re-evaluates range of motion, grip strength, and pinch strength. Orientation to stage three and four occur during this treatment session. The orientation includes the instruction on the use of weights in the exercise program. The addition of weights, 1 to 1.5 pounds, is utilized during stage four. The client is instructed to use soup cans or small weights in a sock, if exercise weights are not available at home. The third treatment session ends with an appointment scheduled in one week.

**Fourth Treatment Session**

This treatment session may be a significant one. Some clients will have more complaints and concerns between three and four weeks post-surgery. These concerns center on increased pain, increased swelling, and continued weakness. These set backs may be the result of overdoing the home exercise program or through the resumption of leisure activities, home management, or child care activities. The client may also be concerned about the slowness of return of strength and endurance, or continued sensitivity of the incision site. Questions related to return to work will often occur. If there are physical problems, the client is instructed to reduce the number of repetitions of specific exercises, or to eliminate that activity from the program. The therapist may perscribe the use of a wrist brace if wrist pain is significant. The therapist may also perscribe the use of rubber-band exercises to give
more control to resistive exercises. Clients with physical problems will be scheduled for additional treatment times, and may be seen by the physician if the problems are significant.

If problems are not evident during this treatment session, the client and therapist begin to approach job related activities. This discussion centers on specific motions, movements, and strength requirements necessary for the client to perform his/her assigned job. The availability of light-duty and job accommodation is also approached. The therapist will utilize this information in designing the remaining exercise program for stages four, five, and six. If the client will return to a job requiring low to moderate strength, the treatment session ends with the scheduling of the next treatment session in one to two weeks. If the client will return to a job requiring high levels of manual work, more resistive activities are added to the program and more frequent treatments are scheduled. The client will move on to stage six during these additional treatment sessions while they are working on stage five at home.

**Sixth Week Post-Surgery Treatment Session**

The treatment session during the sixth week following surgery includes the pattern set from previous treatments. The client is scheduled also to be seen by the physician. The therapist completes an evaluation of the client for range of motion, strength, and coordination. If the physician believes that adequate progress is being made, the treatment sessions will be continued with preliminary decisions being made on dates for return to work. Usually, the client will not be returned to work before two months post-surgery. If problems have been identified by the client and therapist, then specific recommendations are made to address those concerns.
Additional Treatment Sessions

Treatment continues based upon past progress, presence of pain, swelling, and levels of strength and endurance needed in the client's job. The client may remain in stage four or five for additional time, if problems continue. Treatment sessions continue until the client, therapist, and physician feel that the range of motion, strength, and endurance meet the employer's criteria for return to work. At that time, the return to work slip is completed by the physician. The return to work slip may be for light duty or job accommodation if that option is available to the worker. Prior to returning to work the therapist may perform a job site analysis. Therapy sessions stop when the client returns to work. The client is instructed to contact the physician or the therapist if problems arise. This may result in a re-referral to the occupational therapist, or an additional referral to a Back to Work Program which has the potential to more closely simulate the client's job for up to an eight hour treatment day.

Treatment Activities

The program incorporates several treatment activities which are to be utilized throughout the six stages. The activities are organized in a specific manner to facilitate the treatment goals.

Warm up Exercises Out of Water

These exercises are completed at the beginning of each session. The treatment goal of the activities include the gentle stretch of the muscles in preparation for activity and reduction of the risk of trauma during activity. The warm up exercises include the following activities:
1. Sit up straight. Bend head to the left, trying to touch the left ear to left shoulder. Straighten up.

2. Repeat #1, but bend to the right.

3. Turn the head and look over the right shoulder.

4. Repeat #4, but look over the left shoulder.

5. Shrug the shoulders up as far as you can.

6. Rotate both shoulders in a circle.

7. Repeat #6, but go in the opposite direction.

8. Straighten out both arms, at the side, even with the shoulders. Make circles with the arms. Repeat and go in the opposite direction.

9. Bend and straighten both elbows.

10. Bend elbows to 90 degrees. Turn arm so that the palm faces up. Stretch gently. Repeat, making the hand turn palm down.

11. Rotate the hand at the wrist, in a circular movement. Repeat and go in the opposite direction.

12. Straighten the arm in front of you. Gently pull the thumb out and back, using the other hand. Repeat on the other side.

13. Bend the elbows. Stretch the fingers open as wide as you can.

14. Bend your wrist so the hand goes up, and down. Stretch gently.

Warm up Exercises in Water

These exercises are completed at the beginning of each session. The treatment goals include the gentle stretch of the muscles in preparation for activity and reduction of the risk of trauma during activity. The warm up exercises include the following activities:

1. Soak hand and arm, up to elbow, in warm water.
2. Gently open and close the hand while in the water.
3. Touch the thumb to the tip of each finger, one at a time.
4. Gently bend the wrist so that the hand goes up and down.
5. Gently bend the wrist so that the hand goes to the left and right.
6. Gently rotate the hand at the wrist, in a circle.

**Elevated Decongestive Massage**

Edema control is facilitated through elevated decongestive massage which incorporates massaging the hand from distal to proximal while the hand is in an elevated position.

**Pressure Massage**

Using a quality hand lotion, massage/rub the scar in a circular motion with as much pressure as can be tolerated. If the area is very sensitive, start away from the scar, on healed skin, and work toward the area that is more sensitive. The treatment goals for the pressure massage include decreasing sensitivity and decreasing skin/muscle adhesions.

**Ice Pack**

Place ice cubes in a sealed plastic bag. Elevate the hand on a pillow. Cover the hand with a thin towel and place the ice-filled plastic bag on the hand. Cover the hand completely with another towel. Leave the ice pack on for 10 to 15 minutes, until the skin is cool to the touch. The treatment goal for the ice pack is to decrease edema and pain.
Contrast Bath

In a divided sink, place warm water on one side and cold or cool water on the other. Place the hand in the warm water side for three to four minutes. Then place the hand in the cold/cool water side for one minute. Repeat between the warm and cold water, 4-6 times, and end in the warm water.

Putty Activities

Putty activities are delineated through an instruction manual provided by the producer. The goal of the activity is to provide minimal to moderate resistance to active range of motion of the hand.
Appendix B
Instrumentation
Data Collection Sheet

Demographics

<table>
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<th>Gender</th>
<th>Age</th>
<th>Hand Dominance</th>
<th>Hand Involvement</th>
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<td>R</td>
<td>L</td>
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<tr>
<td>F</td>
<td></td>
<td>R</td>
<td>L</td>
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Employment Information

Job Title: ___________________________ Employer ___________________________

Light duty is available: yes  no ___

Return to work date: ___________ Returned on light duty: yes  no ___

Medical Information

Diagnosis: _______________________

Surgery Date: ___________

Physician: _______________________

Occupational Therapy Treatment Data

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<td>rest</td>
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</table>
Occupational Performance Scale for Carpal Tunnel Syndrome

Client: [Name]

Data Collection Period: Baseline _ 3 months _ 6 months _ 9 months _

A. Symptoms: Circle level of symptoms you are experiencing now.

Symptoms Scale: 0 = none, 1 = low, 4 = moderate, 3 = high

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<th>moderate</th>
<th>high</th>
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</tr>
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<td>3</td>
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<tr>
<td>acheing</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>swollen feeling</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>night pain</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>need for additional medication</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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</table>

When do your symptoms occur: use the timeline and indicate when your symptoms occur

B. Employment: Select the number which represents your current work status.

1. can work, but with:
   - intense symptoms present

2. can work, but with:
   - moderate symptoms present

3. can work, but with:
   - no symptoms present

Symptoms: Circle the symptoms you experience during your work schedule

- sharp pain
- numbness
- tingling
- acheing
- swollen feeling
- need for additional medication
- pain which continues past the activity

Are you on Light Duty: Yes _____ No _____

Hours working per week: Regular _______ Over-time _______

Have not been returned to work yet _____ Returned to work, but not working now _____

When do you work: use the timeline and indicate when you work.

1am 2 3 4 5 6 7 8 9 10 11 12noon 1pm 2 3 4 5 6 7 8 9 10 11 12pm
C. Work: home activities, family management, and school. Work represents activities such as doing the laundry, grocery shopping, home repairs, cooking, study, and child rearing. Select the number which represents your current ability to complete these responsibilities.

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<th>4</th>
<th>5</th>
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<td>3</td>
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<td>some</td>
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Symptoms: Circle the symptoms you experience during these activities
- sharp pain
- numbness
- tingling
- aching
- swollen feeling
- need for additional medication
- pain which continues past the activity

When do you do these activities:

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<thead>
<tr>
<th></th>
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</table>

D. Self-Care: feeding, hygiene, dressing, grooming, walking, moving, and coordination. Select the number which represents your current ability to complete these activities as you like to do.

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<td>3</td>
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</table>

Symptoms: Circle the symptoms you experience during these activities
- sharp pain
- numbness
- tingling
- aching
- swollen feeling
- need for additional medication
- pain which continues past the activity

When do you do these activities:

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</table>
E. **Leisure**: sports, hobbies, games, and social activities. Select the number which represents your current ability to participate in the leisure activities that you do.

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**Symptoms**: Circle the symptoms you experience during leisure activities.

- sharp pain
- numbness
- aching
- swollen feeling
- need for additional medication
- pain which continues past the activity

**When do you do these activities?**

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F. **Rest**: includes sleep, relaxation, and rest periods

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</tbody>
</table>

**Symptoms**: Circle the symptoms you experience during rest activities

- sharp pain
- numbness
- aching
- swollen feeling
- need for additional medication
- night pain

**When do you do these activities?**

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<th>1am</th>
<th>2</th>
<th>3</th>
<th>4</th>
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G. Rehabilitation Program Compliance

Indicate the number of days per week that you completed your exercise program.

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<td>1 year</td>
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<td>1</td>
<td>2</td>
<td>3</td>
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</tbody>
</table>

R.g.Cooper. 1988
Appendix C

Human Subjects Review
RESEARCH SHOULD NOT BEGIN UNTIL THE PROTOCOL HAS BEEN REVIEWED AND APPROVED BY THE HUMAN SUBJECTS INSTITUTIONAL REVIEW BOARD, WHICH MEETS ON A REGULAR MONTHLY BASIS. PROTOCOLS MUST BE RECEIVED BY THE HSIRB CHAIR AT LEAST SEVEN DAYS PRIOR TO A REGULARLY SCHEDULED MEETING IN ORDER TO BE REVIEWED AT THAT MEETING. PLEASE TYPE EACH RESPONSE - EXCEPT SIGNATURES. REFER TO THE WESTERN MICHIGAN UNIVERSITY POLICY FOR THE PROTECTION OF HUMAN SUBJECTS TO DETERMINE THE APPROPRIATE LEVEL OF REVIEW.

PRINCIPAL INVESTIGATOR Richard G. Cooper DEPARTMENT O.T.

Home Phone 342-5304 Office Phone 387-1850

Home Address 413 Montrose Office Address 226 Wood Hall

Kalamazoo, 49001

PROJECT TITLE: A Comparative Study of Occupational Therapy Treatment Outcomes on Carpal Tunnel Syndrome

SUBMISSION DATE: 7/19/88 PROPOSED PROJECT DATES 10/1/88 TO 12/1/89

APPLICATION IS: New Renewal Continuation Supplement

SOURCE OF FUNDING: NONE

STUDENT RESEARCH (Fill out if applicable)

Name of Student Richard G. Cooper Phone 342-5304

Address 413 Montrose Kalamazoo, Michigan 49001

The Research Is: Undergraduate Level X Graduate Level

Faculty Advisor Dr. Charles Warfield Department EDLD

Signature of Faculty Advisor

Signature of Investigator
TO: Richard G. Cooper
FROM: Ellen Page-Robin, Chair
RE: Research Protocol
DATE: September 2, 1988

This letter will serve as confirmation that your research protocol, "A Comparative Study of Occupational Therapy Treatment Outcomes on Carpal Tunnel Syndrome" is now complete and has been signed off by the HSIRB.

If you have any further questions, please call me at 387-2647.
November 18, 1988

Richard Cooper, MOT, OTR, FAOTA
Department of Occupational Therapy
Western Michigan University
Kalamazoo, MI 49008

RE: Protocol: A Comparative Study of Occupational Therapy Treatment Outcomes on Carpal Tunnel Syndrome

Dear Mr. Cooper,

The Human Research and Clinical Investigation Committee of Borgess Medical Center has reviewed the above-named protocol. Based upon that review and your personal presentation, the Committee agreed that the protocol met our standards of research and further agreed to approve the study and consent form as presented.

This approval is granted with the understanding that any changes in the protocol are promptly reported to the Committee; that changes in the approved protocol cannot be initiated without Committee review and approval unless there are immediate hazards to human subjects; and that all unanticipated problems involving risks to human subjects are also promptly reported to the Committee.

Approval for this protocol is granted for a period of one year. Thereafter approval is extended only after the Committee has received an annual review of the study. Therefore, we ask that at the end of one year, you send the Committee a summary of the activity you experienced during your research. We do this in order for us to know that the research was carried out as planned, and that patient benefit outweighed the risk. A copy of each signed consent form is also required. You may send this information to the Medical Staff Office.

If you have any questions in this regard, please feel free to contact me.

Sincerely,

Keith Bailey, M.D., Chairman
Human Research & Clinical Investigation Committee
Informed Consent Form (Participant Copy)

You are being asked to participate in a research study of employed adults who have had surgery for carpal tunnel syndrome. The study will help determine the effectiveness of rehabilitation programs used with carpal tunnel syndrome clients who have had surgery. You will complete the rehabilitation program as prescribed and directed by your physician.

For the research study, you will be tested during your recovery period by a registered occupational therapist. The occupational therapist will measure:
1. Your ability to move your hands and fingers (range of motion).
2. The strength of your hands and fingers (muscle testing), and
3. The coordination of your hands.
4. Your ability to do your activities of daily life will be measured by self-report.
5. The length of time before you return to work will be recorded.

You will be tested up to three times during the study which will last from October 1, 1988 to April 1, 1990. The tests will occur: 3 months, 6 months, and 9 months after your surgery. Each test will take approximately 30 minutes. You may be asked to be tested before the rehabilitation program begins. The tests will be scheduled at a time convenient to you at Kalamazoo Orthopedic Surgery, 401 Howard, Kalamazoo. You will not be charged for the evaluation time. There will be a minimum of 25 participants in the research study.

The information collected from your tests will be recorded on two forms (attached). These forms will be held separately from your medical records and will be coded by number only. Data from the research study will be reported by the type of rehabilitation program you were involved in, and no specific individual will be identified. The records of your evaluations will be held in confidence. They will not be made available to your employer, or others.

There is no more than minimal risk or discomfort in participating in this study. You will be expected to follow your rehabilitation program, including any precautions, that your physician has prescribed for you.

Participation in this research is voluntary. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled, you will not receive any payment for your participation, and you may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

For more information concerning the research and research-related risks or injuries, I may contact Richard Cooper, the investigator in charge at 387-3850 at the Occupational Therapy Department at Western Michigan University. I may contact Dr. Ellen Page-Robin at 387-2642 for information regarding patient’s rights in research studies.

I have read this informed consent form and my questions have been answered. I am willing to participate as a voluntary subject in the study.

Signature of Participant or Legal Guardian: __________________________ Date: __________

Signature of Witness: __________________________ Professional Credentials: __________________________

This informed consent form has been read to me and my questions have been answered. I have given verbal approval to be a voluntary subject in this study.

Signature (mark) of Participant or Legal Guardian: __________________________ Date: __________

Signature of Witness: __________________________ Professional Credentials: __________________________
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_________________________ Professional Credentials
Signature of Witness

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Signature (mark) of Participant or Legal Guardian

_________________________ Professional Credentials
Signature of Witness

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