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The Effectiveness of Carpal Tunnel Release

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Abstract:

Hand injuries involving the carpal tunnel are very common in today’s society, affecting 4-10 million people per year. This problem may become more prevalent due to an increase in new hand-oriented activities like texting and gaming. The carpal tunnel is found just under the skin of the palm towards the wrist (Biundo and Rush, 2013) and is made up of carpal bones and the transverse carpal ligament. Breakdown and/or pressure to this tunnel puts pressure on the median nerve of the hand and leads to carpal tunnel syndrome (CTS). CTS decreases hand strength and numbs the hand in the thumb, index, and middle finger. It is often treated by surgery. Carpal tunnel release is the surgery that relieves pressure to the median nerve and flexor tendons inside the carpal tunnel. It is important to determine the long-term effectiveness of carpal tunnel release to improve treatment recommendations and devise post-operative rehabilitation protocols. This study will test post-operative grip strength, pinch strength, and manual dexterity by the Box and Block test in former CTS patients ages 65 and over who have had carpal tunnel release. Subject performance will be compared to age- and gender-controlled normative data from previous literature. It is hypothesized that there will be no significant difference between post-operative scores and normative data since subjective reports find that hand function is fully restored. This study will also determine the role of physical therapy to carpal tunnel release.

Keywords:

Carpal Tunnel Syndrome (CTS)
Grip Strength
Pinch Strength
Manual Dexterity
Elderly Hand Function
Problem Statement:

Hand injuries involving Carpal Tunnel Syndrome (CTS) are very common, currently affecting 4-10 million Americans per year. CTS is painful syndrome causing hand numbness and pain (Biundo and Rush, 2013). Studies have shown that the risk of carpal tunnel syndrome increases with age and is higher for women (Petit et. al, 2015). CTS can impair normal hand function, which includes hand strength, movement, and sensation. CTS is highly prevalent in today’s society because of the steady increase of the elderly population as well as a population that is living longer than ever. In addition, computer and cell phone use is affecting people at younger ages. Treatment in the form of surgery (carpal tunnel release) for CTS is usually successful in alleviating symptoms and restoring hand function. It is important to understand the effectiveness of carpal tunnel release to determine the return of hand function for the millions of people that need this operation. CTS entails multiple impairments, and to truly test the recovery at all levels of hand function, more than one test needs to be performed for analysis. If surgery does return patients to normal hand function then their performance in tests of hand function such as grip strength, pinch strength, and manual dexterity will have no significant difference when compared to age- and gender- controlled normative data. The overall goal of this study is to better understand how effective carpal tunnel release is in returning elderly post-operative patients to the normal strength and function of age- and gender- controlled normal data. Also, if post rehabilitative physical therapy protocols are needed.

Introduction/Literature Review:

The Carpal Tunnel

The carpal tunnel is found just under the skin of the palmar side of the wrist (Biundo and Rush, 2013). Eight bones make up a canal shape that houses the median nerve with the soft
tissue and skin covering this tunnel. The median nerve supplies motor control to the 1\textsuperscript{st} and 2\textsuperscript{nd} lumbral muscles as well as the thenar eminence.

Figure 1 shows the areas of the hand controlled by the median nerve with the thumb, index, and middle finger shaded areas indicating where sensation is provided.

Along with the median nerve, the nine flexor tendons, which aid in flexor extension and flexion, are housed in the tunnel. These nine flexor tendons include the flexor pollicis longus, the four flexor digitorum profundus, and the four flexor digitorum superficialis. These flexors vary slightly in the way they are sheathed but all help to move the fingers (Presazzi et. Al., 2011).

\textit{Carpal Tunnel Syndrome}

Carpal tunnel syndrome (CTS) is a medical condition where some breakdown and/or pressure to the median nerve or flexors housed in the carpal tunnel. This breakdown and/or pressure can cause the numbness in the hand associated with CTS (Biundo and Rush, 2013). Breakdown and/or pressure can be caused by a variety of reasons including a cyst or tumor in the carpal tunnel, fluid retention in the carpal tunnel, hypothyroidism, and swelling. Any kind of fracture to the wrist area can result in a breakdown of the tunnel (Biundo and Rush, 2013). Classic symptoms include any abnormalities to normal hand function and numbness in any of the green shaded areas in Figure 1. Activities that require extra hand function, such as typing or writing, can be very uncomfortable.

The theory that carpal tunnel can be caused by repetitive hand activities is still being evaluated. There are mixed results on the exact activities that can lead to CTS. For example, the Canadian Center for Occupational Health and Safety has reported studies that have found job
tasks and occupations like weeding, knitting, using a laser scanner, and air-powered hand tools all can cause CTS (CCOHs, 1997). Other studies have found that activities like typing, using a mouse, playing sports, or playing a musical instrument does not cause CTS (U.S. National Library of Medicine, 2013). Studies have shown that the risk of carpal tunnel syndrome increases with age and is higher for women (Petit et. al, 2015). It is still unknown why women are of greater risk, but possibilities include a smaller carpal tunnel compared to men, higher rates of autoimmune disorders which are linked to CTS, and hormones have been shown to affect CTS (Penn State Hershey Medical Center, 2011).

**CTS and the Median Nerve**

CTS involves specifically the palmar cutaneous branch of the median nerve. Since electrical signals are being sent and received via this branch of the median nerve, it is important to understand how CTS is affecting these messages. Conduction velocity determines the speed at which a neuron conducts an electrical signal, the messages, down its axon. Many axons bundled into one structure is what we call a nerve. Uluc et al. (2014) examined the difference in conduction velocity between different branches of the median nerve. They found that for some patients with CTS the conduction velocity is slower than normal and less than other nerves in this area of the forearm. Another study on elderly patients compared pre-operation electrophysiological assessment to post-operation assessment, which included conduction velocity, and found improvement in 86% of patients (Kanatani et al., 2014). Both of these studies suggest that conduction velocity is impaired for those with CTS. There are treatment options for carpal tunnel syndrome.
**Treatment for CTS**

Medications that reduce inflammation that may be causing carpal tunnel pressure can be taken to combat the pressure. Like other injuries that include inflammation, CTS may be relieved by drugs as common as Ibuprofen (Carlson et al., 2010). If these over the counter medications do not help, a monthly cortisone injection can decrease symptoms. Like anti-inflammatories, cortisone reduces the white blood cells that are moving towards any sites of damage to cause swelling (Carlson et al., 2010). Sometimes CTS can be alleviated with bracing methods to decrease excessive wrist movements that may be causing irritation. Another relief for some CTS patients is exercise. Often the tendon glides and nerve glide exercises seen in Figures 2 and 3 can be performed to mobilize the nerve and flexors. Some other effective treatments for CTS include acupuncture, laser therapy, and yoga (Carlson et al., 2010). If all of these attempts are unsuccessful in relieving pain and numbness, the last treatment is surgery (Biundo and Rush, 2013).

There are two major types of carpal tunnel surgery, which is commonly referred to as carpal tunnel release (CTR). In both types, patients are anesthetized or are given relaxation drugs and numbing medication so that no pain is felt. Also, both involve the cutting of the transverse carpal ligament to create more room for the flexor tendons and median nerve. An endoscopic or open surgery can be performed where the surgeon will relieve the pressure. In an endoscopic CTR, a small transverse incision is cut in the wrist. Through this cut, a scope is pushed into the carpal tunnel itself. Once inside, a blade is released to slice the transverse carpal ligament by the use of a video screen (SCPS, 2013). In an open CTR, a 2-4 cm proximal incision is made at the wrist. The subcutaneous fat tissue just underneath is parted by use of retractors. After the fibers of the palmar fascia have been pulled away the transverse carpal ligament is exposed. The
ligament is then cut much like the way it is cut in an endoscopic CTR. The incision is then sewed back together (Rodner and Katarinic, 2006).

The benefit of an endoscopic CTR is that there only is a small transverse incision for the scope to pass through. This technique allows for a faster recovery time. The drawback to this procedure is that the endoscopic CTR is more expensive than the open CTR because of the equipment. Conversely, the open CTR technique creates a much larger incision that needs time to heal before much movement can begin. There is some debate on which surgery is more successful from a post-operative pain and recovery standpoint, but neither is proven better than the other (Ferdinand and MacLean, 2002). However, it is noticeable that the endoscopic CTR, while more expensive, allows for patients to begin post-operative wrist movements and exercises, return to work and recover faster than open CTR patients (SCPS, 2013).

*Post-Operative Protocol*

Post-operative protocol varies between physician and surgery type, but in general most patients will not need any types of physical/hand therapy. For the majority of patients who do not need therapy, tendon glide exercises are prescribed like the ones seen in Figures 2. and 3. These patients also can self-massage to reduce swelling. The incision site is monitored by the surgeon and CTR patients generally recover on their own.

In some cases where there appears to be significant stiffness occurring post-surgery, physical/hand therapy may be prescribed. During therapy, the tendon gliding exercises are done but therapy can go more in depth into the exercises, as well as massage techniques to reduce swelling. Range of motion techniques are all aimed towards reducing stiffness and increasing mobility of both the wrist and the tendons and nerve. Full passive range of motion and active range of motion are accessed during the course of the therapy.
Multiple studies evaluated factors that may predict the successfulness of carpal tunnel release. Turner et al. (2010) reviewed past studies and found that weight, gender, and age were not found to be predictors of lesser outcome for carpal tunnel release. However, co-morbid factors such as diabetes as well as factors like smoking and excessive consumption of alcohol were linked with poorer outcomes. There are multiple ways to measure the effectiveness of surgery and post-operative therapy.

*Strength Measurements*

Grip strength is a common measurement for the functionality and strength of the hand. Grip strength is measured in pounds or kilograms of force and is taken by a hand dynamometer. Proper procedure for use is to hold the dynamometer with the arm bent 90 degrees at the elbow. Many normative studies have been conducted to determine the normal grip strength for both sexes and across ages. (Mathiowetz et. al, 1985). Normative data can be used to determine the effectiveness of different surgeries or treatments. For this specific research, carpal tunnel release patients’ post-operative grip strength was compared to age- and gender-controlled normal data to analyze any differences. Grip strength usually decreases as a person gets older. Also, males
tend to have greater grip strength than females across ages and the dominant hand is usually stronger than the non-dominant hand (Mathiowetz et al., 1985). For the normative data, hand dominance was noted as the writing hand. Besides grip strength, pinch strength is often used to determine hand function. Pinch strength is highly associated with hand function, especially when analyzing CTS patients since the thumb, index, and middle finger can become numb. Similar data like that of grip strength gives normal age and sex controlled scores. Strength is important to hand function, but mobility is also key.

**Manual Dexterity Measurements**

Manual dexterity tests involve some type of hand-oriented challenge or task that can be recorded in in seconds or in the number of items moved from one place to another. The Box and Block test involves a shallow box that is separated by a wall. For this test specifically, the subject must try and move as many blocks as possible to the other side of the wall (Mathiowetz et al., 1985). See Figure 4, for a diagram of the box. It tests both coordination by picking up and moving the blocks over the wall and strength by being able to grab the block for the duration of the movement. Carpal tunnel syndrome patients have difficulty squeezing the blocks, as well as feeling their edges. If carpal tunnel release is effective then the scores of these post-operation patients should show no difference to that of age- and gender- controlled normative data. The normative data is very similar to the grip/pinch strength normative data.

![Figure 4 (Mathiowetz et al., 1985)](image)
The Elderly Population

The population used for this study was male and females over the age of 65 years, which is most often considered as elderly. The elderly population was chosen for a variety of reasons. Since CTS occurs more in older people, CTR is often performed on older people (Petit et. al, 2015). Also elderly people tend to be retired and thus have more free time to participate in a study. Data varies depending on the sample, but most often the average age of patients who have the surgery performed was 55 years old (University of Maryland, 2013). The elderly population is at greater risk to falling due to decreases in strength, eye sight, and overall mobility (CDC, 2015). A fall can lead to a greater injury, such as a hip fracture and from that, early death (CDC, 2015). It is important to have the elderly in a state that best prevents them from falling (CDC, 2015). Often the elderly use canes or walkers to walk and the use of their hands is crucial. The elderly population is expected to double by 2030 from the 39.6 million elderly people in 2009 (“Aging Statistics”).

Research Question:

Is endoscopic carpal tunnel release effective in returning CTS patients to full hand function? Will their hand function show any significant difference when compared to age- and gender- controlled normative data for grip/pinch strength and manual dexterity? What are the implications of physical therapy on effectiveness?

Methods:

Subjects:

For our study, 27 subjects were used for this study, 12 males and 13 females, ranging in age from 65-88. A total of 41 hands were tested because 14 of the 27 subjects had bilateral release (both hands performed on). All subjects were treated with endoscopic CTR by Dr.
Richard Green at Salmon Creek Plastic Surgery 5-10 prior to testing. Only healthy subjects were used for this study. Health is defined as free of any physiological deficits that could affect hand dexterity or strength such as arthritis and tendonitis. A questionnaire was given to distinguish hand dominance, occupational history, age, sex, and other CTS related questions. This survey will also determine if the patient has any comorbid/impairments that could affect their scores. Data collection occurred at Salmon Creek Plastic Surgery and PeaceHealth Outpatient Therapies.

Procedure:

Following the questionnaire, a brief interpretation was made to determine the eligibility of the subject. Grip and pinch strength testing followed similar procedure and were performed directly after each other. Subjects were seated with the shoulder neutrally rotated and shoulder adducted. The elbow is at a 90° angle. For both pinch strength and grip strength, the wrist was between a 0° and 30° angle dorsiflexion and 0° to 15° ulnar deviation. On the operated hand, three trials for each strength type were taken with the strongest of the three data points recorded. Figure 5 shows the correct position for grip strength measurements. Figure 6. shows procedural information for measurements of pinch strength.
The Box and Block Test is administered directly after grip and pinch strength testing was taken. Subjects sit at a table with the box in front of them. The 150 blocks were placed in the side of the box that corresponded with the CTS hand. A 15 second trial period was allowed for subjects to familiarize themselves with the procedure. Using a stopwatch, subjects then transferred as many blocks from one side of the box to the other in 60 seconds. If two blocks were picked up at once, they counted as just one block and were noted as such. Scores were indicated as the number of blocks transported of the partition in one minute.

Equipment:

For Grip strength a Jamar dynamometer is used. Multiple studies have found that the Jamar dynamometer is the most accurate of the hand dynamometers for this determination (Mathiowetz et. al, 1985). All of the subjects used the dynamometer on the second handle setting to standardize the data. Figure 1. shows a picture with the Jamar dynamometer. For pinch strength the B&L pinch gauge was used. Figure 6. shows a picture of the B&L pinch gauge. Both pieces of equipment use needle readout for data collection. The box and blocks used met standard dimensional criteria. Figure 4. shows the set up box with the proper dimensions. The 150 blocks used were 1 inch square cubes.

Data Analysis:

The scores for the grip and pinch strength was in the form of pounds. The highest value of the three trials were compiled into age groups. The age groups were broken into three groups. The first group ranged in age from 65-69. The second ranged in age from 70-74. The last age
group included all individuals age 75+. The data fell into one of these groups depending on age, sex, and hand dominance. Because of the low number of subjects in the first two age groups, only boxplots were made to observe the 75+ group. With only a few hands tested in those first two groups they were not a part of the overall analysis. We used R Software to create the figures.

**Results:**

*Pinch Strength:*

The results of our pinch strength tests can be seen in Figures 8 through 11. Figure 8 illustrates the male results for left hand. Figure 9 illustrates the male results for right hand. Figure 10 illustrates the female results for left hand. Figure 11 illustrates the female results for right hand. For all of these figures the red line indicates the gender- and age- controlled normative data averages. For all of these figures, pounds in on the left y-axis and the type of pinch is on the right x-axis.
**Grip Strength:**

The results of our grip strength measurement can be seen on Figure 12. The male data is presented on the left hand side with the female on the right. Again, the red line indicates the normative average for each gender- and age-related box plot.
Manual Dexterity:

The results for manual dexterity are presented in Figure 13. The male data is presented on the left hand side with the female on the right. Once again, the red line indicates the normative average for each gender- and age- related box plot.

![Manual Dexterity](image)

**Discussion:**

Hand Strength:

When looking at the hand strength results – pinch and grip – we found that key pinch, tip pinch, and overall grip strength were restored in our sample. However, the palmar pinch data specifically showed that our sample scored lower than the normative data for both genders and hands. Referring back to Figure 6, tip pinch is the index finger and thumb, key pinch the thumb and base of the index finger, and palmar pinch the index and middle finger and the thumb. Since the palmar pinch uses almost the same finger configuration as the tip pinch it would be likely
that tip pinch is also lower than normal but that is not the case. We concluded that hand strength was restored because of CTR but that the palmar aspect of pinch strength was left lacking.

**Manual Dexterity:**

Manual dexterity results showed that our sample across all genders and hands scored 10-15 blocks lower than the control data. Manual dexterity is the use of fine and precise motor movements of the hand. In this test, gripping blocks use the index and middle finger as well as the thumb which also describes palmar pinch from above. This possible correlation will be discussed later. We concluded that manual dexterity was not fully restored by CTR in our sample.

**Implications:**

Hand function must be looked at as a whole in determining the effectiveness of CTR. With pinch strength from the palmar aspect not fully restored and manual dexterity lacking when compared to normative data, our sample indicated that hand function is not fully restored. When we think about these two specific measures, palmar pinch and manual dexterity, the part of the hand being used is the thumb, index, and ring finger. Those are the digits used to pinch the dynamometer and those are the digits used to pick up the blocks in the box and block test. With this in mind, the manual dexterity via the box and block test may have given lower scores because of a palmar deficiency. To rule this out, we would have to test manual dexterity by other means like a Minnesota Manual Dexterity test seen...
in figure 14. Considering this inference further, tip pinch was fully restored, which uses the thumb and index finger indicating that the middle finger is particularly lacking in recovery.

_The Elderly Population:_

The elderly population was of particular importance when evaluating the effectiveness of CTR because of their use of assistive devices. The results of this study point to hand strength being mostly restored, and from the perspective of using an assistive device, CTR would be effective in restoring their use. However, the lack in palmar pinch and manual dexterity scores could be a hindrance to other daily activities like knitting or playing the piano.

_Physical Therapy:_

All of the subjects tested in our study reported that they did not receive physical therapy after their surgery. Physical therapy is not often prescribed to a patient after CTR unless they are having particular problem in the rehabilitation process. Endoscopic release patients have an even less problematic recovery than open release patients because of the smaller incision. In terms of our results, it would be beneficial to do a study on subjects who have had CTR and also physical therapy after surgery. If this study were done and a comparison found that the physical therapy-treated subjects had higher scores higher and scored closer to the normative averages, then it could be suggested that physical therapy could facilitate rehabilitation.

_Future Directions:_

Along with studies about physical therapy prescribed subjects, further studies should be conducted to support this data. We had a small sample size that was broken down into genders and left/right hands. With a greater sample size, we could confirm our results as well as run statistical tests against the normative data. In addition, our results were found for an elderly
population. Studies on other age ranges could determine if the rest of the population also lacks a restoration in palmar pinch and manual dexterity.

Surveys

Informal surveys were done to look at the subjects’ histories. Questions included any co-morbid factors, post-operative physical therapy, hobbies, and past occupation. In the beginning of this paper, it was discussed that there are mixed results on the exact activities that can lead to CTS. Previous studies found that tasks and occupations like weeding, knitting, using a laser scanner, and air-powered hand tools all can cause CTS (CCOHS, 1997). Other studies have found that activities like typing, using a mouse, playing sports, or playing a musical instrument do not cause CTS (U.S. National Library of Medicine, 2013). Many of our subjects reported that they garden, play piano, and knit. Also, many reported teaching as a past occupation. Gardening and knitting follow previous literature as a cause for CTS, but playing piano does not. Teaching as an occupation can range greatly depending on the setting, but typing could be a frequent activity. This debate about causes for CTS will continue, and with the changing technology to more hand-involved devices, could develop further in the future.

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