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Examining the Reliability of a Force Sensing Resistor as a Possible Tool to Assess Carpal Tunnel Syndrome

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Abstract The purpose of this study was to examine the reliability of a force sensing resistor (FSR) as a possible diagnostic tool to assess Carpal Tunnel Syndrome (CTS) when combined with the modified Phalen's Test. Fifteen healthy undergraduate students participated in this study. Researchers used identical testing protocols on two separate occasions. Statistical analysis results revealed a strong positive correlation, $r = 0.91$, $p < 0.05$ across replications. The outcome of this study sheds light on the use of a FSR as a possible tool to assess and diagnose CTS when combined with the modified Phalen's Test.

Keywords Carpal tunnel syndrome, Force sensing resistors, Diagnostic tool

1. Introduction

Carpal Tunnel Syndrome (CTS) is the result of compression of the median nerve as it passes through the fibro osseous tunnel in the wrist [2, 12]. CTS affects an estimated 3% of Americans [13]. In the Canadian population, however, the estimated lifetime risk of developing this illness is 10% [3]. CTS is three times more common in females than males and affects mainly middle aged individuals [2]. The clinical features of CTS include pain in the wrist and hand region as well as numbness and tingling in the thumb, index, and middle finger [2, 12]. The symptoms associated with CTS are usually worsened at night when sleeping and awaken the individual with increased pain and paresthesia [2, 12]. Individuals may relieve these symptoms by shaking their hands out and flicking their wrists. In some cases further treatment is required including the use of a variety of therapeutic interventions and modalities such as the use of non-steroidal anti-inflammatory drugs, resting wrist splints, ultrasound therapy, ergonomic modifications, and avoidance of movements that require repetitive wrist and hand motions. In unresolving cases, surgery may be required, however, the symptoms may still reappear after treatment, with a 73% chance of CTS recurrence even four years after surgery or treatment has been completed [10]. The majority of CTS cases reported affect both the right and left hand [10].

CTS is common for individuals who work in sedentary jobs (e.g., secretaries) and physically active jobs (e.g., manual labourers) [17]. CTS also develops in individuals who participate in sports (e.g., wheelchair basketball and tennis). This may be due to trauma to the wrist, repetitive gripping tasks, repetitive wrist extension and flexion, and direct compression to the carpal ligament [8].

No conclusive prevention strategy has been identified for CTS [11]. Prevention often involves an engineering, administrative, personal, or multi-factorial intervention [11]. Specific exercises have not been demonstrated to be an effective method for the prevention of CTS [16]; however, prevention may be achieved by implementing ergonomic changes such as the use of an ergonomic keyboard, mouse, or wrist support [7]. Prevention may also be achieved with the avoidance of repeated workplace or sport specific exposures; job rotation; the use of intermittent rest breaks; the use of better workplace practices; a better design to equipment and tools used; and accessing appropriate treatment interventions and rehabilitation [14]. In order to implement effective prevention and treatment strategies requires appropriate and comprehensive assessment and diagnosis.

One avenue to achieve a comprehensive assessment for CTS diagnosis and minimize the risk of disease is by using subjective assessment tools for early detection, which are low cost and easy to implement. Subjective assessment tools include questionnaires or testing methods that individuals perform independently by addressing topics related to physical pain or difficulties with activities of daily living [1]. There is, however, limited evidence to support the use of a single subjective CTS assessment tool to evaluate the effectiveness of preventive and therapeutic CTS interventions [13]. In addition, there is a lack of consistency in the results produced among the tests when administered independently, which may be due to the subjective nature of

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the protocols. An example of this is the modified Phalen's Test, which is a clinical test used to assess CTS [6]. This test requires the patient to actively place the wrists in full flexion, and then press the dorsal aspects of the hands together as hard as possible for 30 seconds [6]. Without an objective method of monitoring the force applied between the hands, it is difficult to ensure that the patient is consistently applying an appropriate and consistent amount of force over the duration of the test.

Objective assessment tools offer a more accurate approach for early detection of CTS. These tools may include ultrasound imaging, magnetic resonance imaging, and electromyography to assess nerve conductions and identify swelling of the median nerve and abnormalities of the tunnel wall [9]. Some of these tools, however, are costly and more difficult to implement. Using a low cost and easy to implement force sensing resistor (FSR) in combination with the modified Phalen's Test administered as a simple test battery may provide an avenue to obtain an objective measure for diagnosing CTS. A FSR is a force sensor built on polymer thick film technology. A FSR externally resembles a membrane switch, but it contains a resistance that varies continuously with an applied force [15]. Positioning a FSR between the dorsal aspects of the hands during the modified Phalen's Test may provide supplemental quantitative data to aid the clinician to more objectively assess the patient. Based on this notion, the purpose of this preliminary study was to examine the reliability of using a FSR in combination with the modified Phalen's Test to establish normative data and develop a simple yet reliable test battery as a possible technique to assess CTS. The outcome of this preliminary study will shed light on future research work that will examine evidence for the validation of this test battery technique to assess CTS.

2. Methods

2.1. Participants

Fifteen undergraduate university students who had no symptoms of CTS participated in this study (eight males and seven females). The researchers selected this population sample in order to more accurately assess the reliability of the test battery technique and establish a reference for future CTS research studies. The participants ranged in age from 21 to 22 years of age. Ethical approval was received from the Lakehead University Research Ethics Board prior to data collection.

2.2. Instruments

Before partaking in the study, the participants completed an Upper Extremity Functional Index questionnaire [8], which was used as a prescreening tool to determine their functional status. That is, to ensure that the participants did not suffer from any musculoskeletal disorders affecting their shoulders, arms, hands and wrists. All participants provided written consent before partaking in the study. A proprietary FSR electronic hardware amplifier connected to a 12 bit resolution analog to digital converter, as depicted in Figure 1, was used to collect the data. The FSR was interfaced to a laptop computer via USB. A visual basic software package was developed to read the FSR and acquire the participants' force exerted during the test battery technique implementation. The force data was collected at a frequency of 1000 Hertz and was measured in Newtons.

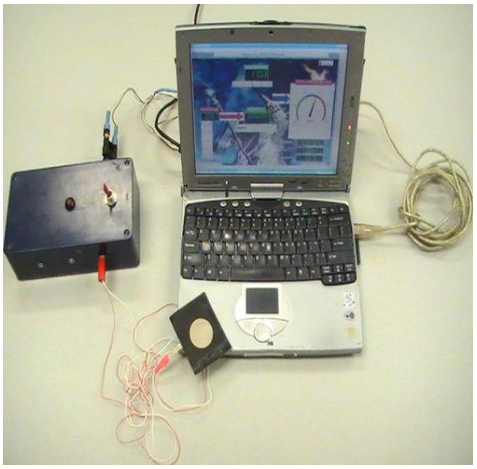

Figure 1. FSR, hardware interface and software package for CTS assessments

2.3. Procedures

The CTS test battery was administered to the participants in the School of Kinesiology Research Center at Lakehead University. Participants came to the test location twice during the week on different days. This approach was implemented to minimize the effect of fatigue as a confounding variable. For each administration of the test, the researchers instructed the participants to follow the same guidelines to complete the CTS test battery. That is, the participants performed the modified Phalen's Test with the FSR pad placed between the dorsal aspects of their wrists. The researchers then asked the participants to press the dorsal aspects of their wrists together as hard as they could, and hold this position for 30 seconds. The researchers recorded the maximum force in Newtons exerted by the participants' wrists for each test administration session.

2.4. Analysis

The researchers conducted a descriptive statistical analysis to compute means and standard deviations to organize and describe the data in terms of gender. The researchers also conducted a mixed factorial ANOVA to examine the effect of time on participants groups (males and females) that could pose a threat to the internal validity of the data. Finally, the researchers conducted an intra-class correlation analysis to examine the reliability of the FSR pad when combined with the modified Phalen's Test across replications.

3. Results

Descriptive statistics revealed that the mean FSR scores for the male participants during the first administration of the test battery (M=52.56N, SD=4.34) was higher than the mean FSR scores for the females (M=40.25N, SD= 2.66). Descriptive statistics also revealed that the mean FSR scores for the male participants (M=55.99N, SD=6.15) during the second administration of the test battery was higher than the mean FSR scores for the females (M=44.81N, SD=3.17) as depicted in Figure 2. Inferential statistics via a mixed factorial ANOVA revealed no effect of time on participants groups. There was, however, a difference between participants groups (males and females) test battery, $F(1, 13) = 16.03$, $p < 0.05$. That is, the males FSR scores were significantly higher than the females FSR scores when combined with the modified Phalen's Test. The intra-class correlations analysis indicated a high degree of reliability of the CTS test battery across replications, $r = 0.91$, $p < 0.05$.

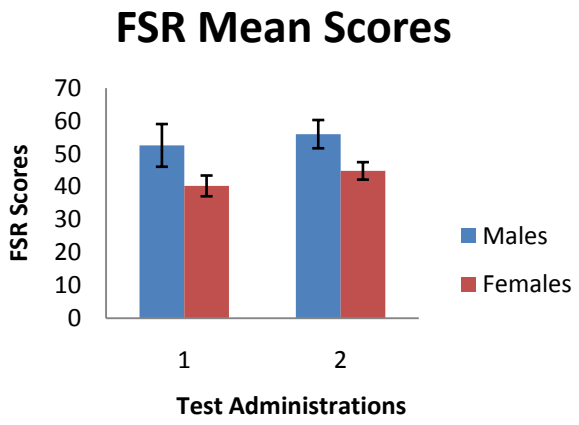

Figure 2. Mean FSR Scores for males and females

4. Discussion

This preliminary study was conducted on healthy individuals to establish normative data for the future development of a simple, yet reliable test battery to be conducted on individuals with CTS to assess the disorder. As stated by Atrosh et al. [2], the irritation of the median nerve in the carpal tunnel space produces symptoms such as tingling, burning, general discomfort, and aching in the affected fingers, which are problematic symptoms for individuals affecting activities of daily living and work tasks. Developing a simple and low cost CTS assessment technique that can be implemented in either clinical or work situations, may help individuals with the early detection of CTS to minimize the progression of the disorder.

The outcome of this preliminary study indicates that using a FSR in combination with a modified version of the Phalen's Test administered as a single test battery on healthy individuals produces reliable results across replications. As the results indicate, a strong intra-class correlation coefficient was found ($r = 0.91$) for the two administrations of the test battery. This finding seems to be promising for future research work that will explore evidence for the validation of this simple and reliable test battery using individuals with CTS. As Emad, Najafi, and Sepehrian [5] indicated, using multiple tests into one test battery proves to be most effective in diagnosing individuals with CTS.

Although the approach used in this study to construct the test battery included a modified version of the Phalen's Test, which involved a forced flexion manuever of the wrist for 30 seconds [6], the outcome of this study revealed that males produced significantly higher FSR values than females during the first and second adminstration of the test. In addition, there was no effect of time on FSR results. Meaning that there were not threats to the internal validity of the data in relation to time for each administration of the test. The standard criteria found for this study in relation to males and females, however, provides an avenue for researchers and clinical professionals to establish a reference based on individuals without CTS for future research involving this test battery as a diagnostic tool for CTS.

While this study is only limited to healthy individuals, it offers an avenue for future research to validate the instrument measures using participants with CTS. As stated by Kane [9] to provide evidence for the validation of an instrument, that is, the degree to which theoretical rationale and empirical evidence support the inferences made from the instrument measures, it is also critical to provide strong evidence of reliability. For this preliminary study, it was important to first assess the reliability of the FSR measures using healthy individuals to establish normative data to better discriminate between healthy and CTS individuals in future research. In addition, individuals with CTS may experience different levels of pain variability before each testing session, which can affect the consistency of the results across replications of the test. As stated by Love [12], individuals with CTS experience degree of pain variability based on the amount of nerve compression over time.

Since the purpose of this study was to examine the reliability of the FSR measures in combination with the Phalen's Test to establish normative data, the degree of pain variability was eliminated by using healthy individuals across replications of the test. Future research work conducted to examine the reliability and validity of the FSR instrument measures in combination with the Phalen's Test on CTS participants will include the Boston Carpal Tunnel self-report pain measure questionnaire by Levine et al. [21]. This questionnaire will be administered before each testing session to account for the degree of pain variability across replications of the Phalen's Test and FSR measures on individuals with CTS.

The results of this preliminary study have implications for future research that will focus on providing evidence for

the validation of this test battery. Some of the limitation of this research work may be related to sample size.

5. Conclusions

This preliminary study examined the reliability of using a FSR in combination with the Phalen's Test to establish normative data and develop a simple yet reliable test battery as a possible technique to assess CTS. The outcome indicates that using a force sensing resistor in combination with Phalen's test provides reliable results across replication of the test, $r = 0.91$, $p < 0.05$ when using healthy individuals. This outcome offers an avenue to establish normative data and for future research to further examine the validation of the FSR measures in combination with the Phalen's Test on individuals with CTS. Finally, the outcome seems to be promising in addressing the need to develop CTS assessment tools that are simple, low cost, and easy to implement in CTS diagnostics for the general population.

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