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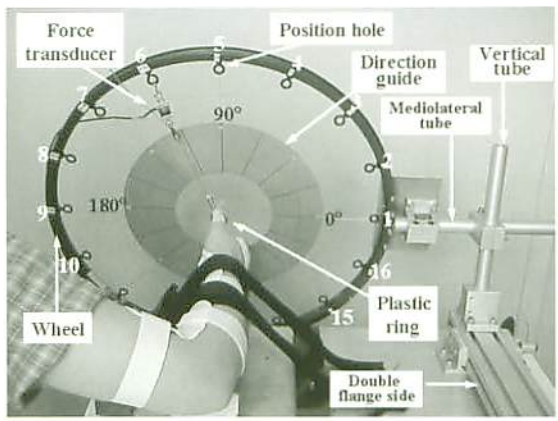
Biomechanical Evaluation of Hand Motor Function

Carpal tunnel syndrome (CTS) is a widely recognized debilitating compression neuropathy. The symptoms associated with it include pain, paresthesia, numbness, weakness, clumsiness, and if left untreated can lead to severe dysfunction of the hand. It negatively affects millions of individuals in their workplaces and in the activities of their daily living. It was the adverse consequences caused by CTS that motivated our study.

Assessment of motor function is an important aspect of the physical examination of the hand, yet existing tests of hand motor function are non-specific, semi-quantitative, or subjective, and also often lack the sensitivity needed to detect subtle but meaningful changes in the deterioration of hand motor function. Therefore, what we believe was needed were more quantitative, sensitive and discriminative methods to detect changes in motor function resulting from pathological conditions, disease progression, rehabilitation, or treatment.

We began by developing a novel apparatus and outcome measures to provide objective, quantitative, systematic, non-invasive, and computer-assisted evaluation of hand motor function. Our apparatus was capable of measuring the force production of a digit at various locations along the digit. The forces can be applied in any direction in the plane perpendicular to the longitudinal axis of the digit. We measured the thumb's maximum voluntary forces either in many isolated directions, or in a continuous and circumferential manner, which allowed us to constructed force envelopes (boundary of maximal forces) for visualization and quantification of thumb motor function. One of the particular advantages is that forces in different directions can be related to the neuromuscular functions of individual muscles, and therefore, our methods have the potential to pinpoint the sources of functional abnormalities.



Apparatus to measure thumb forces in multiple directions

We then studied the thumb motor function of a group of CTS subjects and age and gender-matched controls. On average, the CTS subjects' average forces were 9.9 percent lower than that of the controls, and the area of the CTS subjects' force envelopes were 20.7 percent lower than that of the control group. However, these differences were not statistically significant due to large

individual variations. The percentage contributions of force quadrant to the total envelope did not differ significantly between the CTS and Control groups as well. To study the change in motor function due to surgical treatment, we next tested a subset of our CTS subjects six months after open carpal tunnel release. Our results (with a small sample size) indicated that improvement of thumb motor function after surgical treatment was subject-dependent and did not result in a significant overall change.

In addition to our study of the motor function impairment caused by chronic CTS, we investigated thumb motor dysfunction resulting from acute lower median nerve block at the wrist; a way of simulating severe CTS without the confounding effects of subject variations. We injected bupivacaine hydrochloride (a common anesthetic) into the carpal tunnel to locally anesthetize the median nerve. This temporary median nerve blockage resulted in decreased force magnitudes, and thus smaller force envelopes. The average force decrease around the force envelope was 27.9 percent. The maximum decrease (42.4 percent) occurred in a direction combining abduction with slight flexion, while the minimum decrease (10.5 percent) occurred in a direction combining adduction with slight flexion. Overall, the nerve block caused a decrease of 48.1 percent in the force envelope area.

Our results of chronic CTS subjects support the proposition that motor capabilities, in comparison to other symptoms, are relatively preserved for CTS subjects. The fact that CTS does not preferentially impair thumb abduction strength suggests that the commonly used test of thumb abduction strength may not be an effective means to evaluate the existence or severity of CTS, particularly for mild and moderate cases. Our simulation study demonstrated possible severe motor function impairment as the syndrome develops to advanced stages. Additional studies are needed to further clarify the effects of CTS on thumb strength, for example, monitoring a group of CTS subjects as the severity progresses. We also recommend that future studies focus on functional tasks that require submaximal efforts with sensorimotor integration. By focusing on functional tasks, we hope to create a useful and sensitive tool to quantify the impairment level caused by suspected CTS in patients.

Figure 1. *Robot-assisted testing of thumb motor function*

Figure 2. *Motion analyses of functional opposition of the thumb using VICON motion capture system*