Student: Angus McGregor

Title: Measurement of elbow extensor strength - development and resting of the Troidometer II

Supervisors: Dr Jennifer Dunn, Dr Shayne Gooch and Professor Alastair Rothwell

Sponsor: New Zealand Spinal Trust

Introduction:

Assessment of muscle strength is an important component of neurological examination and is often essential in planning and evaluating medical and surgical interventions. Manual muscle testing (MMT), in which muscle strength is typically assessed on a 0 – 5 scale has been in use for many decades because of its convenience and overall acceptance. The inaccuracies and subjective nature of the approach are widely acknowledged, specifically the inter-subject variability and the wide, difficult to quantify gaps between grades 3 and 4, and grades 4 and 5. Following a cervical spinal cord injury (SCI), and the resultant loss of upper limb strength and function, some surgical procedures can help restore strength to key muscles. One such procedure is a posterior deltoid-triceps transfer (DTT), which aims to restore lost elbow extension following an SCI. After surgery, improvement in strength can be demonstrated using MMT, but the inaccuracies of MMT make the results difficult to quantify. The University of Otago, Christchurch, in conjunction with the University of Canterbury's Department of Mechanical Engineering, developed a new dynamometer – the Troidometer – to measure human strength. The Troidometer was verified in a laboratory setting and found to be very effective at measuring elbow extension strength across the elbow's range of motion. The elbow extension strength of a number of people with SCI's was successfully measured following DTT. Research into DTT is ongoing, but the electronics on the original Troidometer have become outdated in the digital era. By modernising the device's data acquisition system, this project sought to simplify the way the device characterises arm strength.

Aims:

Modify the Troidometer to improve ergonomics for the subject and the clinician. This includes incorporating modern data acquisition to simplify data processing. Develop testing protocols for measuring extension strength in a cohort of normal test subjects to determine test re-test and inter-rater reliability. Determine the minimum number of testing positions that can provide an accurate representation of an individual's strength.

Methods:

Clinician feedback was obtained before upgrading the data acquisition system, with new hardware selected and custom software developed to improve the ergonomic and functional properties of the Troidometer. Fifteen normal test subjects were selected based on age, gender and strength. The subjects were tested using the original method, assessing extension strength at ten degree intervals between full arm extension and 110 degrees toward flexion. Five of subjects were re-tested to assess measuring consistency. Using earlier Troidometer test data and a literature review, a characteristic joint strength equation was established. This equation predicts joint strength over the 0-110 degree interval for both normal and DTT patients. By using a well-known regression algorithm with the equation embedded, the required number of measurements was minimised without compromising accuracy. The algorithm was tested for stability, to ensure that the algorithm (now based on a reduced number of measurements) reliably produces results consistent with those produced using the full data set.

Results:

According to clinician feedback, it was important to keep the Troidometer simple and reliable. With this in mind, processing hardware chosen was an analogue-to-digital converter coupled to a netbook running Windows 7. A simple visual interface was developed using LabVIEW software provided by the University of Canterbury to easily record, save and process patient data. Normal patient testing methods were experimented with, and consistent results were obtained with the subject's shoulder at 90 degrees of abduction so that the shoulder is level with the measurement sensor. Restraining the upper arm prevents a subject's torso or shoulder from influencing the strength readout, and helps to keep their elbow on the centre of rotation. The literature and earlier data reviews found that elbow extension strength in normal subjects is characterised by the triceps and anconeus muscles. These provide an elliptical strength curve, flattened by the slightly different peak strength angles each muscle exhibits. In DTT patients, some of whom have a degree of normal muscle function, the posterior deltoid provides a linear extension strength with a tensioning effect that increases available strength when the arm is flexed past 90 degrees. A single resulting equation is reproducible for normal and DTT patients, and contains three parameters. This equation was found to correlate strongly with extension strength measurements taken from the normal cohort on the 0-110 degree interval. Applying the equation to earlier DTT patient data also revealed a strong correlation in the averaged data sets available. More DTT patient data is required for validation, but the result is promising and more patients are expected to be tested during the course of 2016. Furthermore, a regression analysis incorporating the extension strength equation found that 4 evenly spaced measurements across the joint range reliably produces a result accurate to 5% of a 12 point interpolation. This held for both normal and DTT patient data.

Conclusion:

By reducing the number of measurements from 12 to 4, clinical testing time is reduced by two-thirds. Testing on DTT patients is now expected to take 20 minutes, reducing stress for patients and clinicians. It is advantageous that the upgraded Troidometer allows accurate calculation of elbow extension strength in normal and DTT patients. Although current data suggests the extension strength model is accurate for DTT patients, more data is required to validate this.