INTRODUCTION

The prevalence of shoulder pain and injury in manual wheelchair users (MWUs) is alarmingly high. Bayley et al. found 24% of veterans with spinal cord injury (SCI) had signs of shoulder impingement upon physical examination. Further examination using x-rays and arthrography of the veterans with signs of impingement revealed rotator cuff tears in 65% (Bayley, 1987).

While extremely mobile, the shoulder joint is relatively unstable and relies on surrounding ligaments and tendons to provide its support. During wheelchair propulsion, forces on the pushrim directed toward the hub are necessary to provide friction between the hand and pushrim. However, these forces, acting equal and opposite are transmitted up through the arm and shoulder joint. Repetitive application of large upward forces at the shoulder joint has been implicated as a causative of shoulder pain and injury.

The purpose of this study was to determine the relationship between wheelchair pushrim forces and evidence of shoulder impairment. We hypothesize that MWUs with a higher degree of shoulder impairment will propel with greater pushrim forces.

PROCEDURES

Twenty-six (16 males and 10 females) experienced MWUs with a spinal cord injury at the T-4 level or below enrolled in the study. The average age and years post injury was 34.0 ± 7.6 years and 11.6 ± 5.5 years, respectively.

A standardized MRI examination designed for detection of rotator cuff abnormalities was conducted on both shoulders. Specific sequences were designed to evaluate peritendinous edema, tendon degeneration and tendon tear. The interpretation of the images was made by a musculoskeletal radiologist who was blinded to the study.

Subjects’ own personal wheelchairs were fitted bilaterally with SMARTWheels, force and torque sensing pushrims (VanSickle, 1995). Wheelchairs were secured to a dynamometer with a resistance comparable to that of a tile floor. Participants were instructed to propel at two steady-state speeds: 0.9 m/s (2mph) and 1.8 m/s (4mph) for 20 seconds during which force data was collected.

Shoulder Magnetic Resonance Imaging (MRI) findings were assessed using a modified grading scale of pathology based on accepted radiological criteria (Kjellin, 1991). Pathology of the following anatomical structures was graded: rotator cuff tendons, acromioclavicular joint (degeneration joint disorder (ACDJD) and edema/bursitis), acromion (edema), and coracoacromial (CA) ligament (edema/thickening). In addition, MRI scores for each individual structure were totaled to produce a single summary variable.
Three-dimensional forces, $F_x$, $F_y$, $F_z$, were obtained from the SMARTWheel. $F_x$ and $F_y$ were then transformed to a force directed tangential to the pushrim, $F_t$, and a force radial to the pushrim, $F_r$. The resultant pushrim force, $F$, is defined as:

$$F = \sqrt{F_x^2 + F_y^2 + F_z^2} = \sqrt{F_t^2 + F_r^2 + F_z^2}$$

Peak magnitudes of the $F$, $F_t$, $F_r$, and $F_z$ forces were determined for the first five strokes and then averaged across strokes. A two-tailed bivariate correlation was performed on the group to determine the relationship between pushrim forces and MRI findings. The Pearson correlation coefficients were calculated on a confidence level of $p < 0.05$.

**RESULTS AND DISCUSSION**

MRI results for both left and right sides were highly correlated ($r > 0.95$) and were combined to reduce the number of variables for statistical analysis. In addition, peak forces were highly correlated between right and left sides and across both speeds ($r > 0.8$). Therefore, summary force components were determined by combining side-to-side peak forces and then averaging them across speeds. Statistically significant correlations are shown in Table 1. A sample scattergram is shown in Figure 1.

The function of the CA ligament is to inhibit superior displacement of the humerus from the glenoid fossa of the scapula. Performing various upper extremity activities, like wheelchair propulsion and transfers, tend to force the head of the humerus up into the joint which can over time result in impingement under the acromioclavicular (AC) arch and subsequent inflammation. This study suggests that reducing forces during wheelchair propulsion may minimize the likelihood of developing edema and thickening of the CA ligament as well as slow down degeneration of the AC joint.

### Table 1 - Correlation Coefficients between Pushrim Forces and MRI findings

<table>
<thead>
<tr>
<th>MRI Variable</th>
<th>Force Component</th>
<th>r value</th>
<th>Significance p &lt; 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACDJD</td>
<td>Resultant Force (F)</td>
<td>0.399</td>
<td>0.044</td>
</tr>
<tr>
<td>CA Ligament Edema/Thickening</td>
<td>Tangential Force ($F_t$)</td>
<td>0.392</td>
<td>0.048</td>
</tr>
<tr>
<td></td>
<td>Radial Force ($F_r$)</td>
<td>0.420</td>
<td>0.033</td>
</tr>
<tr>
<td>Total MRI</td>
<td>Resultant Force (F)</td>
<td>0.397</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>Radial Force ($F_r$)</td>
<td>0.415</td>
<td>0.035</td>
</tr>
</tbody>
</table>

Figure 1: Scattergram of peak radial force and CA abnormality at an average velocity of 1.75 m/s

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**REFERENCES**

