INTRODUCTION

Chaffin et al. (1978) demonstrated that when a person is performing an exertion close to his or her maximum strength, movements may cause tissue failure. They defined the job strength rating (JSR) for investigation of job related injuries. The JSR was defined as the ratio of the maximum strength requirement of a job to the average isometric strengths of the workers placed in the job. Subsequent research has confirmed that neither isometric strength nor job demand are sensitive predictors of job-related injuries by themselves, but job demands relative to the maximum isometric strength of the worker is a sensitive predictor (Mostardi et al., 1992; Batti’e et al., 1989).

Overuse injuries are common in manual wheelchair users. To date, no study has compared strength requirements in manual wheelchair propulsion to the isometric strength of the user. The purposes of the current study were: (1) to propose a rating called the Wheelchair Propulsion Strength Rating (WPSR) for assessing the likelihood of injury in manual wheelchair propulsion; and (2) to compare WPSR values for the joints of the upper extremity when ascending ramps with increasing slopes.

PROCEDURES

Ten ambulatory physical therapists with wheelchair experience and no history of serious upper extremity injury propelled a wheelchair up a 3.66 m ramp which could be adjusted to provide four different grades (level, 20:1, 12:1, and 8:1 run:rise, Fig. 1). The wheelchair was equipped with an instrumented handrim and portable data logger that recorded the three-dimensional forces and moments applied to the handrim at a sampling frequency of 100 Hz. The positions of the trunk and upper extremity were recorded at 60 Hz using a motion analysis system (Motion Analysis Corp., Santa Rosa, CA). Subjects propelled the wheelchair up each slope five times. The order in which the conditions were performed was randomized.

Figure 1. A subject propelling the instrumented wheelchair up the ramp.

For each isolated joint motion, the maximum isometric functional strength (torque) was measured using a Cybex II isokinetic dynamometer (Cybex, Ronkonkoma, NY) or custom torque dynamometers. Subjects performed three maximum voluntary isometric contractions 3s in duration for each joint motion. The
average peak torque calculated from three trials for each joint function was used for analysis. The peak joint moments generated in wheelchair propulsion were normalized to those generated in isolated isometric maximum strength tests. Each of these normalized joint moments, expressed as a percentage, was called the WPSR.

**RESULTS AND DISCUSSION**

WPSR values for the level condition ranged from 2.6 to 33.2%. Shoulder flexion had the highest mean WPSR value, at 33.2±13.25%. Pronation also had a relatively high mean WPSR, at 31.5±13.59%. Mean WPSR values for all upper extremity joint functions tended to increase with ramp slope (Figure 2). Increases in mean WPSR from level ground to the lowest ramp (20:1) were dramatic for most joint motions. Shoulder abduction and adduction were the only values that did not increase markedly from level ground values. Mean WPSR values for shoulder flexion exceeded 100% for the steepest ramp (117±44%).

![Figure 2. WPSR values for the major upper extremity joint motions (Sh=Shoulder, El=Elbow, Fl=Flexion, Ext=Extension).](image)

The data collected in the current study demonstrates why shoulder injury is a common complaint among manual wheelchair users. Mean shoulder WPSR values reached 96±35% when propelling up the 12:1 ramp, and exceeded 100% for five of the ten subjects on the 8:1 ramp. Mean WPSR values did not exceed 100% for any other joint function.

Joint strength varies with joint angle and angular velocity. Therefore, an ideal strength rating would take into account these factors. Future studies are necessary to ascertain whether calculating WPSR using isometric strength can be used to predict the likelihood of overuse injuries of the upper extremity in wheelchair propulsion, like its counterpart the JSR has been shown to predict low back injuries.

**SUMMARY**

Mean WPSR values increased dramatically from level ground to the 20:1 ramp. Demands on the shoulder joint approach or exceed maximum isometric strength for many individuals when ascending 12:1 and 8:1 ramps. WPSR values for the wrist and elbow were generally less than those at the shoulder, and rarely exceeded 100%. This data supports previous findings of high incidence of overuse injury in the shoulders of manual wheelchair users.

**REFERENCES**


**ACKNOWLEDGMENTS**

Special thanks to Brian Kotajarvi and Diana Hansen. Supported by NIH grants HD33806 and HD07447.