

# Regulating Shoulder Net Joint Moments During Wheelchair Propulsion

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## INTRODUCTION

Wheelchairs play an important role in maintaining the independence of its users. Wheelchair propulsion requires that repetitive forces be applied to the rim of the wheels. Repetitive loading imposed on the upper extremity during wheelchair propulsion often leads to pain or injury of the shoulder (Mercer, 2006; Koontz, 2002).

The purpose of this study was to identify factors that contribute to the magnitude of the shoulder net joint moments during different phases of the propulsion and determine how these factors are modified during self-selected slow and fast propulsion conditions in user populations with thoracic or cervical level spinal cord injury.

## METHODS

Ten wheelchair users volunteered to participate in this study (n=5 cervical level injury (C6 or C7); n=5 thoracic level spinal injury) in accordance with the Institutional Review Board at the Rancho Los Amigos Medical Center, Downey, CA. The average age of the participants was 43(9) years, average mass was 75(11) kg and average height was 1.71 (0.04) m.

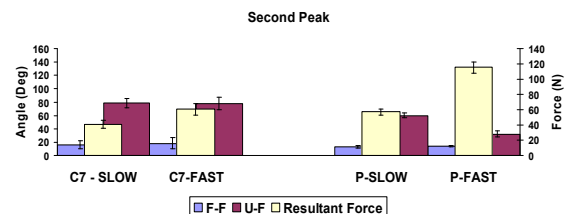
Reflective markers were used to monitor the 3D motion of the hand, forearm, upper arm, and trunk segments. Three markers were also placed on the right wheel to track wheel rotation (Vicon® marker tracking system). The force applied to the wheelchair during propulsion was measured using force transducers mounted along the spokes of the wheel. A four-segment 3D

upper extremity model was generated using segment kinematics (Visual3D). Net joint moments at the time of the first and second peak rim force were determined and compared within subject across speeds. The first peak force occurred immediately after contact with the wheel and the second peak occurred during the push phase (Fig. 1).

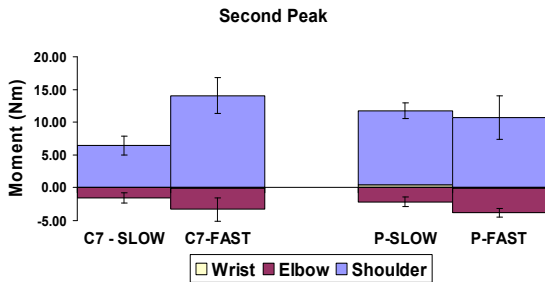
## RESULTS

The magnitude of the shoulder net joint moments were dependent on the force applied to the rim, the relative angle between the proximal and distal net joint forces and the forearm and upper arm segments, and the magnitude of the elbow net joint moment. Users had comparable net joint moments at the elbow during slow and fast propulsion (Fig.2). During fast propulsion, user with paraplegia experienced lower shoulder net joint moment than user with cervical level injury (Fig. 2).

User with paraplegia applied a higher force to the rim yet had a smaller relative angle between the segments and the reaction forces than the user with cervical level injury (Fig.1).



**Figure 1:** Relative angle between forearm and the reaction force (F-F), upper arm and reaction force (U-F) and the magnitude of the resultant force applied to the rim for exemplar users (C-Cervical, P-Paraplegia).



**Figure 2:** The wrist, elbow and shoulder NJMs during the push phase (flexor moment (+), extensor moment (-) for exemplar users (C, P) across speeds (slow, fast).

## DISCUSSION

Net joint moments at the shoulder were regulated either by controlling the relative angle between the force and the segments or by regulating the force itself. Both the cervical and paraplegic user showed a change in the elbow moments direction from flexor to extensor when going from first peak (contact) to the second peak (push). An extensor moment at the elbow during the push phase assists flexor moment at the shoulder thereby contributing to a reduction in shoulder net joint moment magnitude.

Despite having larger reaction forces during fast propulsion, users with paraplegia had smaller shoulder NJMs than users with cervical level injury. These observed differences in shoulder NJM magnitudes for users with paraplegia were related to smaller relative angles between the reaction force and segment angles than those observed for users with cervical level injury. No significant changes in the relative angle between the reaction force and upper extremity segments were observed across speeds for users with cervical level injury.

These observed differences in shoulder moment magnitudes may be associated with the ability of users with paraplegia to control their trunk rotation. Control of trunk rotation allows the user to orient his trunk so that the upper arm can be

more aligned ( $\sim 30^\circ$ ) with the reaction force vector thereby leading to smaller NJMs at the shoulder.

## SUMMARY

Increases in rim forces do not necessarily translate into larger NJMs at the shoulder. Users with cervical level injury used the same technique between slow and fast propulsion. In contrast, users with paraplegia applied greater force to the rim during fast propulsion yet tended to reorient their trunk thereby reducing the magnitude of the shoulder NJM. Future studies will investigate techniques used by wheelchair users with different control deficits to determine mechanisms specific populations use to distribute the mechanical demand imposed on the upper extremity.

## REFERENCES

- Mercer, J.L. et al. (2006). *Clinical Biomechanics*, **21**,781-789.  
 Koontz, A.M. et al. (2002). *J. Rehabilitation Research and Development*, **39(6)**, 635-650