New Jersey Commission on Spinal Cord Research

Final Narrative Report

Principal Investigator: Gail Forrest, Ph.D.
Trevor A. Dyson-Hudson, M.D.

Organization: Kessler Foundation Research Center
1199 Pleasant Valley Way
West Orange, NJ 07052
973-324-3569
gforrest@ kesslerfoundation.org
tdysonhudson@kesslerfoundation.org

Grant Title: Shoulder Pain/Injury Due to Wheelchair Propulsion in SCI

Grant Number: 06-3054-SCR-E-0

Grant Period: January 1, 2006 - December 30, 2009

Date: March 1, 2010

Original Aims of the Project

The original aim of this project was to identify the modifiable biomechanical, physiological, and injury-related factors present during wheelchair propulsion that were associated with shoulder pain (based on results of subjective pain questionnaires and shoulder clinical examination) and shoulder injury (based on results from shoulder x-rays and magnetic resonance imaging [MRI]) in persons with chronic tetraplegia. Our original hypotheses were designed to identify the predictors of shoulder pain and injury in manual wheelchair using persons with tetraplegia. Each hypothesis additionally explored the effect of age, time since injury, neurological level, anthropometry, and actual wheelchair use (as measured by accelerometers) as significant influencing factors.

Shoulder pain and injury is a common medical complication associated with spinal cord injury (SCI). Due to lower limb paralysis, persons with SCI are forced to rely almost exclusively on their upper limbs for mobility and other activities of daily living. Unfortunately, the shoulder is a joint of mobility, not stability. Therefore, the daily performance of weight-bearing activities like manual wheelchair propulsion places a great deal of stress on the shoulder joint and surrounding structures, leading to overuse and repetitive strain injuries. Due to upper limb muscle weakness and balance, persons with tetraplegia may be at even greater risk for shoulder injury and pain. Although a great deal of research has been done on the factors contributing to upper limb pain and injury in manual wheelchair using persons with paraplegia (persons with neurological level of injury T1 and lower), very little has been done in those with tetraplegia who use manual wheelchairs (persons with a neurological level of injury between C5 and C8). Therefore, the purpose of this study was to identify the factors contributing to shoulder pain and injury in manual wheelchair using persons with tetraplegia.

Participants had to have a chronic tetraplegia secondary to a spinal cord injury or disease (motor level between C5 and C8, inclusive) that occurred at least 1 year prior to testing; be between the ages of 18 and 65 years, and use a manual wheelchair for mobility at least 50% of the time. After signing informed consent, all participants underwent a history and a focused physical examination of the shoulder, including range-of-motion, strength (hand-held dynamometer), and provocative tests to elicit shoulder pain, as well as biomechanical and electromyographical analysis of the shoulder during wheelchair propulsion at 2 mph and self-selected speed. Participants also underwent radiographic and MR imaging of both shoulders. The original goal was to enroll 24 persons with chronic tetraplegia.

Project Successes

This project was the largest biomechanical study to date investigating the modifiable risk factors associated with wheelchair propulsion and shoulder pain in persons with tetraplegia, and the first to perform MR imaging in this population. Overall, 22 manual wheelchair using men (mean age, 36.2±11.6; body mass index, 24.2±5.2kg/m2) with chronic tetraplegia (duration of injury, 11.9±7.9y) were enrolled in this study. Data analysis and manuscript preparation are still in progress; however, this is what has been learned to date. Overall, 45.4% (10/22; 6 with unilateral

pain, 4 with bilateral pain) of our subjects reported having shoulder pain within the last month, while 32% (7/22; 4 with unilateral pain, 3 with bilateral pain) reported having shoulder pain when propelling their wheelchairs. Side of shoulder pain was not associated with hand dominance in either case. Preliminary results from MR imaging suggest that most subjects had signs of rotator cuff disease, despite the absence of clinical findings during physical exam. Overall, the presence of shoulder pain did not appear to be associated with either MR imaging results; therefore, it is uncertain whether positive findings on MR imaging are an early sign of rotator cuff injury or a normal artifact in otherwise asymptomatic individuals. The number of participants in our study (sample size) limited our ability to detect significant differences between the two groups; therefore, further research involving a larger number of participants is recommended.

The results from this study provide us with preliminary data in a number of areas relating wheelchair propulsion in persons with tetraplegia. This information can be used in designing larger, multi-center, clinical trials investigating various factors associated with wheelchair propulsion and shoulder pain in persons with SCI.

Project challenges

Participant recruitment for this study was a challenge, thus limiting our sample size. Our original target goal was to enroll 24 participants with SCI.

Implications for future research and/or clinical treatment

Due to lower limb paralysis, individuals with SCI must rely extensively on their upper limbs for their mobility and other activities of daily living. The daily performance of these activities places a great deal of stress on the shoulder joint leading to overuse, injury, and pain. Damage to the upper limb may be functionally and economically equivalent to a SCI of a higher neurological level. Therefore, there is clearly a need for research identifying the modifiable risk factors for should pain in this population so that prevention and treatment programs can be developed.

An unexpected observation made during this study was the overall impact of tire type on wheelchair propulsion in persons with tetraplegia. Wheelchair tires are typically either solid or pneumatic. Solid tires are used by many manual wheelchair users because they require relatively no maintenance, short of replacement, and have no risk of puncture or becoming flat. For these reasons, solid tires are also commonly used on instrumented wheelchair wheels that measure the forces and moments applied to the pushrim during manual wheelchair propulsion. We found, however, that the increased rolling resistance associated with solid tires significantly impacted wheelchair propulsion biomechanics in persons with tetraplegia, even more so than those with paraplegia. This finding has implications with respect to wheelchair prescription in persons with SCI. Furthermore, the use of solid tires on instrumented wheels may impact results and conclusions drawn from wheelchair propulsion studies in persons with SCI. Further research involving larger samples is recommended.

Plans to continue this research, including applications submitted to other sources for ongoing support.

Results from this research will be used as preliminary data to pursue a number of larger grants from the National Institutes of Health and the National Institute for Disability and Rehabilitation Research. These grants will include a larger study investigating the influence of tire type on manual wheelchair propulsion and physical strain in persons with SCI, as well as a study on wheelchair propulsion training as a clinical intervention for the treatment and/or prevention of shoulder pain. Results from the MR images performed during this study will be used as background and preliminary data for a collaborative clinical trial investigating the use of platelet-rich plasma injections for the treatment of persistent rotator cuff disease in persons with SCI that is unresponsive to traditional therapy.

List of presentations and publications emerging from this research, including those in preparation.

Presentations:

Sisto, SA, Yarossi, M, Forrest, GF, Kwarciak, AM, Cole, J, Dyson-Hudson, T, Boninger, ML, Kirshblum, S. Shoulder Biomechanics of Pushrim Impact During Wheelchair Propulsion in Tetraplegia: A Case Report (Paper presentation). International Shoulder Group Annual Meeting, Chicago, IL, October 9-10, 2006.

Yarossi, M, Forrest, GF, Kwarciak, AM, Sisto, SA, Dyson-Hudson, T. Two Segment 3D Kinematic Model of the Trunk in Spinal Cord Injury (poster). Biomedical Engineering Society (BMES) Annual Meeting, Chicago, IL, October 11-14, 2006.

Yarossi, M, Kwarciak, AM, Sisto, SA, Komaroff, E, Dyson-Hudson, T, Boninger, ML. Influence of Tire Type on Wheelchair Coast Down Testing: A Pilot Study (poster). Rehabilitation Engineering & Assistive Technology Society of North America (RESNA) Annual Conference, Phoenix, AZ, June 15-19, 2007.

Yarossi, M., Kwarciak, A., Forrest, G., Dyson-Hudson, T., Ramanujam, A., Kirshblum, S., Boninger, M., Sisto, S.A., Cole, J. Methods for Interpreting Wheelchair Propulsion Biomechanics in Tetraplegia (Poster). International Meeting on Upper Limb in Tetraplegia, Shriners Hospital for Children, Philadelphia, PA, September 17-20, 2007.

Dyson-Hudson, T.A. Upper Limb Overuse Injuries in Spinal Cord Injury (Focus Group). American Paraplegia Society, 53rd Annual Conference, Orlando, FL, August 27, 2007.

Kwarciak, AM., Yarossi, M. Ramanujam, A., Dyson-Hudson, T., Sisto, SA. Influence of Tire Type On Perceived Exertion & Temporal Characteristics of Wheelchair Propulsion. American Congress of Rehabilitation Medicine 85th Annual Meeting and American Society of Neurorehabilitation 15th Annual Meeting, Toronto, Canada, October 2008.

Kwarciak, A.; Yarossi, M.; Ramanujam, A.; Sisto, S.A.; Dyson-Hudson, T. Effect of tire type on manual wheelchair propulsion kinematics in persons with spinal cord injury (Poster). American Congress of Rehabilitation Medicine – American Society of Neurorehabilitation Joint Educational Conference, Denver, CO. October 7-11, 2009.

Publications:

Kwarciak, A.; Yarossi, M.; Ramanujam, A.; **Dyson-Hudson, T.**; Sisto, S.A. (2008). Influence of tire type on perceived exertion and temporal characteristics of wheelchair propulsion (abstract). *Archives of Physical Medicine and Rehabilitation*, 89:E50-1.

Kwarciak, A.; Yarossi, M.; Ramanujam, A.; Sisto, S.A.; **Dyson-Hudson, T.** (2009). Effect of tire type on manual wheelchair propulsion kinematics in persons with spinal cord injury (abstract). *Archives of Physical Medicine and Rehabilitation*, 90:E14.

Kwarciak, A.M.; Yarossi, M.; Ramanujam, A.; Dyson-Hudson, T.A.; Sisto, S.A. (2009). Evaluation of wheelchair tire rolling resistance using dynamometer-based coast-down tests. *Journal of Rehabilitation Research and Development*. 46(7):931-8.

Manuscripts in Preparation

Effect of Tire Type on Manual Wheelchair Propulsion in Persons with SCI
MR Imaging of Rotator Cuff Disease in Persons with Tetraplegia
Shoulder Biomechanics During Wheelchair Propulsions in Persons with Tetraplegia