TRUNK MOVEMENT PATTERNS AND PROPULSION EFFICIENCY IN WHEELCHAIR USERS WITH AND WITHOUT SCI

Alicia M. Koontz, Michael L. Boninger, Ian Rice, Yusheng Yang, Rory A. Cooper
Human Engineering Research Laboratories, VA Medical Center, Pittsburgh, PA, USA
University of Pittsburgh, Dept. of Rehabilitation Science and Technology, Pittsburgh, PA
E-mail: akoontz@pitt.edu Web: www.herlpitt.org

INTRODUCTION

Handrim wheelchair propulsion is a mechanically inefficient mode of locomotion in comparison to arm cranking and cycling (de Groot et al., 2002). In addition, wheelchair propulsion has been associated with high physical strain and repetitive strain injuries (Janssen et al., 1994). The inefficiency of wheelchair propulsion has been attributed to factors such as, improper fit of the user to the wheelchair, decreased strength and poor technique. A recent study found that during propulsion, individuals with paraplegia exhibited paradoxical trunk movements; that is, the trunk moved in the opposite direction of the arms during force production (Rice et al., 2004). The authors suggested that this might be a result of impaired trunk stability due to paralysis of the back and abdominal core muscles. Thus, lack of trunk control may also be associated with lower mechanical efficiency (ME). The purpose of this study was to examine paradoxical trunk movements and ME during two speeds of wheelchair propulsion in two groups of individuals; a group with paraplegia and a group of unimpaired individuals. We hypothesized that the group without paraplegia would be more efficient at propelling a wheelchair despite their lack of experience and training.

METHODS

Subjects: Eighteen individuals (12 men and 6 women) with spinal cord injuries (SCI) ranging from T4 to L4 and seventeen unimpaired individuals (7 men and 10 women) provided informed consent prior to participation in the study. The mean age and years post injury for the SCI group were 37 and 15 years, respectively. The age range for the unimpaired group was 23 – 62 years (mean 36 years) and they had limited to no knowledge about wheelchair propulsion technique.

Experiment protocol: Subjects' with SCI used their own personal wheelchairs while the unimpaired individuals were provided with a test wheelchair that matched their body dimensions. The wheelchairs were fitted on the right side with a SMART^{Wheel} (Three Rivers Holdings, Inc., Mesa, AZ), force and torque sensing pushrim, which measures three-dimensional 3-D forces and moments in a global reference frame. A carbon fiber rigid body chest piece was fitted around the torso via cloth and Velcro^{TM} straps. An infrared emitting diode marker was placed on the chest piece and a three-dimensional camera system recorded the 3-D coordinates (OPTOTRAK, Northern Digital Inc., Waterloo, CA). Subjects were instructed to propel at two steady-state speeds 0.9 m/s (2 mph), and 1.8 m/s (4mph). Propulsion speed was displayed on a 17-inch computer screen placed in front of the subjects. Upon reaching the target speed for one minute, data collection was initiated and continued for 20 seconds.

Data analysis: Kinetic data (sample rate 240 Hz) were filtered and linearly interpolated for synchronization with the filtered kinematic data (sample rate 60 Hz). The propulsion cycle was divided into two phases, push or recovery phase based on the presence or absence of pushrim forces. Number of strokes per second (cadence), percentage of the cycle that comprised the push phase, trunk anterior/posterior range of motion (ROM), and ME for the first ten consecutive cycles were determined and a mean was computed (Table 1). Mechanical efficiency was defined at $Ft^2/Ftotal^2$, where tangential force (Ft) was calculated by dividing wheel torque by the radius of the wheel. We also determined the proportion of the phase (%) that the trunk was moving backward and rearward excursion (mm) of the trunk for the same ten strokes, and for both push and recovery phases (Table 2). A mixed-model ANOVA was applied with within subject factor: speed (slow and fast) and between subject factor: group (unimpaired and SCI) The α value was set at 0.05.

RESULTS AND DISCUSSION

As speed increased, the unimpaired group pushed with fewer strokes per second and spent more time in contact with the rim delivering forces in comparison to the SCI group. ME was higher for the unimpaired group and increased with increasing speed whereas in the SCI group, ME was smaller and decreased with increasing speed. The SCI group exhibited paradoxical motion of the trunk during force production to a greater extent than their unimpaired counterparts during the faster speed condition. In addition, the SCI group had more rearward excursion of their trunk than their unimpaired counterparts at both speed conditions during the push phase.

The unimpaired subjects had no training in propulsion technique and were inexperienced but yet pushed with greater ME than the SCI group which consisted of seasoned wheelchair users. Persons with volitional trunk control can use abdominal and back muscles to some extent to minimize the degree to which reactive forces from pushing forward sends the trunk backwards. In SCI, the body achieves trunk stability in the wheelchair through postural adaptations (e.g, kyphotic posture) that may not be optimal for propulsion. As a result adequately directing the forces tangentially to the wheel may be more difficult or require greater energy expenditure. It's possible that a rigid back support combined with training, may improve ME in persons with SCI.

REFERENCES

De Groot, S. et al. (2002). *Clin. Biomech.,* **17**(3): 219-226.

Janseen, T. W. et al. (1994). *Med. Sci. Sports Exerc.* **26**(6): 661-670.

Rice, I. et al. (2004). *Proceedings of RESNA'04.*

ACKNOWLEDGEMENTS

VA Rehab R&D Service and NIDRR H133A011107.

Table 1: Propulsion measures at both speeds (mean± SD).

	Cadance (1/sec)[b,c]		Push Phase (% cycle)[a,c]		Trunk ROM (mm)[a,b]		Mechanical Efficiency[b,c]	
Speed (m/sec)	**0.9**	**1.8**	**0.9**	**1.8**	**0.9**	**1.8**	**0.9**	**1.8**
UI	1.18 (0.25)	0.83 (0.14)	54.8 (6.8)	52.4 (7.4)	25.5 (10.9)	27.0 (16.2)	0.64 (0.14)	0.74 (0.19)
SCI	1.01 (0.15)	1.33 (0.16)	49.6 (4.9)	45.7 (6.4)	15.7 (5.3)	30.4 (13.0)	0.54 (0.20)	0.46 (0.16)

Table 2: Percent of the phase that trunk was moving backward and excursion during push and recovery (mean± SD).

	Push Phase (%)[b,c]		Push Excursion (mm)[b,c]		Recovery Phase (%)[a,b,c]		Recovery Excursion (mm)[a,b]	
Speed (m/sec)	**0.9**	**1.8**	**0.9**	**1.8**	**0.9**	**1.8**	**0.9**	**1.8**
UI	43.9 (13.7)	30.2 (12.3)	6.54 (3.2)	5.14 (2.4)	62.5 (23.6)	80.3 (13.6)	9.1 (6.2)	22.4 (15.6)
SCI	42.6 (18.0)	52.7 (22.0)	10.0 (5.8)	15.4 (10.4)	59.4 (20.9)	54.2 (19.3)	15.8 (11.8)	16.1 (10.5)

a = significant difference between within-subject factor speed ($p < 0.05$), b = significant difference for interaction between speed and group ($p < 0.05$), c = significant difference for between-subject factor group ($p < 0.05$)