EMG ACTIVITY OF TRUNK MUSCLES DURING WHEELCHAIR PROPULSION

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INTRODUCTION

Paralysis of the core trunk musculature likely contributes to propulsion inefficiency (Koontz et al., 2004). Researchers have been looking into the use of functional electrical stimulation (FES) to improve trunk control, balance and posture in persons with spinal cord injury (SCI). Preliminary findings show that reaching ability can be improved with stimulation of the abdominal and back muscles (Kukke et al., 2002). In order to study the effect of FES on wheelchair propulsion, an understanding of trunk muscle activity during propulsion is needed. This information is necessary to determine the intensity and temporal information for synchronizing the stimulation signals with the propulsion cycle in a future study. Therefore, the purpose of this study was to determine the intensity and timing of trunk muscle activity during the propulsion and recovery phases of propulsion and to observe the corresponding trunk movements.

METHODS

Subjects: One male unimpaired subject provided informed consent prior to participation in the study. He was 24 years old, 58 kilograms and 1.71 meters tall.

Experimental protocol: Bipolar, surface electrodes (Noraxon Inc., Scottsdale, AZ) were placed over three abdominal muscles (rectus abdominis — RA, external oblique — EO and internal oblique — IO), and three back muscles (longissimus thoracis — LT, iliocostalis lumborum — IL, and multifidus — MU). Ten seconds of electromyography (EMG) data were collected with the subject laying supine on the mat at rest to determine the baseline activity levels. In addition, ten seconds of maximum voluntary contraction (MVC) EMG data during maximal effort manual muscle tests were recorded. A test wheelchair was fitted bilaterally with SMART^{Wheel} (Three Rivers Holdings, Inc., Mesa, AZ), force and torque sensing pushrims, and secured to a computer-controlled dynamometer with a four-point tie down system. Infrared emitting diode (IRED) markers were placed on the subject's acromion process and hip to record trunk position in a global reference frame via a three-dimensional motion analysis (Northern Digital Inc., Ontario, Canada). Subjects were instructed to propel at a steady-state speed of 0.9, and 1.8 m/s at a resistance that simulated propulsion up a ramp for one minute before collecting twenty seconds of data.

Data analysis: The EMG data were sampled at 1000 Hz, full wave rectified and smoothed with a 10-Hz low pass filter. The EMG voltages during propulsion were normalized by the highest value attained during the manual muscle tests for each muscle (%MVC). Significant EMG activity was defined as activity with an intensity of at least 3 standard deviations of the mean EMG activity at baseline.

SMART^{Wheel} data were collected at 240 Hz and filtered with an 8th order Butterworth low-pass filter, zero lag and 20 Hz cut-off frequency. Afterwards, the EMG and kinetic data were linearly interpolated for synchronization with the kinematic data collected at a rate of 60 Hz. Trunk flexion angle was calculated based on trunk position during the propulsion trials relative to trunk position in the resting position. Data from all ten continuous strokes on the right side were averaged together to provide a single value for the trial and normalized as percentage of the whole propulsion cycle. The start and end of push phase was determined as the presence/absence of forces detected by SMART^{Wheel}.

RESULTS AND DISCUSSION

In the beginning of the push phase, abdominal muscles (RA, EO and IO) had low levels of activity (Figure 1A), while the back muscles (LT, IL, and MU) showed higher levels of activity (Figure 1B) for both slow and fast speed conditions (Table 1). The trunk was continuously leaning forward from 7 to 11 degrees (slow speed), and 25 to 36 degrees (fast speed) condition during the push phase (Figure 1C). While delivering forces to the rim, the back muscles contracted eccentrically to provide trunk stability and hold the trunk in a flexed position. A forward flexed trunk may help manual wheelchair users transfer their power from their upper extremities to the pushrim thereby improving mechanical efficiency. In early recovery, back muscles acted concentrically to bring the trunk and upper limbs back. Abdominal muscles showed peak activity in late recovery phase (85% to 86 % of the cycle), and contracted concentrically to bring the trunk forward to prepare for the next stroke.

SUMMARY

We are currently extending this study to recruit more subjects. With these data, we plan to develop a stimulation pattern specific for wheelchair propulsion for individuals with SCI who have a functional electrical stimulation neuroprotheses.

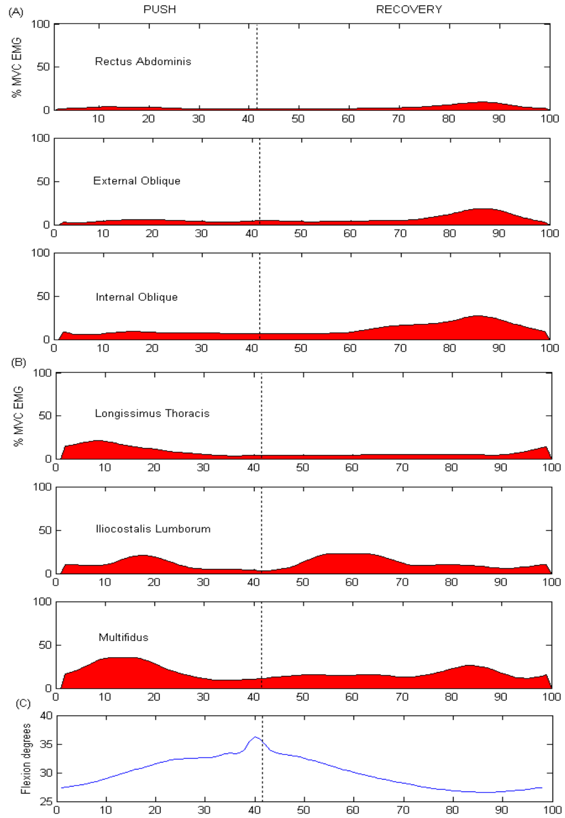

Figure 1. Mean EMG profile of abdominal muscles (A), and back muscles during a stroke cycle at speed of 1.8 m/sec (B). Trunk flexion angle during the stroke cycle(C).

REFERENCES

Koontz et al (2004). *Proceedings of ASB'2004* , in review.
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ACKNOWLEDGEMENTS

NIDRR (H133A011107), and VA Rehab R&D (B3043-C).

		0.9 m/sec						1.8 m/sec					
	Muscle	RA	EO	IO	LT	IL	MU	RA	EO	IO	LT	IL	MU
Push Phase	Duration % cycle	Not active	0-10	0-45	5-38	7-24	0-45	Always active					
	Peak intensity % MVC	Not active	3.6	3.9	9.1	8.7	19.9	3.4	5.8	9.5	20.6	19.9	30.5
Recovery Phase	Duration % cycle	Not active	78-100	46-100	66-100	70-91	46-100	Always active					
	Peak intensity % MVC	Not active	3.6	4.8	7.7	3.8	8.4	8.9	19.0	27.8	14.1	24.6	25.5

Table1. The average timing of EMG activity under two different speeds. The push phase ended at 45% cycle at 0.9m/sec, and 43 % cycle at 1.8m/sec.