USE OF A GEARED WHEELCHAIR WHEEL FOR FACILITATING MANUAL RAMP ASCENT: EFFECTS ON TRUNK MUSCULAR DEMAND

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INTRODUCTION

During wheelchair propulsion, trunk muscle activity is necessary for maintaining an upright posture as well as providing a stable base for upper limb propulsion [1]. While much research has been completed on the upper extremity demands during propulsion on both level and inclined surfaces [2,3], there is yet to be a study of trunk muscular effort during ramp ascent.

The primary goal of the current study was to document the activation required from trunk muscles during wheelchair propulsion on an inclined surface. Secondly, the influence of a geared wheel on trunk muscle activation was also investigated. It was hypothesized that the activation demand from the trunk musculature would increase with ramp grade. Furthermore, the use of a geared wheel would reduce the muscular effort during ramp ascent.

METHODS

Thirteen healthy participants (6 male – age = 23.5 ± 3.5 years, height = 1.73 ± 0.08 m, mass = 77.4 ± 6.4 kg, shank length = 0.45 ± 0.03 m; 7 female – age = 23.4 ± 3.3 years, height = 1.66 ± 0.06 m, mass = 63.3 ± 6.7 kg, shank length = 0.45 ± 0.03 m) without any neurological impairments and no prior history of low-back pain were recruited from a student population. Participants signed an informed consent document approved by the Office of Research Ethics at the University of Waterloo prior to beginning the study.

Participants performed manual wheelchair ramp ascent of four ramp grades (1:12, 1:10, 1:8, 1:6) using three different wheelchair wheels (standard pneumatic wheel (S), MAGICWHEELS® (Seattle, WA, USA) in (G) and out (NG) of gear). Ramp ascent was performed at a self-selected pace.

Electromyographic (EMG) recordings were obtained bilaterally from the rectus abdominis (RA), external oblique (EO), internal oblique (IO), latissimus dorsi (LD) and upper erector spinae (ES) during all ramp ascent trials. Unilateral kinematics of the right upper limb were collected using a 9 camera motion capture system (MX20+, Vicon, Los Angeles, CA, USA). Reflective markers were also affixed to the top and bottom on each side of the ramp and to the anterior frame of the wheelchair. The beginning and end of ramp ascent were defined respectively as the instances when the markers placed on the wheelchair intersected with the markers at the bottom and top of the ramp. Raw EMG data were collected at a rate of 3000 Hz while kinematic data were collected at 50 Hz.

Instances corresponding to the push phase as well as the recovery phase for each propulsive stroke during ramp ascent were extracted from the kinematic patterns of the second metacarpal. EMG data collected during ramp ascent were full wave rectified, low-pass filtered using a single pass Butterworth digital filter with a cutoff frequency of 2.5 Hz and normalized as a percentage to the maximum activity elicited from a maximal voluntary isometric contraction (MVIC). Peak and integrated activities for each muscle were determined separately for the push and recovery phases during ramp ascent. The temporal locations of peak activity within the push and recovery phases were also calculated for each muscle as a percentage of the respective phase duration.

Statistical differences between wheel and ramp conditions were analyzed with a two-factor analysis of variance. Tukey’s post-hoc tests were performed for statistically significant main effects while
Scheffe’s method was used to analyze statistically significant interactions. The level of significance was set to \( p < 0.05 \) for all analyses.

**RESULTS AND DISCUSSION**

Integrated muscular effort during a single propulsive stroke increased with ramp grade for each muscle \( (p < 0.05) \). Peak trunk muscle activity during ramp ascent was higher than previously reported muscle activation levels during level propulsion [1].

RA and EO peak activation during the push phase did not increase with ramp grade during the G wheel condition \( (p < 0.05) \).

![Figure 1](image1.png)

**Figure 1** – Peak activity of the RA and EO for the push phase of wheelchair propulsion during ramp ascent.

Use of a geared wheelchair wheel was able to prevent increased activation requirements from the abdominal musculature during ascent of steeper ramp grades. The peak activity of the RA and EO during ascent of the two steepest ramps with the G wheel condition was reduced by 34% and 24% relative to the NG and S wheel conditions respectively \( (p < 0.05) \).

![Figure 2](image2.png)

**Figure 2** – Location of peak activity within the push phase during ramp ascent.

Peak activity of the abdominal muscles occurred closer to the end of the push phase as ramp grade increased \( (p < 0.05) \).

The geared wheels utilized in this investigation were heavier than the standard wheel by 2.2 kg. However, peak activity of the trunk muscles during the NG condition was not statistically larger than the S wheel condition despite the larger mass of the geared wheel. This is an effect of redistributing the mass on the geared wheel to achieve a similar rotational inertia between the NG and S conditions.

Independence of manual wheelchair users (MWUs) is often predicted by muscular strength and sufficient motor control of the upper limb and trunk [4]. Reducing the demand from the torso musculature by using a geared wheel may allow MWU’s with impaired trunk muscle control or activation capacity to manually propel their wheelchair over longer distances and steeper inclines.

**CONCLUSIONS**

Trunk muscular effort increased with ramp grade during ascent. Use of a geared wheel produced decreases in activation demands of the abdominal musculature during the push phase. The geared wheel may enhance MWU ability to navigate terrains that require higher muscular demands.

**REFERENCES**