KINETIC ANALYSIS OF MANUAL WHEELCHAIR PROPULSION OVER THREE SURFACES

Jennifer Mercer, Michael Boninger, Alicia Koontz, Jon Pearlman, and Rory Cooper
Human Engineering Research Laboratories, VA Medical Center, University of Pittsburgh, Pittsburgh, PA 15206;
email: mercerj@herlpitt.org, web: www.herlpitt.org

INTRODUCTION

Manual wheelchair users (MWUs) encounter a variety of floor surfaces and obstacles during activities of daily living. Some obstacles, such as carpet and ramps, are more difficult to negotiate than a smooth surface [1]. MWUs must increase their propulsion force, stroke frequency, or contact time to propel over these more difficult floor surfaces. Previously, propulsion forces, rate of force application, and stroke cadence have been associated with secondary injuries of the wrist [2] and shoulder [3]. The purpose of this study was to evaluate the biomechanics of wheelchair propulsion over tile, carpet, and up a ramp. We expected to see an increase in propulsion force, torque, rate of force application, pushrim contact time, and cadence, along with decreased velocity, as the MWU propels over carpet and up a ramp as compared to tile.

METHODS

Twenty-three male subjects were consented at The 2004 National Veterans Wheelchair Games (St. Louis, MO). Inclusion criteria included ownership of a manual wheelchair that subjects were capable of propelling and age between 18 and 65 years. Subjects were excluded based on a self-reported history of heart or cardiovascular conditions. Subjects had an average age, height, and weight of 45.8±8.6 years, 1.8±0.14 m, and 99.3±26.4 kg respectively.

The SMART^{Wheel} (Three Rivers Holdings, LLC), a wireless force and torque sensing wheelchair wheel, facilitates biomechanical analysis of wheelchair propulsion over real world obstacles [4]. A SMART^{Wheel} was secured to each subject's manual wheelchair. Subjects were asked to propel at a self-selected comfortable speed over tile, low-pile carpet, and up an ADA compliant ramp while pushrim forces and torques were recorded by the SMART^{Wheel}. All biomechanical variables (Table 1) were calculated based on an average of 5 strokes.

Six separate one-factor ANOVAs with Bonferroni post-hoc analysis were used to compare each of the biomechanical variables (dependent variables) during propulsion over three surfaces (independent factor with three levels).

RESULTS AND DISCUSSION

Table 1 summarizes the comparison of biomechanical variables for wheelchair propulsion over three surfaces. Significant differences were found between the ramp and both tile and carpet for all but one variable (cadence). MWUs used increased resultant force, wheel torque, rate of force application, and contact time. They also propelled slower over the ramp compared to tile and carpet. The same trends were observed for propulsion over carpet compared to the tile, but no significant differences were detected between these two surfaces.

In accordance with our hypothesis, MWUs had to increase their propulsion force, wheel torque, rate of force application, and contact time in order to negotiate the ramp. The MWUs did not increase their stroke cadence but instead went slower up the ramp. Low-pile carpet was used in the study (due to availability) and it may not have provided enough resistance to show significant difference in propulsion over carpet compared to propulsion over tile, as we had expected.

CONCLUSIONS

Unfortunately, using increased force and rate of force application has been previously linked to injury [2,3]. Even with this increased effort, MWUs still propel slower on the more challenging obstacles. It is important that MWUs are able to maintain their independence, without increasing their risk of secondary injuries. Future studies should investigate how changes in wheelchair setup and/or propulsion training protocols can minimize the risk factors for secondary injury that were observed in this study.

REFERENCES

1. Meyers AR, et al. *Soc Sci & Med* **55**, 1435-1446, 2002.
2. Boninger ML, et al. *Arch PM&R* **80(8)**, 910-915, 1999.
3. Boninger ML, et al. *Arch PM&R* **84(11)**, 1615-1620, 2002.
4. Cooper RA, et al. *J Rehab Res Dev* **34(2)**, 162-170, 1997.

ACKNOWLEDGEMENTS

This study was supported by the VA RR+D Center (F2181C).

Table 1: Biomechanical Variables of Wheelchair Propulsion on Three Different Surfaces

	Tile	Carpet	Ramp
Maximum Resultant Force (N)	89.9 (27.1)	95.6 (29.3)	138.3 (22.4)*
Maximum Wheel Torque (N-m)	19.8 (6.8)	22.3 (6.5)	33.9 (5.0)*
Maximum Rate of Resultant Force Application (kN/sec)	1.56 (.87)	1.66 (.75)	2.47 (1.05)*
Contact Time (sec/stroke)	0.51 (.10)	0.54 (.10)	0.74 (.20)*
Cadence (strokes/sec)	0.95 (.17)	1.04 (.20)	1.05 (.23)
Average Velocity (m/s)	1.25 (.27)	1.20 (.31)	0.89 (.33)*

* indicates results significantly different than both Tile and Carpet at $p<.05$ (All Bonferroni corrected p-values were less than .01)
Results listed as mean (standard deviation)