

Differences in propulsion kinetics between wheelchair dependent and non-wheelchair dependent users

Mark Richter^{1,2}, Peter Axelson², Rory Cooper³

¹Stanford University, ²Beneficial Designs, Inc.,

³University of Pittsburgh

Motivation

- Investigation of handrim kinetics provides insight into the demands on the wheelchair user
- Studies enlisting the participation of non-wheelchair dependent (NWD) users risk drawing conclusions which are not relevant to the wheelchair dependent (WD) user population

Previous research: results

- WD users expended less metabolic energy than NWD users for the same propulsion task (Brown et al., 1990)
- WD users tend to have lower peak horizontal and vertical forces on the handrim as well as longer times to reach those peak values (Robertson et al., 1996)

Previous research: conclusions

- Researchers concluded that the lower peak forces and reduced metabolic demand found in the WD users are the result of an optimized propulsion technique

Brown, D.D., et al. (1990). *European J Appl Physiology*, **60**, 179-182.

Robertson, R.N., et al. (1996). *Arch Phys Med Rehabil*, **77**, 856-864.

Previous research: limitations

- Peak horizontal and vertical forces on the handrim were not body weight normalized
 - Weight of the user affects the forces required to propel the wheelchair
- Time to peak forces does not characterize dynamic loading at the beginning of the push
 - “Impact phase”

Specific Aims

- Address the limitations of the previous research by assessing those kinetic metrics not analyzed
- Of particular interest are:
 - Weight normalized handrim kinetics
 - Wheel fixed coordinate system: radial, tangential, axial
 - Average rate of loading over the first 10% of the push (“impact phase”)

Methodology

- 5 WD and 5 NWD users propelled a wheelchair on a dynamometer at a target velocity of 3mph with the resistance set to simulate a 2% grade
 - WD users used their own wheelchair, NWD users used a Quickie Carbon wheelchair
- Propulsion kinetics measured using a SMART^{Wheel} instrumented wheel

Experimental setup



Methodology

- 10 consecutive pushes analyzed
- Data filtered using a 4th order Butterworth digital filter ($f_c = 20$ Hz)
- Forces normalized by body weight
- Transform from inertial to wheel fixed CS
 - Tangential: $F_t = Mz/R$
 - Radial: $F_r = (F_{xy}^2 - F_t^2)^{0.5}$
 - Axial: $F_a = F_z$

Methodology

- Peak force components for each push identified and averaged over each trial
- Average rate of rise of each of the force components calculated over the first 10% of each push and then averaged over each trial
- 2-tailed t-test for means between WD and NWD users: $p < 0.05$

Results: velocity and frequency

Parameter	WD	NWD	Significance (p)
Velocity (m/s)	2.68	3.09	0.053
Push Frequency (Hz)	1.15	1.09	0.697

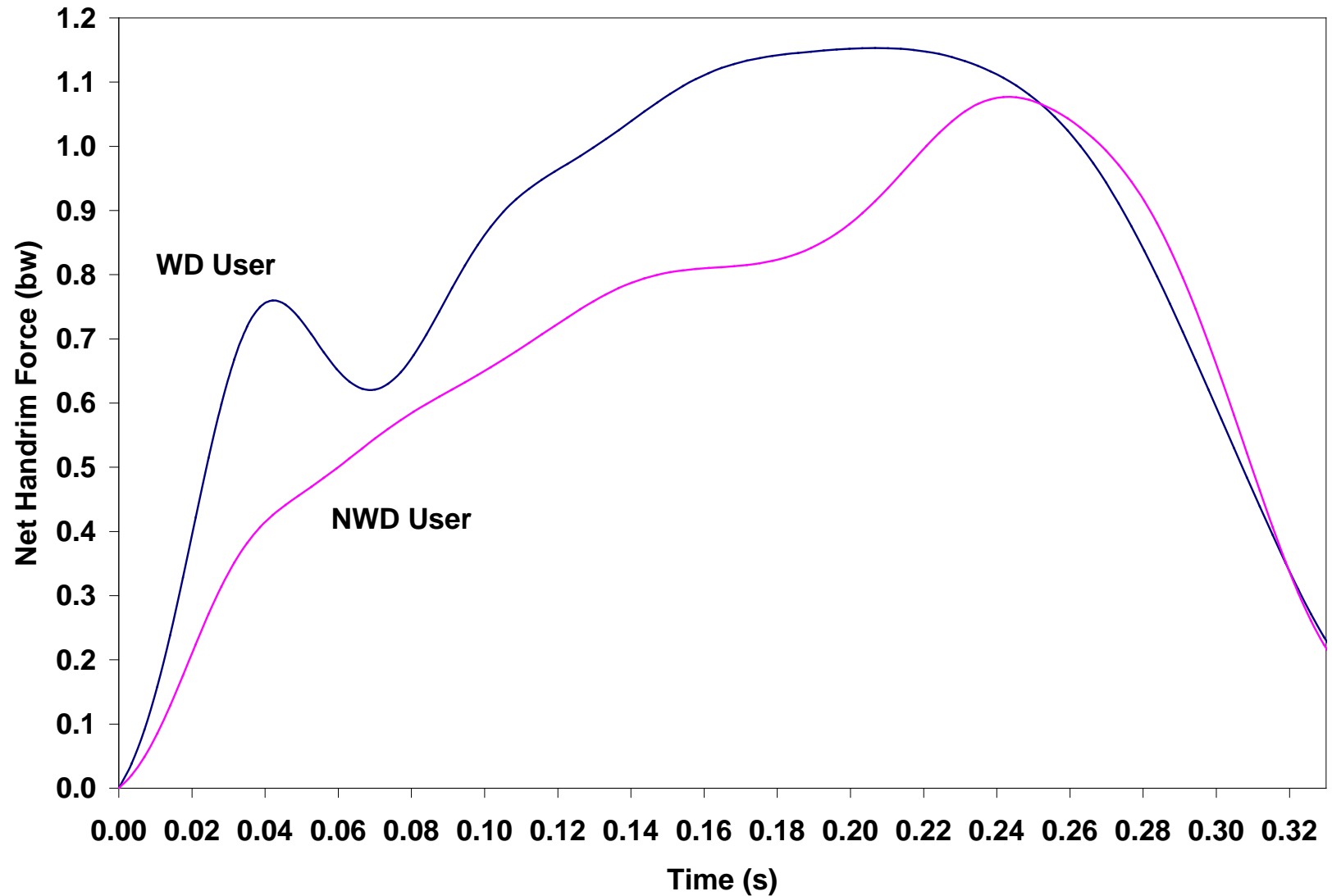
Results: peak force

Parameter	WD	NWD	Significance (p)
Peak Fr (bw)	0.112	0.081	0.070
Peak Ft (bw)	0.072	0.064	0.435
Peak Fa (bw)	0.047	0.040	0.305

Results: rate of loading

Parameter	WD	NWD	Significance (p)
Avg Initial dFr/dt (bw/s)	2.070	1.030	0.035*
Avg Initial dFt/dt (bw/s)	0.434	0.389	0.725
Avg Initial dFa/dt (bw)	1.012	0.470	0.034*

Handrim force profile example



Discussion: propulsion velocity

- Propulsion velocity differences do not explain results
 - NWD users exhibited lower forces and rates of loading while pushing faster
 - Pushing faster would be expected to result in larger (not lower) handrim forces and rates of loading

Discussion: previous research

- While the results of this study appear to contradict those of Robertson et al., the results are not directly comparable
 - Previous research did not normalize forces by body weight
 - Body weight of WD users tends to be less than NWD users due to lower extremity atrophy
 - Likely to result in a reduced net force required to propel the wheelchair

Discussion: rate of loading

- Decreased rate of loading in NWD users is believed to be the result of an actively positioned and stabilized trunk
 - Conclusion may be supported by decreased metabolic demand found by Brown et al. in WD users
 - Metabolic demand would be expected to be greater in NWD users due to the use of the large muscle groups of the trunk during propulsion

Discussion: limitations

- Study was performed using a small number of subjects
- Propulsion environment limited to one speed and one resistance condition

Conclusion

- Results indicate that propulsion kinetic characteristics differ between WD and NWD users
- Future propulsion biomechanics studies should restrict participation to WD users to ensure results are relevant to the intended population

Acknowledgements

- Funding for this research was co-provided by the National Institute of Child Health and Human Development and the National Center for Injury Prevention and Control (NCIPC), Centers for Disease Control and Prevention (CDC) through SBIR Phase I Grant # 1 R43 HD36533-01

Questions