COMPARATIVE FIELD STUDY OF MOTIVATION ROUGH TERRAIN AND WHIRLWIND ROUGHRIDER WHEELCHAIRS

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INTRODUCTION

Comparative field studies of available wheelchairs in low resourced settings which have severely limited financial resources are required (Borg, Larsson, & Östergren, 2011; Toro, Garcia, Ojeda, Dausey, & Pearlman, 2012). These studies provide important feedback to manufacturers to inform design modifications and improvements (Borg & Khasnabis, 2008). It is essential that outcomes studies be done in the settings where these wheelchairs are used because of unique cultural aspects and physical environments (Borg & Khasnabis, 2008). Objective studies are especially important in the changing landscape as more non-profit organizations direct their efforts toward building and distributing wheelchairs designed specifically for low resource settings (Pearlman et al., 2008). Economics would seem to indicate that the lower the cost of manufacturing, the more wheelchairs may be distributed; however, the pressure to produce low cost wheelchairs must be balanced against the need to produce robust, culturally appropriate adjustable wheelchairs that minimize clinical complications related to wheelchair use (Pearlman, et al., 2008).

In some cases, the push for affordability seems to trump the need for a functional wheelchair: depot/transport type chairs, not intended for long term use, are often provided to long term users because they are inexpensive and broadly available (Pearlman, et al., 2008). Wheelchairs are distributed in low resource countries through several different funding and distribution protocols, since the wheelchair users generally cannot pay for the devices (Pearlman, et al., 2008). This model of provision limits user influence on design of chairs since they have limited ability to influence the market, making feedback and accountability for providers through independent studies even more essential (Pearlman, 2006).

To gain a broad understanding of the functionality of a wheelchair type, it is important that multiple approaches be used such as performance studies, user report and professional report studies (Hoenig, Giacobbi, & Levy, 2007; *Towards a Common Language for Functioning, Disability and Health: ICF*, 2002). The Functional Mobility Assessment (FMA), a well validated tool for user feedback on wheelchair function has been modified to visual analogue format with anchors and emoticons for use with children (FMAvas) (Kumar et al., 2013; K. Rispin, Schein, & Wee, 2013). Performance measures, often called skills tests, include physiological and timed tests as users complete common tasks (Fliess-Douer, Vanlandewijck, Manor, & Van der Woude, 2010). A protocol for a suite of skills tests including timed courses for rolling on rough and smooth ground, in tight spaces, ramps and over curbs may be utilized to compare the function of two types of wheelchairs (Karen Rispin & Wee, 2013). Literature indicates that executing a "wheelie," which is balancing on the rear wheels of a wheelchair, is also of key importance in the wheelchair user's ability to get over rocks and rough ground (Kirby, Smith, Seaman, Macleod, & Parker, 2006). The structure of a wheelchair impacts clinical complications such as pressure ulcers and upper extremity symptoms in obligatory wheelchair users; therefore, the assessment of wheelchair outcomes should include assessment for such clinical complications (Janssen, Van Oers, Van der Woude, & Peter Hollander, 1994).

Whirlwind Wheelchair International (WW) and Motivation (MV) are key players in the provision of wheelchairs to low resource settings(Pearlman, et al., 2008). WW, historically based out of the United States, has been moving to a global franchise model of wheelchair production, monitoring quality at franchised manufacturing sites around the world; MV, historically based out of the United Kingdom, has a strong focus on training for appropriate fitting of wheelchairs (Pearlman, et al., 2008) . MV and WW both provide adult sized wheelchairs designed for use by in areas with rough terrain: the WW Roughrider (W-RR) and the MV Rough Terrain wheelchair (M-RT).

We hypothesized that comparative studies for performance, user feedback and professional feedback using protocols likely to produce parametric data would be able to meaningfully differentiate strengths and weaknesses of the M-RT and W-RR wheelchairs, as they are used in the field at our host site. We hypothesized that both the W-RR and M-RT wheelchairs would perform well in most aspects tested, and that M-RT chair would outperform W-RR chair on rough ground, but W-RR would outperform M-RT in tight spaces. We also hypothesized that both M-RT and W-RR chairs would outperform a depot transport chair.

METHODS

Host Organization and subjects: A relationship was built with a host organization which has an agreement to provide rehabilitation for children attending a boarding school in a low resource setting; among other rehabilitation activities, personnel facilitate the fitting and provision of wheelchairs. The physical therapists and occupational therapists employed there have received training to fit and repair wheelchairs; two have also attended the introductory training program provided by the World Health Organization (USAID/WHO, 2012). Our subjects were drawn from the population of wheelchair users served by our host organization. The boarding school is set on a hill with dormitories located some distance from the classrooms. In their daily routine, students negotiate rough ground, ramps, and curbs between dormitories, classrooms, assembly and dining halls. In classrooms and in the dining hall, students navigate around tight spaces. Students may transfer from wheelchair to the ground many times a day during their activities, particularly for personal care and play.

Wheelchairs: MV and WW directly provided 25 wheelchairs each to our host organization, where 23 W-RR and 20 M-RT chairs were fit based on medical need according to World Health Organization guidelines (Borg & Khasnabis, 2008). Both W-RR and M-RT chairs have adjustable axle positions; most were set in the rearward “safe” axle position by local clinicians. Hospital style depot chairs (DP) are ubiquitous and are often the only chair available in many low resource settings; thus we included these in a three way short term comparison of rolling in rough terrain. DP chairs were available at our host site as some had been recently donated and were used for field trips because they fold easily for transport.

Ethics Approval: The study protocol was approved by research ethics boards of LeTourneau University, Queens University and our host organization, and received endorsement from the Kenyan Ministry of Medical Services. Subject consent and assent was acquired from all subjects and their guardians.

Timeline: W-RR chairs were delivered and fit in February 2013. The delivery of the M-RT chairs was delayed by unexpected circumstances, and M-RT chairs were fit in April. In May 2013, the research team from LeTourneau University arrived. Subjects were recruited and performance, user report and professional report data collection was completed. Initial results of all studies were shared with MV and WW in late May and June.

Metrics: Metrics were chosen that were simple to use and likely to result in statistically normal data to enable the use of parametric statistics for more sensitive discrimination of meaningful differences.

User report: Feedback from wheelchair users was obtained using the FMAvas (K. Rispin, et al., 2013).

Performance: The short term repeated measures performance study protocol was modified from that used in an earlier study (Karen Rispin & Wee, 2013). Subjects completed all tests in one chair and then, at least a day later, in the second type of study chair six minute timed tests rolling on rough and smooth ground, and three minute timed tests around a curb and figure 8 track with accompanying heart rate data collection were completed and PCI and distance traveled were calculated. A “wheelie” test was completed along with a test consisting of three timed-transfers to the ground and back to the chair. The order of chair use was randomized as was the order in which tests were completed. Between each test, subjects rested until their heart rate had returned to initial non-exercise heart rate. A three way comparison was completed with subjects rolling for six minutes on rough ground in M-RT, W-RR and DP chairs. For all performance tests, after performing each skill, the user was invited to complete a visual analogue scale question and provide accompanying comment for user report data on the difficulty of each task.

Professional report on maintenance condition: One experienced research physical therapist assessed each of the W-RR and M-RT study chairs using the Wheelchair Parts Questionnaire to rate the specific maintenance condition of 11 regions of each wheelchair and overall (Karen Rispin, Goodwin, Wesley, & Wee, 2013).

Professional report on design A group of clinicians was asked to assess the design of 11 regions of the chair, overall design, and the likelihood that each type of chair would function well with respect to seven properties: durability, function in low-resource settings, prevention of ulcers, enable work/school, enable play/recreation, serve users with cerebral palsy, serve users with spinal cord injury, and easy maintenance in low resource settings.

Clinical assessment: Complications such as musculoskeletal symptoms and skin ulcerations were assessed by research clinicians.

RESULTS

User Report: Subjects included 43 long-term users of study chairs (20 in M-RT and 23 in W-RR chairs) fitted in the wheelchairs based on medical need (ages 10-24 years; 26 M and 18 F). ANOVA analysis indicated no significant difference in FMAvas ratings, with both the W-RR and M-RT chairs receiving high satisfaction ratings. Many subjects had never traveled in a motor vehicle with their wheelchair; thus the question on the FMAvas regarding ease of travel was not included.

Clinical evaluation: No complications were found for M-RT or W-RR chair users; the only exception was due to improper use of a wheelchair by a subject.

Performance: *Two-way M-RT, W-RR comparison:* Subjects consisted of students of the boarding school identified by caregivers as being of appropriate size and having the capability to safely self-propel strongly on rough ground in both types of study chairs, who completed consent and assent forms to join the study (n=33, Ages 10-24 years; 23 M and 10 F). The wheelchairs differed significantly from each other in all measures for the six minute tests, but only for the subject feedback on the three minute tests (Table 1).

Table 1: Two way repeated measures comparison of M-RT and W-RR chairs on six minute tests on rough and smooth ground tracks and three minute tests on figure 8 and curb tracks. 33 subjects completed these tests in one wheelchair type and then the other. P values are for significant differences revealed by ANOVA analysis using Tukey simultaneous comparison of means.

Rough and smooth tracks	P value	Interacton	Advantage
Timed Roll Test (m)	p=0.017	no interaction	M-RT
Physiological Cost Index	p=0.010	Rough: p=0.046	M-RT
User repsonse: VAS (mm)	p=0.005	Rough: p=0.015	M-RT
Curb and Figure 8 tracks			
User repsonse: VAS (mm)	p=0.017	no interaction	M-RT

Ten subjects mentioned difficulty with the W-RR casters getting caught in rocks or in sand. In comments accompanying the user feedback question for the figure 8 course around chairs, 7 subjects mentioned that the W-RR casters knocked against the chairs with 4 specifically mentioning the bolts on the casters bumping the chairs. For the wheelie test, 20 subjects completed the wheelie test in the W-RR chair and 19 in the M-RT chair. Six subjects preferred not to do the transfer test.

Three way M-RT/W-RR/DP comparison: 30 subjects who had taken part in the M-RT/W-RR study the previous week performed one additional six minute test in the DP chair on rough ground. This data was compared to the M-RT and W-RR data. The W-RR and M-RT chairs outperformed the DP chair in all tests (Table 2). In accompanying comments, 26 subjects mentioned the DP chair armrests being too high, and in the way or causing pain; 8 commented on DP front casters getting stuck or wobbling; and 7 commented on unstable or slippery foot rests on the DP chair.

Table 2. Three way repeated measures comparison on a six minute track rolling on rough ground. 30 subjects completed this test in each of the three types of wheelchairs: M-RT,. W-RR and DP chairs. P values are for ANOVA analysis using Tukey simultaneous comparison of means.

Rough ground track	P value	Advantage
Timed Roll Test (m)	p<0.0005	M-RT and W-RR over DP
Physiological Cost Index	p<0.0005	M-RT and W-RR over DP
User repsonse: VAS (mm)	p<0.00005	M-RT and W-RR over DP

Professional report on design: Ten clinicians evaluated the design of the M-RT and W-RR chairs. ANOVA analysis indicated no significant difference in the ratings of the two chair types with both types receiving generally high ratings for design.

Professional report on maintenance condition: The 20 M-RT chairs and 23 W-RR chairs which had been in long term use served as subjects. The M-RT chairs had been in use a little more than a month, while the W-RR chairs had been in use for almost four months. ANOVA analysis indicated that the M-RT chairs were rated as being in better condition than the W-RR chairs with the castors of the W-RR chairs rated more poorly than the other parts.

DISCUSSION

As hypothesized, the M-RT chair outperformed the W-RR on the rough ground track; however, it also did on the smooth ground track. This may be due to the M-RT chair's larger diameter wheels, a larger diameter caster and a longer wheel base than the W-RR chair, factors known to reduce rolling resistance (Brubaker, 1986).

Because of the somewhat shorter wheelbase, we had hypothesized that the W-RR chair would be easier to maneuver and do better in the figure 8 tight spaces track. We had anticipated that the exceptionally long wheelbase of the Motivation chair would hinder movement in tight spaces, but this did not seem to be the case. The PCI and distance traveled for the M-RT and W-RR were not statistically different. In addition, the results for FMAvas questions regarding use indoors use were not significantly different for the two wheelchairs. Comments from subjects after the figure 8 test mentioned the W-RR casters with their exterior bolts often caught on obstacles. In the professional report study for maintenance condition, it was these casters that received lower rating with mention of chips and cracks in the rubber.

As expected, both the W-RR and M-RT chairs dramatically outperformed the DP wheelchairs in the three way comparison on rough ground. These findings could be used to educate donors that it is worthwhile to spend adequate funds to purchase a wheelchair that will provide functional mobility.

We were able to meet with leadership personnel from WW and MV who have expressed the value of this study in supporting their ongoing mission.

Limitations: The unequal time the M-RT and W-RR chairs had been in use before assessment was not ideal, especially for the FMAvas and wheelchair condition studies. Follow-up studies with the M-RT and W-RR chairs planned for May of 2014 should be of value in providing long term assessment of user satisfaction and durability. The "safe" rearward axle positions may have increased the energy cost of rolling for all study chairs. Any maintenance performed on site may have influenced results. However, our real world study sought to assess the function of the wheelchairs as they were used at our host site and these factors were part of the normal use of wheelchairs at that site. Due to time constraints, our study was limited to the selected performance, user report and professional report tests although there clearly could have been additional data collection that would have shed light on the function of the study wheelchairs.

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