A Paired Outcomes Study Comparing Two Pediatric Wheelchairs for Low-Resource Settings: The Regency Pediatric Wheelchair and a Similarly Sized Wheelchair Made in Kenya

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This comparative study of two similar wheelchairs designed for less-resourced settings provides feedback to manufacturers, informing ongoing improvement in wheelchair design. It also provides practical familiarity to clinicians in countries where these chairs are available, in their selection of prescribed wheelchairs. In Kenya, 24 subjects completed 3 timed skills and assessments of energy cost on 2 surfaces in each of 2 wheelchairs: the Regency pediatric chair and a pediatric wheelchair manufactured by the Association of the Physically Disabled of Kenya (APDK). Both wheelchairs are designed for and distributed in less-resourced settings. The Regency chair significantly outperformed the APDK chair in one of the energy cost assessments on both surfaces and in one of three timed skills tests.

Keywords: International Classification of Function (ICF), outcome measurement, outcomes research, manual wheelchair propulsion, pediatric wheelchair, wheelchair

Introduction

Wheelchairs provide a means of mobility for people unable to ambulate. The potential of a particular wheelchair to enhance the user’s ability to function in several of these categories is strongly influenced by characteristics of the wheelchair that impact its ability to provide appropriate mobility (Cooper, Cooper, & Boninger, 2008; Geyer et al., 2003; Greer, Brasure, & Wilt, 2012).

To adequately serve a population of persons with disabilities in a given location, it is important to understand the specific needs of that population (Jeffers, 2011; Jeffers et al., 2010). Although many similarities exist between the needs of wheelchair users worldwide, some specifics are not universal. Appropriateness of technology depends on the environment and culture. For example, many of the world’s less-resourced settings are in tropical environments where daily activities often occur outdoors on unpaved surfaces (Monk & Wee, 2008).

Mobility provision in low-resource settings is also unique because of a lack of resources available for end-users; insurance may be limited or unavailable, and family and community income is often inadequate (Armstrong, Reisinger, & Smith, 2007; Eide & Öderud, 2009; Pearlman, 2006; Wee, 2006). In addition, appropriate fitting by trained wheelchair providers may not be available; this is now being addressed by the World Health Organization’s recently instituted training program (Zollars & Hall, 2012). Several organizations are currently attempting to build chairs specifically designed for use in these challenging low-resource settings (Armstrong et al., 2007; Authier, Pearlman, Allegretti, Rice, & Cooper, 2007; Pearlman, Cooper, Chhabra, & Jeffers, 2009; USAID/WHO, 2012; Winter, Bollini, DeLatte, Judge, O’Hanley, & Scolnik, 2010; Winter, Bollini, DeLatte, Judge, O’Hanley, Pearlman et al., 2010; Zipfel, Cooper, Pearlman, Cooper, & Mccartney, 2007).

For accurate and meaningful data, studies that evaluate functionality of wheelchairs in the settings where they are used are essential (Borg & Khasnabis, 2008; Jutai, Fuhrer, Demers, Scherer, & DeRuyter, 2005; Scovil, Ranabhat, Craighead, & Wee, 2011). Feedback from outcomes studies of assistive devices such as wheelchairs is crucial for effective utilization of limited funds, enabling ongoing improvement and innovation (Cooper et al., 2008; Jutai et al., 2005). Clinical outcome measures provide systematic and quantifiable means of assessing the extent to which assistive devices achieve their intended results (Fuhrer, 2001). Even in high-resourced settings where funding is more adequate and most studies have been done, there are calls for objective studies on wheelchair performance (Cooper et al., 2008).

The World Health Organization’s guidelines for the provision of wheelchairs in less-resourced settings emphasized the need for user trials set in low resource setting to ascertain the appropriateness and effectiveness of wheelchairs provided in such settings (Borg & Khasnabis, 2008). Without feedback, optimal design of wheelchairs intended for use in these settings can only be based on informed guesses (Armstrong et al., 2007; Borg, Lindström, & Larsson, 2009, 2011). Several objective studies of wheelchair
function in low resource settings have been done; however, many of these studies looked at the function of a particular design of wheelchair (Authier et al., 2007; Pearlman et al., 2009; Shore, 2008; Winter, Bollini, DeLatte, Judge, O’Hanley, Pearlman et al., 2010; Zipfel et al., 2007). Literature indicates that donated chairs from developed countries may fail in low-resource settings and cause adverse events (Toro, Garcia, Ojeda, Dausey, & Pearlman, 2012). Comparative outcomes with study participants using one wheelchair designed for low-resource settings and then another are more likely to shed light on strengths and weaknesses of each device, and are known to greatly reduce the impact of individual variation on results (Best, Kirby, Smith, & Macleod, 2006; Kirby et al., 2008). Very few studies done in low-resource settings have included more than one type of wheeled mobility device (Mukerjee & Samanta, 2001, 2005).

Assistive device properties can be mechanically measured using testing devices, they can be assessed by clinicians, or they can be assessed from the wheelchair users’ perspective utilizing questionnaires and physiological or timed tests that look at the impact of the wheelchair’s properties on the user’s mobility (Burke, Kennedy, Miskala, Papadopoulos, & Trentacosti, 2008; Chow & Levy, 2011; Gailey, 2006; Giesbrecht, Ripat, Quanbury, & Cooper, 2009). Objective timed and physiological outcomes metrics can highlight the impact of the wheelchair on the subjects’ mobility; however, most validated assessment tools available to evaluate wheelchair skills seemed to be primarily designed to assess the wheelchair users rather than the wheelchairs themselves (Fliess-Douer, Vanlandewijck, Manor, & Van der Woude, 2010; Haisma et al., 2006; Jette & Haley, 2005; Mortonson, Miller, & Auger, 2008). Some researchers have used skills tests of various sorts to investigate the functionality of wheelchairs or specific parts of wheelchairs (Algood, Cooper, Fitzgerald, Cooper, & Boninger, 2005; Kirby, Corkum, et al., 2008; Kirby, MacDonald, Smith, MacLeod, & Webber, 2008).

This study was undertaken as a step toward addressing the lack of objective paired studies done in less resourced settings. This article, in particular, addresses timed and physiological tests. We hypothesized that selected timed and physiological tests done by subjects using one study wheelchair and then the other would meaningfully differentiate some strengths and weaknesses of these two wheelchairs designed for use in less resourced settings. Specifically, in this study, we hypothesized that the Regency pediatric chair might be expected to outperform the other in individual timed and physiological tests due to the larger wheel size and better manufacturing quality control. Our long-term goal is to facilitate design improvement and improve wheelchair provision by providing our results to collaborating wheelchair manufactures and providers.

**Methods**

**Location**

Data was collected at a boarding school for children with disabilities in Kenya. Due to physical and social barriers in that country, children with disabilities are largely unable to attend school unless they attend a boarding school intended for that population. At this boarding school, more than 150 of the students are wheelchair users. Because the places they eat, play, and attend class are several hundred meters apart via rough sidewalks or unpaved surfaces, wheelchair users at this boarding school typically travel relatively long distances outdoors.

**Wheelchair Provision for the Study**

In the months previous to the broader study, two types of wheelchairs were provided that met identified needs of children at the school. Both were chairs designed for and distributed in less resourced settings. Each had a 30-cm wide seat, options for lateral support, headrest, and lap tray. Twenty Regency Pediatric Wheelchairs made by Joni and Friends International Disability Center (JAF, Fresno, CA) were provided and shipped to our host organization (Figure 1). The Regency chair had 51-cm diameter wheels with 2.5-cm wide solid tires with plastic “mag” spokes and a rigid frame. This chair had two axle positions, both resulting in a very stable configuration with a rear center of gravity. The forward of the two positions was utilized. The design for this pediatric wheelchair was modified from the design of Hope Haven’s KidChair (Hope Haven, Rock Valley, IA). The initial Hope Haven KidChair design was developed by engineering students at Dort University (Sioux Center, IA) and has been refined over the years. JAF modified the design to a smaller frame and seat width, altered it for assembly by a different process, and named it the Regency pediatric chair. In 2009, JAF began
production and global distribution of this wheelchair. Funds for the production and distribution of these chairs are largely provided by charitable donations to the parent organization. For this study, JAF donated 20 Regency pediatric wheelchairs that were shipped to the host organization in Kenya for children at the boarding school.

Ten pediatric wheelchairs were purchased by this study from the Association for the Physically Disabled of Kenya (APDK) and provided to the study population (Figure 2). These wheelchairs had a rigid frame, 56-cm diameter spokeed wheels with 5-cm wide pneumatic tires. The rear axle had been intended to be somewhat adjustable, but the frames for many of these chairs were twisted forcing the axle to be crooked and greatly increasing rolling resistance. The axles were straightened and fixed in the central setting when the chairs were fit. The design for this wheelchair was roughly derived from the 2007 version of Whirlwind’s Rough Rider (Whirlwind Wheelchair, San Francisco, CA). APDK manufactures this wheelchair in Kenya with some parts outsourced to India. Production and distribution is partially funded by a grant from USAID. These chairs are distributed throughout Kenya through APDK’s rehabilitation sites.

Because the host organization therapists were unfamiliar with wheelchair seating principles at the beginning of the study, both types of study chairs were fit to the children under the supervision of a physiatrist (second author) or a RESNA certified seating specialist to ensure appropriate fit. These professionals mentored host organization therapists working at the boarding school, facilitating ongoing appropriate wheelchair provision (Borg & Khasnabis, 2008). A RESNA-certified seating specialists also assessed fit when she arrived on site.

The research team assessing timed and physiological tests arrived in May 2010 after most of the study chairs had been in use for several months. Before data collection could proceed, we found that we needed to address the perpetually flat tires of the APDK wheelchair. We did this by filing off the protruding spokes, adding a spoke protector and replacing the tubes.

**Participants**
For the study presented in this article, a convenience sample of 27 subjects was recruited. All subjects were students at the boarding school and clients of therapists from our host organization in Kenya who work at the boarding school, identified as able to self-propel independently. Potential subjects were approached among the children, along with their caregivers, for consent to participate in this comparative study. Consent and assent forms were completed; these had been developed to satisfy the ethics review boards of LeTourneau University (Longview, TX), Queen’s University (Kingston, ON), and our host organization in Kenya. It was made clear in the letter of information that subjects were in no way obliged to be part of the comparative study and could withdraw at any time without consequences or impact on their wheelchair provision. This was also verbally explained to all subjects and guardians when they completed the assent and consent forms. A protocol was provided to the Kenyan Ministry of Medical Services, which then provided a letter of support for the study.

A RESNA certified seating specialist with 25 years of pediatric experience approved each subject as able and safe to self-propel both study wheelchairs for the purposes of this study. Eight of the subjects were long-term users of one or the other of the study chairs. The others had no previous experience in either of the study wheelchairs, but were long-term wheelchair users. Clinicians from our host organization were present during data collection. Subjects were monitored to ensure they did not become over-fatigued or stressed. They were also asked if they wanted to continue at each stage of the study.

**Outcome Measures**
In the literature for wheelchair skills tests, there seem to be five key wheelchair skills that are included in many assessments, and were selected for this study. These include: rolling on rough ground, rolling on smooth ground, going over a curb, going up and down a ramp, and completing a track in the shape of a figure “8” (Fliess-Douer, et al., 2010; Kilkens, Post, Dallmeijer, Seelen, & Van der Woude, 2003; Kirby, Swuste, Dupuis, MacLeod, & Monroe, 2002). Because these seemed to be the key skills measured, and because time was limited, we did not choose to include any additional skills. All activities performed during this study were common in the subjects’ daily lives. Lap trays were left on the chairs during testing to reflect the manner in which the subjects use them in daily life.

For rolling on rough and smooth ground, we wanted to assess energy cost. The gold standard for assessment of energy cost of propelling a wheelchair is done on a wheelchair treadmill.
at a controlled speed using gas analysis respirometry (Algood et al., 2005; Dallmeijer et al., 2005; van der Woude, Veeger, Dallmeijer, Janssen, & Rozendaal, 2001). Such equipment is simply not available in most less-resourced settings. However, there are well-validated alternatives. We used the timed roll test (TRT) and the physiological cost index (PCI). The TRT is an accepted measure of mobility function that also gives insight on energy cost with the well-validated understanding that people will travel more slowly when the energy cost of travel is higher (Cress, Kinne, Patrick, & Maher, 2002; Kilkens, Post, Van der Woude, Dallmeijer, & Van den Heuvel, 2002; Kilkens et al., 2003; Middleton et al., 2005; Routhier, Vincent, Desrosiers, & Nadeau, 2003). The PCI also provides a simple formula to assess the cost of travel, which has been applied to the energy cost of wheelchair use (Mukherjee & Samanta, 2001; Peebles, Woodman-Aldridge, & Skinner, 2003).

Polar heart rate monitors and watches were utilized to collect heart rate data for the PCI. The resting heart rate to calculate the PCI was obtained after the subject had been sitting quietly in a chair for five minutes. Exercise heart rate and velocity for the PCI were the average heart rate and velocity during the six-minute TRT. The smooth ground test was done on a level sidewalk. The rough ground test was performed on a stretch of unpaved road. Both tracks were measured using a Dura Wheel™ Survey wheel (Stakemill, Largo, FL).

For the ramp, figure “8” and curb test, we timed 12 iterations as subjects rolled on a short track. Twelve iterations were chosen to give sufficient time to enable the sensitivity to differentiate between the two wheelchairs. The presupposition in these timed tests as in the TRT was that a shorter time indicated greater ease of travel. The curb test was performed on an available low curb with a height of 2.5 cm. Parallel lines were drawn 70 cm from the low and high sides of the curb. A timer was started when the subject crossed the lower line for the first time and stopped when they crossed the lower line after 15 iterations. The ramp test was performed on an available ramp with a 5.75% incline and a length of 1.84 meters. Subjects were asked to go up and down the ramp 12 times at a comfortable pace, turning within lines drawn on the surface of the ground. At the end of the session the stopwatch was stopped when instead of turning, the subject rolled forward and crossed the “start” line. The figure “8” track was established with four chairs placed in a row 0.75 meters apart. A start line was placed two meters from the center of the row of chairs. Subjects were timed as they crossed the start line, wave between two of the four chairs in a figure eight pattern fifteen times and returned across the start line.

Undergraduate research students conducted the data collection along with Kenyan clinicians from our host organization. All subjects spoke English as it was the language used in school, but a few were more comfortable in their mother tongue or Swahili. When necessary, the Kenyan clinicians who were very familiar with the subjects acted as interpreters. Subjects completed all tests in an order of convenience, starting with one wheelchair or the other depending on which was available. The order of task completion was also dependent on which testing area was available. After each task was completed, there was a rest period to allow subjects to return to their resting heart rate. Comments were solicited from subjects on the ease or difficulty of each task immediately upon completion. The research team in consultation with the subject assessed if the subject was rested and ready for the next task. To avoid any possible long-term tiredness that might have affected results for the second wheelchair, there was a longer rest period between wheelchairs with the tasks for the second wheelchair usually being done the following day.

The total testing time to complete all 5 tests with one chair was just under 30 minutes; however, the data collection time for each chair was just under an hour because this included time for rests between assessments and time for moving from site to site, such as moving from the location of the ramp to the location of the figure “8” track.

### Statistical Analysis

Data was tested for normality using the Shapiro Wilks test. Data was analyzed by comparing each subject to himself or herself utilizing within subjects analysis of data. Thus, individual subject parameters of age, diagnosis, fitness, strength, style of propulsion and so on, were controlled (Dytham, 2011; Loftus & Masson, 1994). This was done by utilizing three repeated measures ANOVA analyses. One analysis was done for the PCI data, one for the TRT data, and one for the three timed tests. Post hoc paired T tests were also completed.

### Results

Three subjects withdrew because of fatigue, stress, or by choice they were unable to complete all the tests. Twenty-four subjects completed the study. Mean age was 10.5 years ± 2.17 standard deviation. Seven were females and seventeen were males. The ratio of male to female reflects the enrolment ratio at the boarding school. The diagnoses on their medical charts included thirteen with spina bifida and/or hydrocephalus; five with congenital malformations of limbs; two with osteogenesis imperfect; two with cerebral palsy; and one each with club foot and muscular dystrophy.

The Shipiro Wilks test indicated all data sets consisted of normal data. Means and for all tests are given in Table 1. Within

| Table 1. Results and analysis for the six-minute time roll test (TRT). Each subject completed each test in the Regency wheelchair and in the Association of the Physically Disabled of Kenya (APDK) wheelchair. Individual variation was high resulting in a high standard deviation but repeated measures analysis allowed each subject to be compared only to himself or herself reducing the impact of the high variation; see Figure 3. |
| --- | --- |
| Meters traveled in 6 minutes | Smooth terrain, Mean (SD) | Rough terrain, Mean (SD) |
| Regency | 333 (124) | 263 (105) |
| APDK | 286 (130) | 226 (99) |
| Repeated measures ANOVA for both terrains | Factor A – Wheelchairs differ, \( F(1,23) = 22.863, P < 0.001 \) |
| Factor B – Terrains differ, \( F(1,23) = 44.298, P < 0.001 \) |
| Post hoc paired T tests: | on smooth | on rough |
| Wheelchairs differ | \( P < 0.001 \) | \( P = 0.003 \) |
subjects ANOVA indicated a significant difference between the distance the subjects traveled in six minutes in the two wheelchairs with subjects traveling significantly farther while rolling in the Regency wheelchair than the APDK chair (Table 1). There was no significant difference between the PCIs of the subjects while rolling in the two wheelchairs (Table 2); however, the subjects’ PCI values were significantly higher for rolling on rough ground than they were on for rolling on smooth ground. For both the PCI and the six-minute roll test, analysis indicated that neither chair was significantly more advantageous to the user for rolling on rough ground than it was for rolling on smooth ground (Tables 1 and 2). Not all subjects offered comments. Of those who did, three subjects indicated that that the APDK wheelchair pulled to one side and wobbled, and one indicated that the rear edge of the APDK chair’s tray uncomfortably bumped his arm. For both chairs, two subjects commented on castors catching on rough spots and twisting.

For the figure “8,” curb, and ramp course timed tests, analysis indicated analysis indicated no overall significant difference in the time the subjects were able to complete 12 iterations of the course (Table 3). Post hoc T tests with Bonferroni corrections were completed indicating that subjects were able to complete the curb course significantly more quickly in the Regency wheelchair, but no significant difference for the other two tests.

In all tests, there was wide individual variation, and the within subject ANOVA indicated that the subjects were indeed significantly different from each other. Between subject variance generally plays no role in statistical analysis using within subject design in which each subject is only compared to him or herself, the high standard deviation from the mean does not weaken results (Loftus & Masson, 1994). Figure 3 displays the data for the distance rolled by each subject in each chair on smooth ground in the TRT illustrating the wide individual difference and giving a visual image of repeated measures or paired analysis in which subjects are compared to themselves.

### Table 2. Results and analysis for the PCI. Exercise heart rate data and velocity for the PCI was collected concurrently with the TRT (Table 1 and Figure 3). Looking at PCI and TRT data, it seems subjects may have slowed down rather than tolerate a higher physiological cost.

<table>
<thead>
<tr>
<th>PCI during rolling on two courses</th>
<th>Smooth terrain, Mean (SD)</th>
<th>Rough terrain, Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regency</td>
<td>1.12 (0.40)</td>
<td>1.38 (0.46)</td>
</tr>
<tr>
<td>APDK</td>
<td>1.17 (0.36)</td>
<td>1.43 (0.52)</td>
</tr>
</tbody>
</table>

Repeated measures ANOVA for both terrains

Factor A – Wheelchairs differ, $F(1,23) = 0.739, P = 0.399$

Factor B – Terrains differ, $F(1,23) = 35.261, P < 0.001$

Post hoc paired T tests: on smooth on rough

Wheelchairs differ $P = 0.52$ $P = 0.48$

### Table 3. Results and analysis for the PCI. Exercise heart rate data and velocity for the PCI was collected concurrently with the TRT (Table 1 and Figure 3). Looking at PCI and TRT data, it seems subjects may have slowed down rather than tolerate a higher physiological cost.

<table>
<thead>
<tr>
<th>Seconds to complete course 12 times</th>
<th>Curb, Mean (SD)</th>
<th>Ramp, Mean (SD)</th>
<th>Figure “8”, Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regency</td>
<td>176 (75)</td>
<td>243 (79)</td>
<td>516 (215)</td>
</tr>
<tr>
<td>APDK</td>
<td>214 (110)</td>
<td>269 (95)</td>
<td>531 (217)</td>
</tr>
</tbody>
</table>

Repeated measures ANOVA for three courses

Factor A – Wheelchairs differ, $F(1,23) = 3.889, P = 0.061$

Factor B – Skills differ, $F(2,46) = 83.358, P < 0.001$

Post hoc paired T tests: Wheelchairs differ

on curb $P = 0.007$ on ramp $P = 0.084$ on fig 8 $P = 0.48$

### Figure 3. The distance each subject traveled in six minutes in each wheelchair while self-propelling on a smooth surface is displayed. The smooth surface was a level sidewalk. The wide variation between subjects is apparent. A line links the distance traveled by each subject in one wheelchair to the distance that subject traveled in the other chair to demonstrate data analysis in which each subject is compared to him or herself using repeated measures and paired experimental design and data analysis.
Discussion

In the TRT and the curb test, the Regency wheelchair outperformed the APDK pediatric wheelchair. As mentioned earlier, underlying the utilization of the TRT as a measure of energy cost is the understanding that, in general, subjects slow down when the energy cost of travel is higher. If our subjects simply traveled more slowly rather than tolerating a higher energy cost, this could have resulted in the non-significant difference between the PCI values for the two wheelchairs. We did another study in the United States (Ott & Rispin, 2012) in which we measured the energy cost of able-bodied students pushing the two study wheelchairs. We found that the able-bodied pushers had statistically higher PCI while pushing the APDK chair, but the distance they traveled pushing the two chairs for six minutes was not significantly different (Ott & Rispin, 2012). This would seem to confirm that the APDK wheelchair does indeed have a higher energy cost of rolling than the Regency wheelchair.

Our study would seem to indicate that when both wheelchairs are available, the Regency wheelchair, in some instances, might better serve self-propelling clients in settings similar to our host boarding school. The chair provided more ease in rolling on smooth ground and on rough ground and would likely enable children who self-propel to get between classes, their dormitory, and the dining hall more quickly and easily. This may be of significant benefit to children with disabilities who are often functioning much nearer their physiological limits than are able-bodied children (Fragala-Pinkham, Haley, Rabin, & Kharasch, 2005). Low curbs are a regular part of daily life for children in wheelchairs at the boarding school; it would seem that being able to do this task more quickly and easily would also be of tangible benefit.

Because rolling resistance is inversely proportional to wheel diameter, the larger diameter wheels of the Regency wheelchairs may have given those chairs a mechanical advantage in rolling. The larger wheels may have also enabled the chair to roll over some depressions in the ground, which might have stopped the smaller wheels of the APDK chair (Brubaker, 1986).

The less favorable results for the APDK chair may also have been partly due to what appeared to be manufacturing control issues for the APDK chair. In an accompanying study, clinicians and wheelchair technicians who had worked with the chair completed questionnaires on study wheelchair condition and design. They reported that the frames seemed to be assembled asymmetrically resulting in wheels out of alignment, castors out of contact with the ground, and a tendency to pull to one side while rolling; the bolts holding the adjustable footplate in place seemed to strip easily and the footplates would occasionally drop into the castors, stopping the chair abruptly (Rispin, Geyman, Nemati, & Wee, 2012).

Through the parallel study done in the United States (Ott & Rispin, 2012), we knew of these problems before coming to Kenya. We had worked with engineering faculty to devise a way to align the wheels and straighten the axles. After the data collection for the study was completed on the APDK study chairs, the wheels were aligned with a modified axle; soft metal stripped bolts were replaced with better quality bolts; and the frames were straightened as much as possible using a modified pipe bending tool. The cushions were replaced with waterproof cushions and chairs were custom fit with various modifications for specific children. We met with personnel from APDK who were very open and interested in our input.

The results of this study, and the other aspects of our broader study, have been provided to APDK and JAF. Both organizations have evidenced interest in improving the design of their wheelchairs based on our study results.

Limitations

A sample size of 24 subjects is smaller than statistically ideal. However, because we were doing a within-subjects paired analysis, the impact of individual variation was decreased and statistical power was therefore increased. Subjects invited to join the study came from a pool of students who were believed by their caregivers to be able to self-propel well. This would make our data atypical for the weaker wheelchair users because we had chosen for physically capable users. The three subjects who were not able, or chose not to, complete the tests were not included in this study. Our primary goal was to evaluate the impact of the wheelchair on the user’s mobility. Our presupposition was that the impact of any significant difference in the difficulty or energy cost of movement for more able users would likely be similar or be amplified for less able wheelchair users. There may have been some learning effect on the skills test results because subjects were not given a chance to practice before testing; however, we felt this was negligible because subjects did all the skills tested many times a day during their normal routine. A learning or fatigue effect may have also resulted because we did not include a formal randomization of the order in which the wheelchairs were utilized for testing for each subject. Rather than do this and wait for wheelchair availability, we decided to simply use the order of convenience. The result of this was near randomization with the Regency chair being used first in 60% of the trials. Trials also may have been some accommodation effects because none of the subjects was in his or her wheelchair for both sets of tests. The weight of the wheelchairs and the real axle position in respect to the users center of gravity was not recorded at the time of the study; both weight and axle position are design factors that are known to impact the energy cost of rolling.

Wheelchair fit was limited by the design of each chair and not necessarily ideal for each subject. The subjects had not received uniform training on the skills performed and so were performing them in whichever way they had learned to normally use in daily life; however, the paired study design should again have minimized the impact of this individual variation. We realize that subjects would not normally have done 15 iterations consecutively for the ramp, curb or figure “8” track; however, once again, our aim was to differentiate between the 2 types of wheelchair in a meaningful way, and in preliminary testing in the United States, we had found that fewer repetitions did not provide sufficient time to allow the sensitivity to differentiate between the two wheelchairs. In addition, though not normally consecutive, 15 iterations of something very similar to each skill were experienced by many of the children at the boarding school during their daily routine; therefore, we felt that any significant difference imparted by a particular wheelchair in their ability to negotiate these obstacles would reflect impact on the children’s daily lives.

Data collection for another phase of this project (Rispin et al.,
2012), comparing two slightly larger pediatric wheelchairs was completed in May of 2012 and a study with two adult chairs was completed in May of 2013. Plans for dissemination of results are underway.

Conclusion

This study was able to meaningfully differentiate between two similarly sized pediatric wheelchairs produced for use in less-resourced settings. Study results have implications for wheelchair design and manufacturing and wheelchair provision. In fact, the wheelchair providers have expressed great interest in the results of this study and have indicated the intention to improve their wheelchair designs based on the findings of this study. These studies have led to interaction between the organizations providing the wheelchairs. We are hopeful that the Wheels project studies will have a positive impact on the quality of wheelchair provision in Kenya and other less-resourced settings.

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