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RESEARCH PAPER

Comparison between performances of three types of manual wheelchairs often distributed in low-resource settings

Karen Rispin[1] and Joy Wee[2]

[1]Department of Biology, LeTourneau University, Longview, TX, USA and [2]Department of Physical Medicine and Rehabilitation, Queens University, Kingston, Ontario, Canada

Abstract

Purpose: This study was conducted to compare the performance of three types of chairs in a low-resource setting. The larger goal was to provide information which will enable more effective use of limited funds by wheelchair manufacturers and suppliers in low-resource settings. *Methods*: The Motivation Rough Terrain and Whirlwind Rough Rider were compared in six skills tests which participants completed in one wheelchair type and then a day later in the other. A hospital-style folding transport wheelchair was also included in one test. For all skills, participants rated the ease or difficulty on a visual analogue scale. For all tracks, distance traveled and the physiological cost index were recorded. Data were analyzed using repeated measures analysis of variance. *Results*: The Motivation wheelchair outperformed Whirlwind wheelchair on rough and smooth tracks, and in some metrics on the tight spaces track. Motivation and Whirlwind wheelchairs significantly outperformed the hospital transport wheelchair in all metrics on the rough track skills test. *Conclusion*: This comparative study provides data that are valuable for manufacturers and for those who provide wheelchairs to users. The comparison with the hospital-style transport chair confirms the cost to users of inappropriate wheelchair provision.

Keywords

Assistive technology, energy cost, low-resource settings, outcomes, participation, rough terrain, skills tests, wheelchair

History

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➤ Implications for Rehabilitation

- For those with compromised lower limb function, wheelchairs are essential to enable full participation and improved quality of life. Therefore, provision of wheelchairs which effectively enable mobility in the cultures and environments in which people with disabilities live is crucial. This includes low-resource settings where the need for appropriate seating is especially urgent.
- A repeated measures study to measure wheelchair performances in everyday skills in the setting where wheelchairs are used gives information on the quality of mobility provided by those wheelchairs.
- This study highlights differences in the performance of three types of wheelchairs often distributed in low-resource settings. This information can improve mobility for wheelchair users in those settings by enabling wheelchair manufacturers to optimize wheelchair design and providers to optimize the use of limited funds

Introduction

It is broadly acknowledged that outcomes studies are essential to the appropriate provision of assistive devices and enable effective use of limited funds [1–4]. It is estimated that 20 million people in low-resource settings have mobility impairments and are in need of wheelchairs [5]. This urgent need results in pressure to produce very low-cost wheelchairs, which must be balanced against the necessity of providing appropriate seating and mobility [6–8]. Providers of wheelchairs in low-resource settings often find themselves trying to balance quality and cost; in some cases, affordability seems to trump the need to provide appropriate wheelchairs [8–11]. The range of available wheelchairs and training for those who fit wheelchairs is extremely uneven across the globe and in any given setting, the number and type of wheelchairs available through donations or for purchase may be limited to only a few options [7,12]. Thus, wheelchair prescription, as it is usually conducted in high-resource settings, cannot be done in low-resource settings; rather, one must fit the most appropriate available wheelchair to a given user. Often, donors in more affluent regions send hospital-style folding transport wheelchairs to such settings, and in some settings these are the most available wheelchairs. Some organizations, including Whirlwind Wheelchair International and Motivation, have led the endeavor to enable appropriate fitting and wheelchair provision [13–15]. Non-profit organizations and foundations directing their efforts toward providing wheelchairs in

Address for correspondence: Karen Rispin, Associate Professor of Biology, Department of Biology, LeTourneau University, 2100 South Mobberly Avenue, Longview, TX 75602, USA. Tel: 903 233 3352. E-mail: karenrispin@letu.edu

low-resource settings need objective data to effectively focus their use of extremely limited recourses and to evaluate available choices [4,6,16–20].

Performance study measures, often called skills tests, measure performance as wheelchair users complete tasks [21–24]. Methods that directly measure time, distance, heart rate, or energy cost are objective, etc., are well validated [23–26]. Other skills tests are completed by clinicians or users who asses the performance of a skill and assign a rating, and these are subject to inter-user variation [27,28]. Most skills tests include wheelies, transfers, rolling on rough and smooth ground, over curbs, and in tight spaces [23,24,29]. It is crucial that outcomes studies intended to benefit wheelchair providers for low-resource settings be done in the setting where the assistive devices are used so that they will bring into play the various variables and factors that may impact wheelchair provision [1,17]. Challenges include cross-border and cross-cultural interaction which can complicate the process of providing study wheelchairs, obtaining appropriate ethical consent, enrolling participants, and obtaining participant response through questionnaires [22].

This study was conducted because wheelchair manufacturers wished to gain information about how their wheelchairs performed compared to another similar wheelchair made by other low-cost wheelchair manufacturers, and in relation to a hospital transport chair. The goal was to utilize skills testing protocols to provide data which discriminate between wheelchair types and provide meaningful information to wheelchair providers, donors and manufacturers. To that end, tests were selected with the intention of gaining insight on the strengths and weaknesses of wheelchair design as it impacts mobility in the completion of everyday skills. The primary goal of discriminating between wheelchair types led to a secondary goal of selecting types of measures, which could be used in a repeated measures study design and which would increase sensitivity by producing objective data sets appropriate for parametric statistical analysis.

Methods

Study site

A stable relationship was established with a partner organization in Kenya which provides rehabilitation and wheelchair for students at a boarding school for children with disabilities. The school is on hilly region, and students typically traverse sloped and uneven ground, on paved and unpaved surfaces as they travel between dorms, classrooms and the dining hall. Our partner organization benefited through acquiring wheelchairs for clients and training for clinicians. Enabled by backing from this partnership, two of the therapists working for our partner organization at the study site have completed the World Health Organization's level two training in wheelchair fitting [30]. Care was taken to avoid burdening this organization while the research team was present on site; for example, in-country assistants were hired where appropriate. The research team comprised of North American clinicians experienced in wheelchair fitting as well as faculty and undergraduate research assistants. Funding for travel and research was provided by individual fund raising of the research team.

Wheelchairs

Wheelchairs were provided directly to the host organization by Whirlwind and Motivation using their existing funding for wheelchair provision in Kenya. This study focused on the Whirlwind Rough Rider (W-RR) and Motivation Rough Terrain (M-RT) wheelchairs, both of which are intended for users in settings with rough or uneven terrain (Figures 1 and 2, Table 1) [31,32]. Twenty-five Motivation and 25 Whirlwind wheelchairs were delivered by Motivation and Whirlwind directly to our partner organization several months before this study. These wheelchairs were provided to students at the boarding school according to the user need, and provision was not dependent upon their agreement to enroll in any study. Representatives from the wheelchair manufacturing companies were asked to be present during the fitting of the wheelchairs to users and again several months later during this study for first-hand observation of data collection and preliminary results. A representative from Motivation was present at both time periods. A representative of Whirlwind was unable to attend, but indicated that the Motivation representative could also represent Whirlwind. Fitting and assignment of wheelchairs was completed by the organization providing rehabilitation whose personnel had been previously trained according to the World Health Organization guidelines [1,8].

Figure 1. Motivation Rough Terrain (M-RT) wheelchairs utilized in this study were designed in the United Kingdom and built in China. M-RT chairs are distributed around the world by Motivation Charitable Trust which is based out of the United Kingdom [24].

Figure 2. Whirlwind Rough Rider (W-RR) wheelchairs in our study were designed in the United States and built in Indonesia. W-RR chairs are distributed around the world by Whirlwind Wheelchairs which is based out of the USA.

During the initial distribution of the study wheelchairs, two wheelchairs of each type were not fit to users and were reserved

Table 1. Metrics of motivation rough terrain and whirlwind rough rider wheelchairs.

Aspect measured	M-RT	W-RR
Wheel diameter (cm)	66	61
Wheel width (cm)	3.5	4.5
Type of tire	Pneumatic	Pneumatic
Castor diameter (cm)	22	9.5
Castor width (cm)	6	8
Wheel base (cm)	75.1	57.8
Height of front of seat above ground (cm)	55.5	50
Weight (kg)	22	19
Vertical distance seat to foot plate (cm)	38, 42	27–32
Seat widths used in study (cm)	36, 40	35.5, 39.4
Axel positions available	2	4
Mean distance (cm) of CoG forward of rear axe, for axel positions utilized in study		
Forward (M-RT), 2nd from forward (W-RR)[a]	11	11

[a]Wheelchair/user CoG was measured in the USA with able-bodied university students.

These wheelchairs have adjustable widths, axle position and foot rests. The settings used in our study are below.

for this study. All participants were identified as being appropriately sized for the Whirlwind and Motivation wheelchairs reserved for this study. As this was a repeated measures study, all participants completed all trials in both wheelchair types. Participants who were long-term users of one of the study chairs utilized their own chair for that facet of the skills testing, and one of the reserved study wheelchairs for the chair type for which they were not long-term users. For each wheelchair type, one of these was 36 cm wide and the other 40 cm wide. Because participants were selected as appropriately sized for the study chairs, the chairs were not individually adjusted to each user (see below for more details on participants). Both of the study wheelchairs are specifically designed for use in low-resource settings and both organizations strongly express support for appropriate seating.

One aspect of this study included a comparison with a hospital transport chair. This was done to compare the Motivation and Whirlwind chairs to a less appropriate but commonly utilized alternative wheelchair [1,8]. Our goal was to look for objective evidence for the widely agreed upon necessity for appropriate seating [1]. A supply of hospital transport chairs was already at the host site through provision from another donor and were not prescribed to long-term wheelchair users unless there was no other option available, so many were unused except for field trips in which a folding wheelchair was necessary for transport in the school vehicles.

Participants

Several months after the initial distribution of Motivation and Whirlwind wheelchairs, appropriately sized participants were invited to join this study from the complete pool of wheelchair users at the study site who had sufficient skills and fitness to safely self-propel on rough ground for 6 min without undue stress. A total of 33 participants completed this study (23 M, 10F; age 16.3 SD 3.9, ages ranged from 11 to 21 years). The groups of participants overlapped but were not identical to those who had been fit with Motivation and Whirlwind chairs several months before the study (13 Whirlwind users, 9 Motivation users, and 10 users of other wheelchair types). Diagnoses by the clinicians at our partner site were as follows: 11 spina bifida, 6 spinal cord injury, 5 osteogenesis imperfecta, 3 tuberculosis of the spine, 3 cerebral palsy, 2 arthrogryposis, 1 proximal femoral deficiency, 1 polio and 1 amputation. One participant withdrew after one day due to illness. One chose not to try to do a wheelie in the Motivation wheelchair; all the rest tried to do so, but 14 were unable to do the wheelie track in either wheelchair. Two chose not to do the curb test. Six chose not to do the timed transfer to the ground test. Three chose not to do the rough ground test in the hospital transport wheelchair.

Skills tests

A group of skills common to most published skill assessments and which would produce continuous data in a repeated measures protocol have been developed and have undergone refinement through several studies [33]. The skills protocol for the Motivation and Whirlwind wheelchairs included a timed transfer test and five measured tracks, two used in 6 min timed roll tests and two in 3 min timed roll tests. The 6 min tests were on a track on the smooth paved-level surface around a swimming pool and a track on the rough surface of an unpaved road. The 3 min tests were as follows: a tight spaces track consisting of a figure eight around the middle two chairs of a line of four chairs placed 70 cm apart, a track that included two 9 cm curbs, and a track on a smooth floor which was completed with the front castors off the ground in what is commonly known as a wheelie position. For the wheelie track, participants were first asked if they could balance with their front castors off the ground. Those able to do so for 30 s were asked if they would like to complete the wheelie test. For all timed tracks, the Physiological Cost Index [34] was calculated with exercise heart rate collected from the last 4 min of the 6 min tests and last minute of the 3 min tests. Heart rate was obtained with a PolarPro S400 or S800 heart rate monitor, and distance was measured with a survey wheel. For the timed transfer to the floor, participants were timed as they transferred to a gym mat on the ground, raised their hands in the air, transferred back to the wheelchair seat and raised their hands in the air; this cycle was completed three times. After performing each skill, participants completed a visual analogue scale question to rate the ease or difficulty of the skill and explained their rating in an accompanying comment to provide participant feedback. A 100 mm visual analogue scale was utilized with emoticons and school grades as anchors. The positive end of the scale was the left-hand end of the VAS line, anchored by ''A'' grade and a smiley face, therefore a greater number of mm indicated a more positive score. Some initial validation has been done and ongoing validation for this format is underway [35,36].

Participants performed the suite of skills tests in one type of study wheelchair, and then a day later in the other. The order of wheelchairs utilized was randomized, as was the order of skills. The only aspect of the study which included the hospital transport chair was the 6 min test on a rough surface. A day after participants had completed all the skills tests in Motivation and Whirlwind wheelchairs, participants were asked if they would like to complete the rough surfaces test in a hospital transport chair.

Ethics approval

The protocol was approved by the Institutional Review Board of both authors' universities and our partner organization's ethics committee. Approval was sought, and a support letter was obtained from a representative of the Kenyan Ministry of Medical Services. Informed consent and assent were obtained from all participants and their guardians. Participation in all studies was voluntary and participants were allowed to withdraw at any time or opt out of any study or any aspect of any study.

Statistical analysis

After data were tested for suitability for parametric analysis, comparative analyses were performed using an analysis of variance (ANOVA) approach. The focus of this study was primarily on the wheelchair main effect since discrimination between wheelchairs was the focus of this study. If significant interaction was indicated between the ANOVA main effect for ''wheelchair'' and ''measure'', a comparison of treatment means was conducted using Tukey's simultaneous comparison method to determine specifically which means differed significantly. The repeated measures design meant that variation between participants could be modeled using a blocking term, thus significantly increasing sensitivity. To record qualitative data from participants, comment topics were counted across questions, and only counted once per participant, so that if one participant made the same comment regarding one wheelchair type on several questions, it was not counted more than once. Although grouping comments into topics was necessarily subjective, great care was taken to accurately interpret the participant's meaning.

Results

This study was able to discriminate between study wheelchair types, and all tests produced quantitative data suitable for analysis using parametric statistical methods and also provided descriptive and qualitative information through comments accompanying the participant visual analogue scale question. In all trials, individual variation was high as might be expected from such a diverse group of participants. This resulted in high standard deviation in means, but repeated measures, study design and analyses allowed each subject to be compared only to him or herself removing much of the loss of sensitivity due to high variation.

On the smooth and rough 6 min track tests, ANOVA for the wheelchair main effect indicated that the Motivation wheelchair outperformed the Whirlwind wheelchair in distance traveled, physiological cost index and participant response visual analogue scale result measures (Table 2). ANOVA of the test type main effect indicated that there was a significant difference between rough and smooth track results for all three measures. There was no significant interaction between the wheelchair and skills factors indicating that differences between wheelchairs were consistent across the smooth and rough tests.

In comments accompanying the participant visual analogue scale question for the rough ground track, 15 of the 33 participants commented that they got stuck in gravel or on obstacles in the Whirlwind chair while only five did so in the Motivation chair. In the Motivation chair, five participants commented on slippery footrests and four commented that the push-rims were uncomfortably close to the wheels. Participants commented that the castor/s were helpful on rough ground (11 for Motivation, 4 for Whirlwind), the wheels were helpful on rough ground (six for Motivation, seven for Whirlwind) and the push rims were helpful on rough ground (two for Motivation, seven for Whirlwind).

For the test which timed three transfers to the ground and back, there was no significant difference between wheelchairs in the seconds to complete the test or on the participant response visual analogue scale question (mean for Motivation 122 s, for Whirlwind 124 s). For both wheelchair types (nine for Motivation and five for Whirlwind) participants commented that the front rigging and foot supports were in the way when transferring. Others commented that the front rigging and foot rests were helpful for transferring (17 for Motivation, 8 for Whirlwind).

On the curb, tight spaces and wheelie tracks, the ANOVA for the participant response visual analogue scale question indicated that the Motivation wheelchair received higher participant ratings.

Table 2. Analysis of variance results for the wheelchair main effect for the 6 min tests on the rough and smooth track comparison of the Whirlwind and Motivation wheelchairs.

Test	Wheelchair factor
Distance traveled in 6 min	$F(1,32)=6.78$; $p=0.011$
Physiological Cost Index	$F(1,32)=7.51$; $p=0.007$
Subject response rating (mm)	$F(1,32)=6.08$; $p=0.007$

Table 3. Analysis of variance results for the wheelchair main effect for the 3 min tests on the curb, tight spaces and wheelie track comparison of the Whirlwind and Motivation wheelchairs.

Test	Wheelchair factor
Distance traveled in 3 min	$F(1,32)=0.33$; $p=0.57$
Physiological Cost Index	$F(1,32)=0.64$; $p=0.42$
Subject response rating (mm)	$F(1,32)=7.8$; $p=0.006$

Table 4. Analysis of variance results for the wheelchair main effect for the three way 6 min tests on a rough track.

Test	Wheelchair factor
Distance traveled in 6 min	$F(2,32)=151.5$; $p<0.001$
Physiological Cost Index	$F(2,32)=19.91$; $p<0.001$
Subject response rating (mm)	$F(2,31)=32.95$; $p<0.001$

This is a comparison of the Whirlwind and Motivation wheelchairs with a hospital-style transport wheelchair.

There was no significant interaction between the wheelchair and skill factors indicating that differences between wheelchairs were consistent across these three skills tests. There was no significant difference in between the wheelchairs on these tracks for meters traveled or for physiological cost index (Table 3).

For the tight spaces track between chairs, participants commented that the wheelchair was difficult to turn (three for Motivation and eight for Whirlwind), that the front rigging was in the way in tight spaces (seven for Motivation, four for Whirlwind), seven commented that in the Whirlwind chairs the bolts on the outside of the castors got caught on the chair legs, and seven commented that the Motivation single front castor turns well. For the curb track, participants mentioned that it was difficult to climb up the curb (eight for Motivation, seven for Whirlwind), that the castors were heavy to lift up the curb (6 for Motivation, 10 for Whirlwind), and that castor/s were helpful on the curb track (18 for Motivation, 3 for Whirlwind). For the wheelie track, participants commented that the front of the wheelchair was heavy in a wheelie (four for Motivation, five for Whirlwind) and five commented that the back of the Motivation chair was uncomfortable in a wheelie position.

In the three-way comparison on the rough ground track, the wheelchairs differed significantly for all measures (Table 4). The mean distance participants traveled on the rough track in 6 min in the three wheelchair types illustrates the magnitude of the difference in participants' performances in the three wheelchairs: 186 m in the hospital transport wheelchair as opposed to 380 m in the Motivation chair and 358 m in the Whirlwind wheelchair. This very large difference was also apparent in participant ratings and physiological cost index. There were no positive comments for the hospital transport chair. Twenty-six participants commented that the arm rests were in the way, eight commented that the castors got stuck, seven that the footrests were unstable or slippery, five that the wheels spun without engaging and five that the push rims were slippery.

Discussion

Motivation and Whirlwind have recognized that uneven terrain is often encountered by users in low-resource settings, and their intention to design wheelchairs that roll well on rough surfaces is reflected in the names of the two study wheelchairs, W-RR and the M-RT wheelchairs. Both have a long wheelbase and large front castors, characteristics known to reduce rolling resistance on rough ground [37]. These characteristics are also of interest in settings with higher resource levels for wheelchairs used for hiking and outdoors, and the W-RR is available in the USA for that purpose [14]. The Motivation chair performed significantly better than the Whirlwind chair on the rough and smooth ground tracks, possibly because the Motivation chair has an even longer wheelbase and larger diameter wheels and castors than the Whirlwind chair, factors known to reduce rolling resistance [37]. On the rough track, comments for Motivation which indicated that the push rim was too close to the wheel are of concern because participants indicated that this can result in damaged hands. Some avoid the push rims and use the wheel itself; however, it would seem that many would prefer not to get their hands dirty on the way to class or meals. Comments on unstable or slippery footrests for the Motivation wheelchair indicated a problem that seemed especially difficult for taller users whose feet tended to slide off onto the single front castor.

The frequent comments on the castors of the Whirlwind chair getting stuck may be due to the fact that they are less than half the diameter of the Motivation castor and the height of an obstacle that will stop a wheel is also proportional to wheel diameter [38]. This may also be why several participants mentioned that the Motivation castor was helpful on the curb track.

Although the Motivation chair received higher ratings on the participant response visual analogue scale question on the wheelie track, it is concerning that participants also commented that the back rest of the Motivation chair is uncomfortable in the wheelie position. This is of special concern since wheelies are important skills for self-propelling wheelchair users who often encounter rough terrain [29]. Part of the selection criterion for the skills tests was that participants be identified as able to self-propel well on rough ground. However, a little more than a third of these strong participants could not complete the wheelie track in either chair type. The Wheelchair Skills Program was taught at the study site in 2011, but many of the participants in this study were not part of that training. Teaching wheelchair skills on a regular basis would very likely enhance mobility [39].

The Motivation chair has long front beam and a single castor anterior to the foot rest producing a very long wheelbase, a characteristic which has thought to have a negative impact on mobility in tight spaces [40]. However, our study did not seem to confirm a negative impact of this very long wheel base. This may have been somewhat masked because both wheelchairs have long wheelbases and, in fact, both received negative comments on the footrest and front rigging being in the way. However, participants gave higher visual analogue ratings for the Motivation chair and gave positive comments on the helpfulness of the ease of turning. Whirlwind received more comments on the difficulty of turning the chair possibly because a single larger, and somewhat narrower castor, has a lower turning resistance than two wider castors [38]. In addition, it may be that the very long wheelbase of the Motivation chair might have been more of a liability if there had been obstacles along the lateral sides of the line of four chairs that made up the tight spaces track.

Motivation and Whirlwind have designed the two wheelchairs used in this study for active users who do not need trunk, hip or head support, and they express this clearly on their websites [31,32]. However, the fact that not all the long-term Whirlwind and Motivation users were able to join this study is partly due to the fact that of these wheelchairs were provided to weaker users, some of whom would likely have benefited from trunk, hip and head support. This occurred because the Motivation and Whirlwind wheelchairs provided for this study were a significant proportion of the wheelchairs available at our main study site. In low-resource setting, the ideal wheelchair for a user may not be available and clinicians fitting wheelchairs must match the best wheelchairs for users with what is available [8,18]. Worldwide, there seems to be very few appropriate low-cost wheelchairs for teens and adults who need lateral supports [8]. We hope that manufacturers such as Motivation and Whirlwind would take into consideration the potential need for such accessories in future designs. These, often weaker, users also need more frequent assistance rolling on rough surfaces or for long distances, and we observed that even users able to self-propel well may need assistance on rough surfaces or for long distances, or if castors get stuck on uneven terrain, as was reported by many Whirlwind users. Therefore, we feel that wheelchairs designed for use in low-resource settings should be designed to enable assistant pushers to move the wheelchairs without difficulty, especially on uneven terrain.

Several of the differences between the Whirlwind and Motivation wheelchairs would not have been statistically apparent without a repeated measures study design in which participants are compared to themselves, thus essentially eliminating much of the impact of individual variation [41]. As we had hypothesized, selecting this type of study design did increase sensitivity and enable meaningful discrimination between wheelchair types. Unlike the 6 min tests, the 3 min tests on the curb track, wheelie track and tight spaces track did not discriminate between Whirlwind and Motivation other than through the participant response visual analogue scale question. This may have been partly because of the shorter duration of these timed tracks since data from longer timed tests are known to be more sensitive to differences between users simply because of there is more time to magnify and demarcate a slower rate of travel [42]. There is always a tension between the ability to collect optimum amounts of data and the primary importance of respecting the participant's energy and time constraints [43].

In results from the comparison of the hospital transport chair to the Motivation and Whirlwind wheelchairs on the rough ground track, the hospital transport chair performed more poorly than the other two wheelchairs in all measures that these differences would not have been obscured by individual variation; in other words, if the data analysis is done as though we were not using a repeated measures study design, the differences are still significant. It is interesting that in spite of the much better ratings for the Whirlwind and Motivation chairs, the castor diameters sizes of the three wheelchairs parallel the frequency of the comment that castors were getting stuck, with the Motivation chair receiving the least negative comments on getting stuck (5), the hospital transport chair with intermediate-sized castors received an intermediate number of negative comments (8), and Whirlwind with most comments to that effect (15). Most participants commented on the arm rests of the hospital transport chair, so perhaps the results would have been somewhat altered if the arm rests had been removed. However, the chairs are most often provided with armrests, and clinicians at our partner site observed that chair users often do not remove the armrests themselves.

The finding that Motivation and Whirlwind both very significantly outperformed the hospital-style folding transport wheelchair in all measures was not surprising given that the transport wheelchair is not designed for self-propelling users or for rough ground. The very poor performance of the transport chair as compared to Whirlwind and Motivation wheelchairs may be of special interest to organizations that may have chosen to distribute these low-cost transport wheelchairs instead of more appropriate wheelchairs. This happens quite frequently when well-intended donor agencies seek to provide as many wheelchairs as possible with limited funds, without fully understanding what this choice will mean in mobility and health costs to the users [8,18]. For example, in the past, hospital transport wheelchairs were sometimes the only type of wheelchair available to our partner organization, and consequently users with those chairs had limited mobility, and although this skills study does not address the issue of clinical complications, inappropriate seating also increases the risk of clinical complications [1,44]. The objective findings in this study strongly support clinical recommendations to provide appropriate seating for obligatory wheelchair users [1,12].

Limitations

This study only covers one part of wheelchair function and offers no direct insight into the clinical appropriateness of the wheelchairs to their users or the durability of the study wheelchairs. However, the study described in this article was part of a suite of studies which included studies on wheelchair durability, patient reported outcomes on mobility, satisfaction and participation, and professional report outcomes from clinicians on wheelchair durability, design and clinical appropriateness to users. Analysis and publication of results from other studies is underway.

Participant selection for very strong self-propelling wheelchair users may limit the value of results for weaker populations. This study did not include those who could not self-propel or could only self-propel on smooth ground or for short distances.

Accommodation to a wheelchair and skill in using that wheelchair are both important to effective mobility. Wheelchairs are not exactly alike, so participants who were long-term users of Whirlwind or Motivation chairs may have favored the wheelchair they are more familiar and comfortable with. However, 13 participants were Whirlwind users and 9 were Motivation users, and yet results favored the Motivation chairs for all significant differences, so the effect of accommodation may have been minimal. There may also have been accommodation effects for the 10 participants who were users of other types of chairs and thus new to both the Motivation and Whirlwind chairs, but presumably this would have been essentially the same for both study chairs since both were unfamiliar. On school field trips, hospital transport wheelchairs are often used because they are very easy to fold, so most participants likely had some limited experience with hospital chairs.

Conclusion

Motivation and Whirlwind have confirmed that the results from this study are of great interest to them, and in some cases design changes in response to findings are already underway to optimize the mobility provided by their wheelchairs. Organizations and donors that provide wheelchairs in low-resource settings may find that applying this protocol with standardized outcome measurement on a few trial chairs may be helpful in the selection of larger batches of donated chairs. This information should be disseminated appropriately to foundations which provide grants or funds to enable the donation of wheelchairs so that they may be well informed, particularly in relation to the drawbacks of providing hospital transport wheelchairs as compared with more appropriate wheelchairs for long-term wheelchair-dependent users. If organizations that directly provide wheelchairs in low-resource settings – such as our partner organization – are offered a choice of different low-cost wheelchairs by manufacturers or donors, the results of this study could provide insight on the strengths and weaknesses of wheelchair design as it impacts mobility in the completion of everyday skills.

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Declaration of interest

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