J Rehabil Med 2010; 42: 605–607

SHORT COMMUNICATION

COMPARATIVE EVALUATION OF ELECTRIC WHEELCHAIR MANOEUVRABILITY

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Objective: **The aim of this study was to determine whether manoeuvrability varied between electric wheelchairs.**
Design: **Randomized, prospective, repeated measures design.**
Subjects: **Twelve wheelchair users.**
Methods: **Three different electric powered indoor/outdoor wheelchairs (Invacare® Storm 3, Ottobock® B500, and Meyra® Champ) intended for use by patients with severe impairments were tested over an indoor and an outdoor circuit. Points were assigned when the users touched the circuit boundaries or failed to pass obstacles. The users completed the Quebec User Evaluation of Satisfaction with Assistive Technology questionnaire (QUEST).**
Results: **Performance was significantly worse with Ottobock® B500 compared with the other 2 wheelchairs on the indoor test (Wilcoxon, $p<0.05$ for both comparisons) and compared with Invacare® Storm on the outdoor test (Wilcoxon, $p<0.05$). The mean 6-item QUEST score, effectiveness, and simplicity of use were significantly worse for Ottobock® B500 than for the other 2 wheelchairs (Wilcoxon, $p<0.05$).**
Conclusion: **Differences in manoeuvrability exist between commercially available electric wheelchairs belonging to the same category. Driving tests and QUEST provide complementary and concordant information.**

Key words: wheelchairs; quadriplegia; mobility limitation.

J Rehabil Med 2010; 42: 605–607

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Submitted December 14, 2009; accepted February 25, 2010

INTRODUCTION

The prevalence of wheelchair users is increasing in western countries, having been estimated in the last decade at 60–200 per 10,000 (1–4). Wheelchair driving skills are taught during rehabilitation, and further training may be available subsequently (5). Nevertheless, the number of wheelchair-related injuries treated in emergency rooms in the USA was estimated at more than 100,000 in 2003 (6). Tips and falls caused 65–80% of the injuries (6) and, although only approximately 10% of the users had electric wheelchairs (1, 4), approximately 25% of wheelchair-related injuries were related to electric wheelchairs (7).

Many studies have evaluated the performance of electric wheelchairs that are designed to negotiate obstacles such as kerbs and stairs (8, 9). However, we are not aware of any studies comparing several electric wheelchairs in terms of their manoeuvrability on standard indoor and outdoor circuits.

Manoeuvrability contributes to the degree of access that the wheelchair provides to the user and to the degree of wheelchair use (10). Therefore, we designed this study with the primary objective of comparing the manoeuvrability of several currently available electric wheelchairs handled by habitual wheelchair users on indoor and outdoor circuits. We also compared user satisfaction across wheelchairs.

METHODS

Wheelchair selection

Three electric powered indoor/outdoor wheelchairs that offered better-than-basic functions (i.e. were not totally reimbursed by the French health insurance system), with non-folding frames, were selected by 10 occupational therapists. The choice was based on a survey of 77 users of this wheelchair category. The criteria for wheelchair selection were the most frequently used devices by patients who had completely lost the ability to walk (e.g. with tetraplegia due to spinal cord injury or with severe neuromuscular disease), and suitability of the wheelchair for both indoor and outdoor use.

Participants

The local ethics committee approved the study, and written informed consent was obtained from all participants prior to study inclusion.

We recruited 12 consecutive users of wheelchairs who met our selection criteria.

Tests

Each participant tested each of the 3 wheelchairs in random order on 3 different days, driving twice on an indoor circuit and twice on an outdoor circuit. Before the tests, the wheelchair was adjusted to the participant for optimal comfort and ease of use. The participant received training from a physical therapist on driving each wheelchair and was allowed 60 min to practice with each wheelchair.

The outdoor circuit consisted of the following sequence: forward travel over a 7-cm kerb ascent; forward travel along a 360° clockwise curve and anticlockwise curve with 1 large side wheel on level ground and the other on a segment of sphere (3.1 m in diameter and 15 cm high at the centre); forward travel up 3 ramps with slopes of 5%, 10% and 15%, respectively, followed by a 360° turn; forward travel up an 8% ramp followed by a 180° turn on a landing then by forward travel down the ramp (–8%); forward travel over a 3-cm door threshold;

 doi: 10.2340/16501977-0562
 ISSN 1650-1977

and forward travel to descend and ascend 4 3-cm kerbs. The indoor circuit involved travelling forwards and backwards along a hallway (1 m wide and 7 m long) then performing a U-turn in a 1.5 × 1.5-m square without touching the boundaries, passing between 2 traffic cones placed 70 cm apart without touching the cones, and finally tracing 2 figures of 8 between 2 traffic cones placed 1.1 m apart in a 3.3 × 2.2-m rectangle. Lightly touching a circuit boundary or cone without stopping was scored 1 point and stopping after bumping into a circuit boundary or cone was scored 3 points if moving backwards before restarting along the circuit was unnecessary and 6 points otherwise. Passing an obstacle on the first attempt was scored 0 points; on the second attempt 2 points; and on the third attempt 4 points; and failure to pass the obstacle despite 3 attempts was scored 6 points. The total score was our primary evaluation criterion and the trial completion time was 1 of our secondary evaluation criteria. For each criterion, we selected the better of the 2 rounds (lowest total score and shortest completion time). The other secondary evaluation criterion was the score on the Quebec User Evaluation of Satisfaction with Assistive Technology questionnaire (QUEST) (11) completed at the end of the tests. This questionnaire has 8 items about the wheelchair (dimensions, weight (which was omitted), adjustments, safety, durability (which was omitted), simplicity of use, effectiveness and comfort). Each item is scored from 1 to 5, i.e. “not satisfied at all” to “very satisfied”.

Statistical analysis

Because the samples were too small for an assessment of normality, we used non-parametric tests. Repeated measures were evaluated using the Friedman test. When p was less than 0.05, pair-wise comparison was performed using the Wilcoxon test. Data were expressed as median and interquartile range (25–75%).

RESULTS

The wheelchairs selected for the study were Invacare® Storm 3, Ottobock® B500, and Meyra® Champ (their features are shown in Table I). The main characteristics of the 12 study participants are reported in Table II.

Significant differences were found for the indoor and outdoor tests (Table III). The pair-wise comparisons showed that the score with Ottobock® B500 was significantly worse compared with the other 2 wheelchairs on the indoor test (Wilcoxon, $p<0.05$ for both comparisons) and compared with Invacare® Storm on the outdoor test (Wilcoxon, $p<0.05$).The QUEST scores are reported in Table III. Significant differences were found for the 6-item mean score, dimension, simplicity of use, and effectiveness (Friedman, $p<0.002$, $p<0.03$, $p<0.003$, and $p<0.001$, respectively). The pair-wise comparisons indicated that the 6-item mean score, simplicity of use, and effectiveness were significantly worse for Ottobock® B500 than for the other 2 wheelchairs (Wilcoxon, $p<0.05$).

Table I. *Wheelchair characteristics*

Feature	Invacare® Storm	Ottobock® B500	Meyra® Champ
Price (€)	9000	8475	8739
Weight (kg)	130	95	106
Motor power (W)	350	300	300
Battery range (km)	45	35	ND
Width (cm)	64	63	64
Length (cm)	110	110	110
Seat level (cm)	45–60	44–54	54–ND
Front wheel diameter × width (cm)	26 × 4	26 × 7	23 × 4
Rear wheel diameter × width (cm)	36 × 6.5	36 × 8.5	30 × 8

ND: not divulged.

DISCUSSION

We found that 3 electric wheelchairs considered very similar by 10 occupational or physical therapists showed significant differences in manoeuvrability on both the indoor and the outdoor circuit. The largest differences were between the Ottobock® and the other 2 wheelchairs. Interestingly, differences were also found for the mean 6-item QUEST score, effectiveness, and simplicity of use, suggesting that the 2 circuit tests ranked wheelchair performance similarly and that the patients evaluated wheelchair performance correctly.

Two reasons may explain the differences in manoeuvrability between the Ottobock® B500 and the 2 other wheelchairs. First, the Ottobock® B500 has a wider front wheel, which causes friction during swivelling, resulting in loss of driving precision. Secondly, when starting or stopping the wheelchair, the response time of the motor to commands given via the Ottobock® joystick seemed to be longer than with the 2 other wheelchairs. Although raw dimensions were similar for the 3 devices (Table I), the Meyra® Champ was preferred by the patients (Table III) because the seat was higher than for the 2 other wheelchairs (Table I).

The main limitations of our study are the small number and heterogeneity of the included patients. Despite these limitations, we found significant differences between devices, and our results did not change when we considered only the 9 neuromuscular patients.

We acknowledge that the scoring scale used in our study was arbitrary. It was developed based on suggestions by the 10 occupational/physical therapists, who considered that slightly touching a boundary of the circuit or a cone (1 penalty point) was less problematic than failing to clear an obstacle (2 penalty points), and that the most serious problem was bumping into a boundary (3 penalty points).

Among tests used to evaluate wheelchair skills, most are intended for manual wheelchair users (12, 13). These tests mainly assess patient performance; that is, the component of manoeuvrability that can be improved by training, as opposed to wheelchair-related factors. Many scales for measuring outcomes after rehabilitation fail to consider the use of assistive technologies (14). The contribution of the wheelchair to the outcome may be best evaluated using a dual rating system that

Table II. *Patient diagnoses*

Characteristics	
Age (years), median (IQR)	39.0 (29.5–44.5)
Sex ratio (F/M), *n*	(2/10)
Body mass index, kg/m^2, median (IQR)	23.5 (16.0–29.0)
Able to walk in the home, *n*	2
Diagnosis, *n*	
Neuromuscular disorder	9
Cerebral palsy	2
Spinal cord injury	1

IQR: interquartile range.

Table III. *Driving test results and QUEST scores for the 3 wheelchairs. Data are expressed as median and interquartile range (25–75%)*

	Invacare® Storm	Ottobock® B500	Meyra® Champ	*p*-value (Friedman)
QUEST (mean of the 6 items)	3.75 (3.33–4.25)	2.58 (2.33–3.09)*	3.83 (3.59–4.42)	0.002
QUEST (dimensions)	3.0 (3.0–4.0)	3.0 (2–3.5)	4.0 (4.0–5.0)†	0.03
QUEST (adjustment)	4.0 (3.0–4.0)	3.5 (2.5–4.0)	4.0 (3.0–4.5)	0.64
QUEST (safety)	4.0 (3.0–5.0)	2.0 (1.5–4.0)	4.0 (3.0–4.5)	0.10
QUEST (simplicity of use)	5 (4.5–5.0)	1.5 (1.0–3.5)*	4.5 (4.0–5.0)	0.003
QUEST (comfort)	4.0 (2.5–4.5)	3.0 (1.5–4.0)	3.5 (3.0–4.0)	0.36
QUEST (effectiveness)	4.0 (3.5–4.0)	2.0 (1.0–3.0)*	4.0 (3.0–4.5)	0.001
Outdoor test score	0.0 (0.0–05)†	4.5 (0.5–7.0)	2. (0.5–3.0)	0.03
Indoor test score	0.0 (0.0–1.5)	3.5 (0.0–7.0)*	0 (0.0–1.5)	0.01

*Significantly different from the 2 other conditions (Wilcoxon test).
†Significantly different from the Ottobock® B500 (Wilcoxon test).
Each item of the Quebec User Evaluation of Satisfaction with Assistive Technology questionnaire (QUEST) (11) was scored from 1 to 5 (1, not satisfied at all; 2, not very satisfied; 3, more or less satisfied; 4, quite satisfied; 5, very satisfied).

separates performance with and without the wheelchair (or across 2 wheelchair types) (12, 13). Our study showing differences in manoeuvrability across electric wheelchairs confirms that the wheelchair influences the outcome.

Although the results of the indoor and outdoor tests were concordant, we believe the 2 tests evaluated different wheelchair features. We used both tests because electric wheelchair users report difficulties both indoors, often in relation to the size of the wheelchair; and outdoors, where many barriers are encountered (10). We believe that outdoor manoeuvrability is a greater problem in Europe, where access to public spaces in cities is more difficult, compared with North America. This fact may contribute to explain the difference in the wheelchairs used in these 2 continents. For example, mid-wheel drive wheelchairs are often used in North America because they are very easy to manoeuvre over level surfaces, (15), but they cannot easily clear obstacles frequently encountered in Europe, such as kerb cuts higher than 10 cm. Thus, mid-wheel drive wheelchairs may perform very well on our indoor test, but not on our outdoor test. Finally, the indoor and outdoor tests seemed complementary: the indoor test evaluated manoeuvrability in cramped surroundings with a level surface; and the outdoor test evaluated the ability to negotiate standard slopes, pavements, kerb cuts, and thresholds that must be accessible to disabled individuals according to French law (16).

In conclusion, patient performance on driving tests varied across electrical wheelchairs. It suggests that manoeuvrability may differ across wheelchairs and that both simple driving test scores and QUEST scores may be useful to detect these differences. Further studies are needed to confirm differences in wheelchair manoeuvrability.

ACKNOWLEDGEMENTS

We thank E Boirel, Y Deschamp, S Pouplin, S Nadeau, O Perigault, V Lafosse, H Mulliez, V Rundstadler, B Legarlantezec and A Gloanec for selecting the electric wheelchairs compared in this study.

The study was supported by the Ile de France region.

Conflict of interest: No commercial party having a direct financial interest in the results of the research supporting this article has conferred or will confer a benefit upon the authors or upon any organization with which the authors are associated.

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