

End-user Testing of a Variable Position Mid Wheel Drive Power Wheelchair

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BACKGROUND

Power wheelchairs (PWCs) are either rear, mid or front wheel drive. Each drive wheel position has its advantages and disadvantages, especially as a function of the terrain and environment. Mid-wheel drive PWCs are highly maneuverable indoors. Focus groups of power wheelchair users confirmed their awareness of the limitations of single position drive wheel systems. There are currently no power wheelchairs available that can provide the advantages and avoid the disadvantages of a single position drive system.

As a Phase II SBIR project, funded through NIDRR, Criterion Health designed and fabricated a prototype variable position mid-wheel drive system power wheelchair, Varpo (**V**ariable **P**osition). The design was consistent with available popular mid-wheel drive power wheelchairs although the wheelbase was approximately 5 cm. longer. The gearboxes, motors, and control system (MK61) from an Invacare TDX SP power wheelchair base were used.

For Varpo an electromechanical system was used to change the drive wheel position, linear actuator, and to raise and lower the front and rear casters, cam following, when in front wheel and rear wheel drive respectively. The rear suspension was manually stiffened or softened for the front and mid wheel drive respectively. The first three panels in Figure 1 show Varpo in Rear Wheel, Mid Wheel, and Front Wheel drive positions with the rear casters raised in rear wheel drive and the front casters raised in front wheel drive. The last two panels in Figure 1 show the rear suspension “soft” for mid wheel drive and “stiff” for front wheel drive.

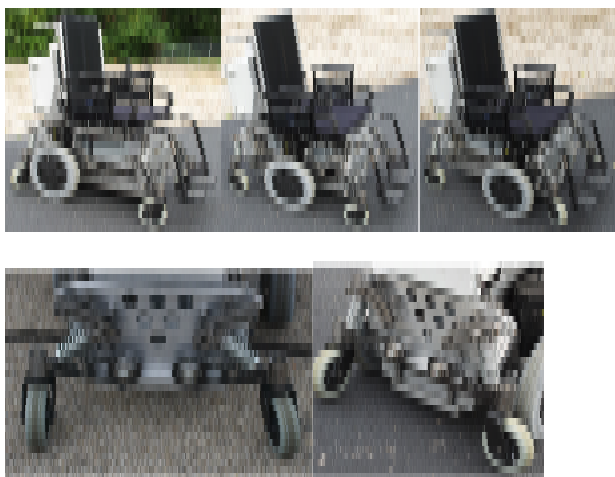


Figure 1. Varpo in rear, mid, and front wheel drive and showing “soft” and “stiff” rear suspension.

Varpo was tested extensively against the RESNA/ANSI wheelchair standards, especially those for static and dynamic stability. In addition, Criterion tested Varpo in a variety of indoor and outdoor environments and terrains. This testing showed that Varpo was most maneuverable indoors in mid wheel drive and most able to go through ruts and handle rough terrain in front or rear wheel drive. The testing also showed that if Varpo became stuck in, for example, deep gravel, it was possible to change the drive wheel position and pull out. Only after Varpo was deemed safe, was human subject testing undertaken.

METHOD

Subjects

Six adult who have used a joystick controlled power wheelchair for at least five years were recruited. Three of the subjects had spinal cord injuries and three had cerebral palsy. They received \$100 for their participation in an individual test session that lasted between two and three hours. (The test protocol was subjected to a full review by the Indiana State University Institutional Review Board.)

Procedure

Each session consisted of a sequence of tasks that emulated those one would typically encounter in indoor and outdoor environments. The subject would complete the task in each drive wheel position, Front wheel drive (FWD), Mid wheel drive (MWD), and Rear wheel drive (RWD). The order was changed for each subject but counterbalanced across the six subjects. The subject was instructed on how to use the linear motion controller to change the drive wheel position and then given an opportunity to familiarize him or herself with the drive wheel positions.

After completing a task in a drive wheel position the subject answered a series of questions. After completing a task in all three drive positions, the subject answered a series of questions comparing the experiences. Finally, after the completion of all tasks, the subject underwent a debriefing on the overall experience of using a variable position power wheelchair.

Questions at the end of each task in a single drive wheel position:

1. How safe did you feel while doing the task “very unsafe (1) to very safe (5)”
2. How comfortable did you feel while doing the task “very uncomfortable (1) to very comfortable (5)”
3. How difficult was it to accomplish the task “very difficult (1) to very easy (5)”
4. How easy was it to control the pwc during the task “very difficult (1) to very easy (5)”
5. How stable did you feel while doing the task “very unstable (1) to very stable (5)”

Questions after completing a task in all three drive wheel positions:

a. Which condition felt safest ____, second safest ____, any additional comments
b. Which condition felt most stable ____, second most stable ____, any additional comments
c. Which condition felt most comfortable ____, second most comfortable ____, any additional comments
d. Which condition was most difficult to accomplish the task ____, next most difficult ____, any additional comments
e. Which condition made it easiest to control P1 than the others ____, second easiest ____, any additional comments
f. Which condition was the smoothest, least bouncy ____, second smoothest least bouncy ____, any additional comments
g. Which condition did you prefer most ____, second most ____, any additional comments

At the end of the test session, subjects were asked the following questions:

a. Would you like to have a power wheelchair for which you could change the drive wheel position? (10 pt scale)? (1 no, not at all, 10 yes, a great deal) Why?
b. In your daily life, what would having a variable drive wheel PWC help you do
c. In a typical day, how and when might you use different drive wheel positions
d. Would you want to be able to change the drive wheel position while moving, on the fly
e. What else can you tell us about the use of different drive wheel positions
f. What don't you like about a variable position drive PWC
g. How does this PWC compare to your current wheelchair
h. What is your history using power wheelchairs, what drive wheel position and for how many years

Tasks

Hall and Doorway: Proceed down a 91.4 cm (36 inch) wide hallway and turn into an 81.0 cm (32 inch) doorway. Then reverse and come out the doorway and turn into the hallway.

Simulated indoor driving: Drive power wheelchair into an elevator (152 cm x 244 cm) with two occupants and turn the wheelchair around; Take elevator to lower floor and drive in and among several different room environments and return to start location (70 meter). Reenter elevator and return to main floor.

Simulated side entry to over-the-road bus PWC area: Federal guideline prescribed maneuvering space: for entry from front or back a 31 in x 48 in (78.7 cm x 121.9 cm) space or for entry from the side a 30 in x 54 in (76.2 cm x 137.2 cm) space.

Ascend and descend a 5 cm (1.96 inch) curb at 90 and 75 degree angles of approach.

Descend a 7.62 cm (3.0 in) curb at 90 degree angle.

Ascend and descend 10 degree ramp (only conducted in Rear and Front wheel drive since Varpo would hang up (bridge) in Mid wheel drive)

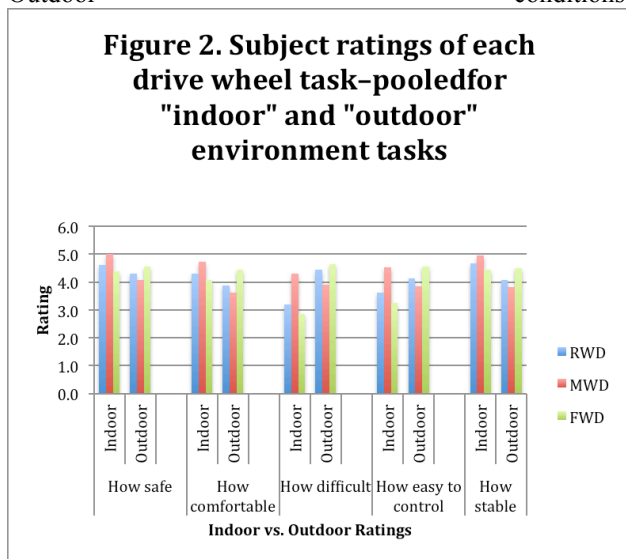
76 meter outdoor course: course that includes different surfaces (grass, gravel, dirt), sharp turns, quick stops, transitions, uphill, downhill, and side slopes The course was marked and followed a squared figure 8..

Free style environment: Subjects were given the opportunity to go wherever they wanted in whatever drive wheel position within the field that was used for the outdoor course.

RESULTS

The primary result was the subject’s rating for each question after completing a task in a single drive wheel position. The results were then pooled to form two broad categories: Indoor and Outdoor. Indoor incorporated the “Hall and Doorway,” “Simulated indoor driving,” and “Simulated side entry” tasks. The “Ascend and descend” tasks and “76 meter outdoor course” formed the outdoor tasks.

Figure x summarizes the results. For each drive wheel position it shows the mean rating across subjects for each of the five questions, combined into Indoor vs Outdoor conditions.



The primary result is that MWD has the highest scores for indoor tasks with RWD having the second highest scores. FWD has the highest scores for outdoor tasks, with RWD having the second highest scores.

Since some subjects seemed to have difficulty remembering which condition was which when they were asked to pick the one they liked most and second most, those results are not presented.

The final debrief was informing. When asked to rate on a scale how much they would like to have a variable position drive power wheelchair, four subjects gave a “10” and two an “8.” When asked why, they basically said it would allow them to get out of different situations, e.g., if stuck; also, mid wheel drive for indoors and front wheel for outdoors. Subjects expressed their desire to spend time in more environments without concern of getting stuck, the increased ability to go more places, and the increased versatility.

Of the six subjects, three own a mid wheel drive, one a front wheel drive, and two a rear wheel drive power wheelchair.

CONCLUSIONS

Subjects, who are already long-term users of a joystick controlled power wheelchair were able to quickly learn to use a variable position power wheelchair. Within the tasks they were asked to perform, they reported consistent differences in their evaluation of the different drive wheel positions. The breakdown was essentially indoor vs. outdoor usage. The maneuverability of a mid wheel drive PWC indoors is well established. However, its limitations outdoors are equally well established, whether accomplishing a task or the comfort and smoothness of operation on rough terrain.

The final debriefing of subjects indicated their perceptions of the potential value of a variable position drive wheel power wheelchair.

ACKNOWLEDGEMENTS

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