

## Introduction

Safe, efficient and effective wheelchair locomotive activities of daily living for the elders are important due to their ages and physical conditions. Although wheelchair propulsion in young populations and/or athletes has been extensively investigated, researches of wheelchair propulsion in the elderly population are limited. Moreover, wheelchair locomotive activities of daily living, such as moving turn, door negotiation and parallel parking including the time efficiency of propelling performed by the older adults have not been studied. Based on the feedback from focus groups and surveys on wheelchair users, caregivers, nurses and physical therapists from the larger study, the issues of propulsion and maneuverability were identified as the barriers to independent mobility for the elders. As a result, the front, mid and rear positioning drive-axis wheelchairs were designed and tested in order to determine if propulsion and maneuverability were facilitated or hindered by any of these wheelchair designs.

## Purpose

The purpose of this study was to examine time efficiency in wheelchair locomotive daily activities among four differently positioning drive-axis wheelchairs propelled by elderly with arms and/or legs.

## Methods

### Participant

Sixteen manual wheelchair users (11 females and 5 males) aged from 65 to 90 years participated in this study. Each participant was carefully screened for diseases and conditions that would limit the ability to propel his/her own wheelchair. The exclusive criteria in this study included 1) having heart disease, lung disease, uncontrolled diabetes, chronic renal disease, etc., 2) having spinal cord injury, 3) with arm or leg amputation, 4) unable to propel wheelchairs with arms or legs, 5) severely cognitively impaired (Folstein Mini-Mental State Examination score less than 24 points<sup>1</sup>). All subjects signed informed consent indicating their voluntary participation. The basic information is presented in Table 1.

**Table 1** General information of the participants

Wheeling group	Age Years (SD)	Body mass Kg (SD)	Years of Using WC (SD)	No of participant (n)
Arm wheeling	79.33 (8.33)	65.91 (17.01)	0.83 (0.29)	3
Leg wheeling	78.33 (12.66)	59.26 (14.23)	4.67 (6.35)	3
Arm-leg wheeling	77.56 (8.49)	72.66 (19.52)	3.44 (2.96)	10
All together	78.07 (8.63)	68.89 (17.01)	3.17 (3.53)	16

## Testing wheelchair

The participant's own wheelchair plus three wheelchairs with the main drive-axis wheels positioning in front, middle and rear were used in the study. The three differently positioning drive-axis wheelchairs are presented in Figure 1.

## Acknowledgments

This project was supported by and

## Wheelchair skill test

Standard wheelchair skill test<sup>2,3</sup> was used to evaluate the time efficiency of wheelchair locomotive activities. Seven fundamental wheelchair locomotive activities of daily living were selected in this study.

- 1) Straight moving: moving the wheelchair forward and backward on a 10m-long, 1.2m-wide smooth level surface.
- 2) Turn in place: turning the wheelchair 180° in place, to the left and right in a circle with the diameter of 1.5m.
- 3) Moving turn: turning the wheelchair 90° to the left and right while moving forwards/backwards on a 1.2m-wide and 1.5m-long level surface.
- 4) Three-point turn: the combination of left forward and right backward moving turns or the combination of right forward and left backward moving turns on a 1.2m-wide and 1.5m-long level surface.
- 5) Parking parallel: manoeuvring the wheelchair sideways so that it would be parallel to an object on both left and right sides on a 1.2m-wide and 2m-long level surface.
- 6) Door open-away: opening and passing through and closing a hinged door that opens away from the participant.
- 7) Door open-toward: opening and passing through and closing a hinged door that opens towards the participant.

## Experimental Procedure

The participants were randomly assigned to wheelchair and activities. The participants were given 10-minute warm up to get accustomed to the three different wheelchairs (2 min on each chair). Each participant was given one chance to try an activity with the first (randomly picked) tested wheelchair. When the participant got ready at the starting line, the experimenter set a timer. The time to complete each wheelchair activity from the starting line to the finish line was recorded by this timer. Three trials for each wheelchair and locomotive activity condition were recorded. A two-minute break was given at the end of each tested wheelchair activity. Due to the multiple trials and wheelchair locomotive activities, the participants were tested in two sessions on different days (in 72 hours) with approximately one hour for each session. Three or four wheelchair locomotive activities were tested in one session.

## Data Analysis

A Mixed-Model ANOVA (4 chairs x 3 groups) was employed to determine the time efficiency ( $p < 0.05$ ) of these four wheelchairs and three wheelchair propelling techniques (groups) on each wheelchair locomotive activity.

**Figure 1** Three main drive-axis wheelchairs: a. Frontal drive-axis wheelchair with the big drive wheels in front, b. Mid drive-axis wheelchair with the big drive wheels in middle and a small castor behind for balance purpose, and c. Rear drive-axis wheelchair with the big wheels in rear.



## References

1. Cock, J. R., Folstein, M. F. (1988). Mini mental state examination (MMSE). *Psychopharmacology*, 24:689-692.
2. Kirby, R. L., Dupuis, D. J., Macphree, A. H., Coolen, A. L., Smith, C., Best, K. L., Newton, A. M., Mountain, A. D., Macleod, D. A. & Bonaparte, J. P. (2004). The wheelchair skills test (version 2.4): measurement properties. *Archives of Physical Medicine and Rehabilitation*, 85 (5), 794-804.
3. Kirby, R. L. (2005) <http://www.wheelchairskillsprogram.ca/eng/manual.htm>. Standard biology format

## Results

**Table 2** Means and SDs of seven wheelchair locomotive activities in time (seconds) among three groups

Seven activities	AOPG	LOPG	ALPG
Straight moving	15.13 (8.35)	12.75 (6.29)	12.17 (6.02)
Turns in place	11.88 (9.61)	19.91 (14.96)	9.86 (10.71)
Moving Turn	38.74 <sup>(A-AL)</sup> (25.48)	36.41 (19.77)	24.95 <sup>(AL-A)</sup> (10.68)
Three-point turn	29.39 (10.21)	30.02 (7.50)	24.95 (10.19)
Parking parallel	15.05 (3.98)	17.70 (3.24)	13.56 (9.15)
Door open-away	36.11 (14.96)	47.49 <sup>(L-AL)</sup> (30.97)	27.77 <sup>(AL-L)</sup> (15.19)
Door open-toward	89.36 <sup>(A-AL)</sup> (57.93)	92.91 <sup>(L-AL)</sup> (40.19)	45.85 <sup>(AL-A-L)</sup> (41.56)

**Table 3** Means and SDs of the dimensional variables of wheelchair locomotive activities among four wheelchairs

Activities	Frontal drive-axis wheelchair (F)	Mid drive-axis wheelchair (M)	Rear drive-axis wheelchair (R)	Participant's own wheelchair (O)
Straight moving	18.13 <sup>(F-M)</sup> (9.26)	10.40 <sup>(M-F)</sup> (3.47)	10.72 (3.37)	11.92 (5.26)
Turns in place	11.10 (5.30)	7.83 (3.93)	15.90 (19.24)	11.14 (9.87)
Moving Turn	42.78 <sup>(F-M,R,O)</sup> (24.62)	25.66 <sup>(M-F)</sup> (11.33)	23.64 <sup>(R-F)</sup> (8.31)	23.82 <sup>(F-O)</sup> (7.83)
Three-point turn	30.28 (13.18)	23.14 (10.29)	24.73 (10.32)	23.09 (7.57)
Parallel parking	17.16 (8.63)	12.59 (5.50)	11.88 (5.37)	15.78 (10.52)
Door open-away	39.37 (24.93)	30.61 (15.63)	26.07 (14.21)	31.16 (17.34)
Door open-toward	78.05 (60.67)	52.56 (38.53)	59.89 (48.84)	56.69 (45.33)

## Conclusions

Propelling the mid drive-axis and the rear drive-axis wheelchairs would result in better time efficiency in the wheelchair locomotive activities among the elders; and using arms and legs simultaneously to propel wheelchairs would be more time efficient than using the arms only or using the legs only in the wheelchair locomotive activities. However, the sample size was small in the present study, especially for the comparisons between three groups. Future study should warrant more participants in each group for the generalization of the research results, and may also consider the biomechanical and physiological changes while using these differently drive-axis wheelchairs.

## Contact Information

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