IMPACT AND USAGE OF PUSHRIM ACTIVATED POWER ASSIST WHEELCHAIR AMONG INDIVIDUALS WITH TETRAPLEGIA

by

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Submitted to the Graduate Faculty of

The School of Health and Rehabilitation Sciences in partial fulfillment

of the requirements for the degree of

Masters of Science in Health and Rehabilitation Science

University of Pittsburgh

2007

UNIVERSITY OF PITTSBURGH

SCHOOL OF HEALTH AND REHABILITATION SCIENCES

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IMPACT OF PUSHRIM ACTIVATED POWER ASSIST WHEELCHAIR AMONG INDIVIDUAL WITH TETRAPLEGIA

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The primary objective of this study was to investigate the usage of Pushrim Activated Power Assist Wheelchairs (PAPAW) among individuals with cervical level spinal cord injuries (tetraplegia) in real-life environments. Fifteen full-time manual wheelchair users with tetraplegia completed a four-week trial including a two-week own wheelchair trial and a two-week PAPAW trial where both the PAPAW provided and personal wheelchairs were tracked. The order of wheelchair use was randomized. Throughout the study period both the PAPAW and participants personal chairs were equipped with a data logging device, which collects time stamps at each wheel rotation. The PAPAWs used in this study were equipped with the JWII (Yamaha Motor Corporation). Participants were asked to daily complete a take home questionnaire with questions regarding type of wheelchair used, places visited, methods of transporting the wheelchair, obstacles preventing travel outside the home, and satisfaction and dissatisfaction with the PAPAW. At the end of each two-week trial, the Psychosocial Impact of Assistive Devices (PIADS) survey was conducted to assess the effects of the PAPAW and the personal chair on user's competence, adaptability, and self-esteem. Data logging device analyzed variables included the average daily distance traveled, average speed and the actual daily driving time. Results from this phase showed that participants used the PAPAW significantly more than their personal wheelchairs in the two-week PAPAW trial, indicating that PAPAWs might improve functional independence as well as community participation of individuals with tetraplegia. Overall benefits of the PAPAW reported by participants included easy propulsion, increased independence, and good performance in difficult terrains, increased quality of life, faster speed, and decreased upper-limb pain. Limitations reported included difficult drive wheels disassembling and transportation.

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ACKNOWLEDGMENTS

I would like to thank my academic advisor, Dr. Mark Schmeler, for providing me with the leadership, knowledge and friendship during all master's program. I would also like to thank Dr. Rory Cooper and especially Dr. Dan Ding for the opportunity, funding and work experience throughout this research study. Additionally, I would like to thank all the students and staff at HERL who helped in guiding me with data collection and analysis specially Eliana Chaves for all her friendship and support throughout my thesis process, without her support I would not be able to finalize my thesis on time. I would also like to extend my thanks to my friend Ana Allegretti for her support, patience and friendship during these two years here in Pittsburgh.

I would also like to extend my deepest thanks to my parents and my brother for all the love, support and patience throughout my master program. Finally, I would like to thank my husband, Lucimar for all the love, support and dedication he always had, particularly over the last several months. His love and support were always present as he said in our wedding "until death do us part".

1.0 INTRODUCTION

Spinal cord injury (SCI) is the main cause of disability in young adults. There is an estimate of 250,000 to 400,000 individuals with SCI in the United States. The annual incidence is approximately 11,000, accounting for thirty new injuries every day. The average age at injury is 38 years with a higher incidence among men (78%). The most common cause of injuries are motor vehicle accidents (50%), followed by falls (22%), acts of violence (primarily gun shots wounds) (11%), and recreational sporting activities (8%) (Lin, 2003; Somers, 2001). The effects of SCI depend on the type and level of injury. SCI can be divided into two major types of injury: complete and incomplete according to the American Spinal Injury Association (ASIA) impairment scale. The most common injury levels are: Cervical (C1 to C8), Thoracic (T1 to T12) and Lumbar (L1 to L5) levels. The paralysis is known as tetraplegia if the injury is in the cervical spine region or as paraplegia if the injury is in the thoracic, lumbar or sacral region. It is estimated that there are approximately 53% of individuals with tetraplegia and 47% with paraplegia (Somers, 2001).

1.1 Mobility Options for Individuals with Tetraplegia

Most individuals with SCI, regardless of their levels of injury, rely on mobility devices such as wheelchairs as their primary means of mobility. Individuals with paraplegia are usually capable of propelling manual wheelchairs (MWCs) due to good upper body strength, while individuals with tetraplegia may choose either manual or power wheelchairs (PWCs) based on their physical conditions and injury levels. MWCs are usually smaller and lighter, easier to transport, and maneuver well in confined spaces. MWC propulsion also provides wheelchair users good means of physical exercise and cardiopulmonary fitness (Somers, 2005). However, propulsion overtime is likely to increase injuries and pain in upper extremity especially in individuals with tetraplegia (Boninger & colleagues, 1999). Studies have shown that more than two thirds of individuals with SCI report suffering or having suffered from shoulder pain since the onset of using a MWC. In addition, upper limb pain as a result of MWC propulsion may occur as early as five years post injury (Sie & colleagues, 1992). Individuals with tetraplegia have a higher prevalence of shoulder pain than individuals with paraplegia. This may be due to musculoskeletal compromises and increased contact between anatomic structures. Further, there is a high correlation of shoulder pain in individuals with tetraplegia and time since injury, age, weight, use of a manual wheelchair, poor trunk stability, imbalances in the rotator cuff and scapular stabilizing muscles (Dyson-Hudson & Kirshblum, 2004).

For individuals who cannot propel MWCs, or who prefer to save energy and avoid injuries on the upper extremity, PWCs can provide an effective means of mobility. Unfortunately, PWCs are typically larger, wider, and heavier than MWCs, creating accessibility issues particularly within the home environment and transportation. PWCs may also be perceived by users as creating a more disabled image and appear more obvious than MWCs.

Some alternative devices have been developed in recent years to offer options between power and manual wheelchairs. These alternative devices include lever and crank-drive units (van der

Woude *et. al*., 1997), geared wheelchairs (O'Connor, 1998; Meginniss, 2006), and pushrim-activated power-assisted wheelchairs (PAPAW) (Levy, 1999; Cooper, 2001; Corfman, 2003). The PAPAW is a relatively new concept, providing an option for individuals who experience difficulty propelling a MWC, but would not like to switch to a PWC. PAPAWs are typically MWCs with a motor linked to the pushrim in each rear hub, where the user's manual pushrim input is sensed and amplified proportionally by the motor. PAPAWs have been shown to require considerably less energy expenditure to propel than a manual wheelchair (Cooper *et. al*., 2001). PAPAWs have some advantages over other powered mobility options. Where a power chair typically weighs 150lbs or more, a PAPAW including the wheelchair frame and the power-assist add-on unit may weigh around 60lbs. PAPAWs are usually less expensive than other powered mobility options. As the power-assist add-on units are often directly mounted onto a manual wheelchair frame, they can also be removed to allow easy transportation. Table 1 shows the weight and cost information of several commercially available MWCs, PWCs, and PAPAWs.

Table 1: Weight and retail cost information of wheelchairs

WC Type	Classification	Device weight	Brand	Price range
MWC	Lightweight	22 lbs - 34 lbs	Invacare, Quickie	$925.00-$2.135.00
	Ultra lightweight	22.5 lbs - 28 lbs	Quickie	$795.00-$1.560.00
	Titanium	14 lbs - 23 lbs	TiLite, Quickie	$1.625.00-$2.9914.00
PAPAW	E-motion	53 lbs*	E-motion	$6.590.00**
	JWII Yamaha	37 lbs*	Quickie X-Tender	$6.295.00
Lever or geared	Magic wheels	10 lbs*	Magic Wheels Inc.	$4.995.00**
	Lever drive chair	32 lbs	Drive Medical Viper	$629.00
PWC	Basic base	103 lbs-164 lbs	Pride, Invacare, Quickie	$ 1.985.00-$ 5.695.00
	With features (seat functions)	304 lbs-350 lbs	Permobil, Invacare	$10.091.00-$30.000.00 and up

* Weight of the power assist add-on unit including battery but without wheelchair frame

** The power assist add-on unit price only

PAPAWs have started to gain attention among wheelchair users recently. Medicare released new policies toward coverage of PAPAWs as of November, 2006. A PAPAW will be covered by Medicare if certain criteria can be met such as: mobility limitation that would prevent participating in one or more mobility-related activities of daily living (MRADLs), no sufficient upper extremity function to self-propel an optimally-configured manual wheelchair in the home to perform MRADLs during a typical day, and specialty evaluation performed by a licensed/certified medical professional (US Department of health and human services, 2007).

1.2 Outcome Instrumentation to Measure the Impact of AT and Community Participation

According to the International Classification of Functioning, Disability and Health (ICF) framework, decreased participation in community activity is a result of the incongruence between an individual's health condition (e.g., impairment to ambulatory function) and the context in which they live (World Health Organization, 2002). Community participation is usually compromised for wheelchair users due to barriers such as environment accessibility, transportation, climate, social attitude, and internal personal factors. Different types of wheelchairs may provide different benefits and limitations to community access. Users must decide which technology provides the optimal balance of accessibility and performance. Most individuals with tetraplegia have an active lifestyle, and the impossibility of being able to propel their MWCs due to physical incapacity may decrease their participation in the community and ultimately, decreasing their quality of life (Kilkens *et. al*., 2005).

Many measurement tools have been developed to assess the impact of AT devices on individuals' independence in performing activities of daily living (ADLs) and community participation (Mills *et. al. 2002*). Craig Handicap Assessment and reporting technique (CHART), including 4 subsections, i.e., physical independence, mobility, occupation, and social integration was developed to measure community participation across disability groups (Walkers *et. al.*, 2003). The Psychosocial Impact of Assistive Device Scale (PIADS), a 26-item self-report questionnaire, was designed to assess the effects of an AT on the users' competence, adaptability, and self-esteem (Day *et. al.*, 2002). It particularly focuses on the user's perception of self and disability within the physical and social environment. The Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST) is another measurement tool focusing primarily on the user's satisfaction with the AT device and its attributes such as device dimensions, weight, adjustments, safety, durability, simplicity of use, comfort, and effectiveness (Demers *et. al.*, 2002). It also has 4 items associated with related AT services. The reliability and validity of these instruments have been extensively investigated and reported in the literatures (Walkers *et. al.*, 2003, Day *et. al.*, 2002, Demers *et. al.*, 2002)

Although the impact of AT and community participation have been measured by many surveys, researchers have begun to investigate physical activity patterns in individuals with disabilities through the usage of electronic sensor technology as a direct and objective method of data collection. It eliminates possible bias and misinterpretation of survey questions associated with self-report questionnaires. The wheel rotation data logging device has been shown to be a valid tool for investigating the driving characteristics of wheelchair users in the community (Cooper *et. al.*, 2002). Tolerico (2005) used such a device to analyze mobility characteristics and activity levels among wheelchair users in two different environments: the National Veterans Wheelchair Games (NVWG) and the subjects' residential setting. The activity levels of the individuals in the two environments were significantly different. They drove longer distances, with higher speed and for longer time during the NWMG, possibly due to the lower number of physical barriers encountered than in real life environments.

Survey-based outcome instruments and sensor-based objective data collection are usually complementary to each other and the divergence between them could lead further interrogation of each dataset more fully and assist in in-depth analysis. A combination of these two methods could help generate deeper insights into the impact of AT on people with disabilities and contribute to further understanding of its benefits and limitations.

1.3 Literatures Review on PAPAW Studies

The PAPAW has been evaluated in laboratory settings on its influence on metabolic demands, propulsion biomechanics, and functional capabilities during activities of daily living among different populations.

- Algood (2003) conducted a two-phase study to test the influence of a PAPAW on the functional capabilities of individuals with tetraplegia in two different laboratory settings: a biomechanics laboratory and an ADL laboratory. Fifteen fulltime MWCs with tetraplegia were tested in both phases. The first phase examined the differences in mean steady-state oxygen consumption, ventilation, heart rate, mean stroke frequency, and maximum upper-extremity joint range of motion (ROM) during PAPAW propulsion and traditional manual wheelchair propulsion. Results revealed a significant improvement in kinematics, speed, and metabolic variables when participants were propelling with a PAPAW. The second phase examined usage of the PAPAW during activities of daily living in a simulated setting to determine its usability and acceptability. Participants propelled both their own manual wheelchairs and a PAPAW three times over an ADL course. Results showed PAPAWs received higher user ratings than the participant's own manual wheelchair for 10 out of 18 obstacles. Additionally, when using a PAPAW, participants were able to complete the course in the same amount of time while maintaining a lower mean heart rate.

- Best *et. al.* (2006) compared the benefits of the PAPAW with those of a light weight manual wheelchair in individuals' daily activities performance using a sample of 30 able-body individuals. Results showed that activities such as going up ramps or going through different terrains were easily performed with the PAPAW.
- Arva *et. al.* (2001) conducted a study with 10 MWC users with SCI and Multiple Sclerosis (MS) in a laboratory setting while propelling the PAPAW over a dynamometer with five different resistances. Results showed decreased oxygen consumption, lower user power, and higher mechanical efficiency while propelling the PAPAW.
- Corfman *et. al.* (2003) studied the use and efficacy of PAPAW in reducing upper extremity excursion and stroke frequency among nine individuals with paraplegia and one individual with multiple sclerosis (MS). The authors found that for some speeds and resistance combinations, PAPAWs reduced joint excursion at the shoulder, elbow and wrist. However, these results did not show significant difference in stroke frequency between the PAPAW and subjects' own manual wheelchairs.

- Levy *et. al.* (2004) evaluated the utility and performance of the PAPAW among elders. Results showed that subjects had lower heart rate while propelling the PAPAW as well as decreased exertion while propelling. Overall, participants rated the PAPAW to be easier to propel in carpets and inclined surfaces. In addition, muscle activity in the upper extremities decreased with the use of the PAPAW.
- Love & Benson (2006) conducted a case study with an individual with fascioscapuloumeral muscular dystrophy to compare the PAPAW and his manual wheelchair use in the community. Results showed decreased heart rate and perceived exertion while propelling the PAPAW. Propulsion speed was twice higher with the PAPAW and time to complete activities was lower with the PAPAW.

Overall these studies are consistent on concluding that PAPAWs can decrease heart rate during propulsion, decrease perceived exertion, are time saving and also save propulsion energy especially when climbing obstacles and traversing difficult terrains. Although these studies showed that the PAPAW is more beneficial than a regular MWC, these studies were performed in the laboratory settings with a relatively small sample size. The impact of the PAPAW during activities of daily living within home environment and community is still unclear.

The only study that evaluated PAPAWs in a real-life environment with individuals with SCI was conducted by Fitzgerald *et. al.* (2003). Seven MWUs with paraplegia participated in a four-week trial: two weeks using their own wheelchairs and two weeks using the PAPAW in the home environment and community. The results did not show a significant difference between the PAPAW and manual wheelchairs in terms of distance traveled and average speed recorded by a wheel rotation data logging device, but 85% of the subjects reported that it was easier to use the PAPAW during daily activities.

The study in this thesis is the continuation of the previous two-phase laboratory-based evaluation study by Algood, 2003. We will use both objective data collection via a new wheel rotation data logging device, and survey-based data collection such as daily questionnaires and the PIADS to evaluate the impact of a PAPAW among MWUs with tetraplegia within their home and community environment.

2.0 SPECIFIC AIMS & HYPOTHESIS

The primary objective of this study was to evaluate the impact of PAPAWs on mobility, community participation, satisfaction, and psychosocial impact among individuals with tetraplegia in the home and community environment quantitatively and qualitatively. Mobility characteristics were collected through the use of a wheel rotation data logging device which directly monitors wheelchair usage and provides indication of community participation. Community participation in terms of frequency and variety of places visited, and satisfaction with the PAPAW were collected through daily questionnaires. Psychosocial impact was determined by the PIADS. A secondary objective of this study is to contribute to the collection of evidence on the impact of PAPAW on individuals with tetraplegia in order to assist prescription and justification of PAPAWs.

The specific aims and hypothesis of this study include:

Specific Aim 1: Compare the mobility levels of individual with tetrapledia using the PAPAW versus their personal wheelchair.

Hypothesis 1a: *Subjects will use the PAPAW more hours of the day than their personal wheelchair as measured by the data logging device.*

Hypothesis 1b: *Subjects will use the PAPAW more miles per day than their personal wheelchair as measured by the data logging device.*

Hypothesis 1c: *Subjects will travel at a higher average speed using the PAPAW than with their personal wheelchair as measured by the data logging device.*

Specific Aim 2: Compare the community participation and satisfaction with the PAPAW versus their personal wheelchair.

Hypothesis 2a: *Subjects will participate in more activities outside the home while using the PAPAW than their personal wheelchair as measured by the daily questionnaire.*

Hypothesis 2b: *Subjects will participate in a larger variety of activities outside the home while using the PAPAW than their personal wheelchair as measured by the daily questionnaire.*

Hypothesis 2c: *Subjects will prefer the PAPAW to their personal wheelchair as measured by the daily questionnaire.*

Specific Aim 3: Compare the psychosocial impact of the PAPAW versus their personal wheelchair.

Hypothesis 3a: *Subjects' perception on competence, adaptability and self-esteem will be higher with the PAPAW than their personal wheelchair as measured by the PIADS.*

3.0 METHODS

3.1 SUBJECT RECRUITMENT

Participants were recruited for the study through registries maintained by the Human Engineering Research Laboratories (HERL) and the Center for Assistive Technology (CAT). They were initially contacted by either letter or telephone. In order to meet the inclusion criteria, subjects must 1) be full time manual wheelchair user with a cervical level spinal cord injury (tetraplegia) for at least one year; 2) be between the ages of 18 to 65; 3) be free from pressure sores; 4) have no shoulder pain prior to the study that prevents the participants from propelling their wheelchairs or performing their daily activities; and 5) have no history of cardiopulmonary disease.

3.2 PROTOCOL

The study used a cross-over design with subjects acting as their own controls. The protocol consisted of a four-week trial including a two-week trial during which subjects used their personal wheelchairs (i.e. own chair trial) and a two-week trial during which they were provided with a PAPAW (i.e. PAPAW trial). The Yamaha JWII (Yamaha Motor Corporation) power-assist add-on unit including two power-assist wheels and one battery was used in the study. It was mounted to either a Quickie 2 (folding) or

Quickie GP (rigid) frame. The frame was selected and adjusted to best match each participant's current wheelchair seat dimensions such as seat width, seat depth, backrest height, seat to footplate length, axle position, and folding option. Subjects used their own cushion while using the PAPAW. The order in which the wheelchairs were tested was randomized for each subject. During the PAPAW trial, subjects were instructed to use either the PAPAW or their personal wheelchair according to their preference.

The study's protocol was approved by the Institutional Review Board (IRB) at both the University of Pittsburgh and the VA Pittsburgh Healthcare System before its initiation. The nature of the study was explained and written informed consent was obtained from all subjects prior to the start of data collection. At that time, all risks and benefits were explained to subjects and they were asked to complete a demographic survey including age, gender, ethnic origin, injury level, year of wheelchair use, and type/model of their personal wheelchair. In addition, subjects received a packet including a set of fourteen daily questionnaires, a PIADS survey sheet and a copy of the signed consent form. Throughout the study period, both the PAPAW and subjects' personal wheelchairs were equipped with a data logging device, which collects time stamps at each wheel rotation. The data logging device was attached to the spokes of the wheelchair such that they would not interfere with propulsion or ADLs (see Figure 1). The daily questionnaire required the subjects to report placed visited, obstacles preventing their travel outside the home, methods of trespassing obstacles, and satisfaction and dissatisfaction with the wheelchair being used. At the end of each two-week trial, the PIADS survey was conducted to evaluate the impact of the PAPAW and the subject's personal wheelchair on perceived competence, adaptability, and self-esteem.

Figure 1: PAPAW with a data logging device attached

3.3 DATA LOGGING DEVICE

The data logging device used in this study was developed and tested at the Human Engineering Research Laboratories (HERL) to provide a valid and reliable means of monitoring mobility levels of manual wheelchair users in a real life environment (Figure 2). The device has a diameter of 5 centimeters and a height of 3.8 centimeters. It is self-contained, lightweight and powered by a 1/6D lithium wafer cell battery allowing data collection for over three months. The device can be easily attached to the spokes of a manual wheelchair using a small aluminum strap and screws (Tolerico, 2005) (Figure 3). Therefore, it does not interfere with the manual wheelchair configuration and wheelchair propulsion or other ADLs. Wheel rotations are measured by three reed switches on the circuit board and a magnet mounted at the bottom of a pendulum. The device can collect date and time stamps of an event to the nearest tenth of a second. The time stamp data enables the calculation of mobility characteristics in terms of distance traveled, speed, accumulated movement time, the number of starts/stops, maximum period of continuous activity, maximum distance traveled during continuous movement, and percentage of time when driving over a certain speed.

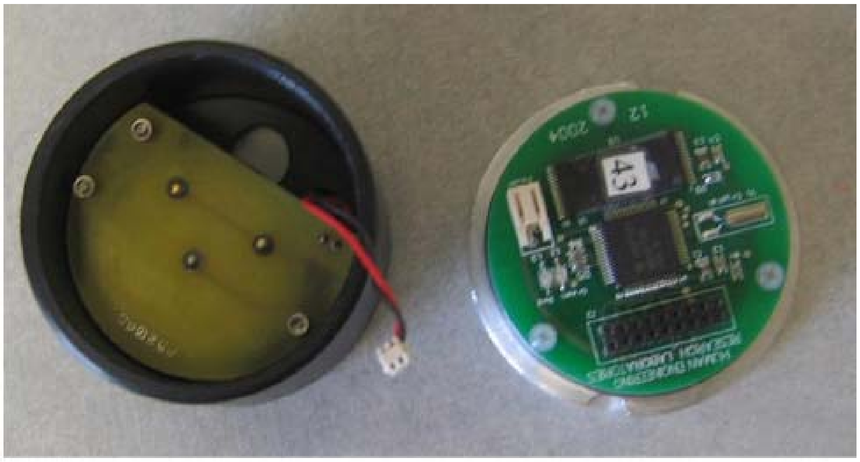

Figure 2: Data logging device used in this study

Figure 3: Data logging device attached to spokes of a manual wheelchair

3.4 TAKE HOME QUESTIONNAIRE

The daily questionnaire used in this study was developed at HERL. Participants were asked to fill out the questionnaire at the end of each day related to certain aspects of the wheelchair used for the day and the ADLs performed throughout the day. The survey investigated questions concerning the number of trips taken, time away from home, reasons that prevented leaving their home. These questions were answered with an “X” placed on the chosen answer, where satisfaction with the wheelchair was rated on a visual analog scale of one hundred millimeters (mm) in length from poor to very good in terms of comfort and maneuverability. Starting from the 10-th subject, we added the rating for accessibility at home. If the participant left their home during the day, they were asked to answer the questions related to the type of transportation used, how they loaded the wheelchair, places visited, and obstacles trespassed. The answers were chosen with an “X” on the preferred choice. Finally, the last three questions were open-ended to solicit qualitative feedbacks on the advantages and disadvantages of the PAPAW (see appendix A).

3.5 PIADS

The Psychosocial Impact of Assistive Devices Scale (PIADS) was selected for this study because it offers a measure of how an AT device impacts on the user’s life experience. It is a brief questionnaire developed to be a reliable and valid indicator of the impact of AT on people with physical and sensory disabilities (Day, H., Jutai, J. & Campbell, K. A., 2002) (see appendix B). It is a 26-item rating scale where each item is rated from -3 to +3; with a -3 meaning “maximum negative impact” and +3 indicating “maximum positive impact”. Zero denotes no perceived impact. The questionnaire yields three subscales, i.e., competence (12 items), adaptability (6 items), and self-esteem (8 items). The competence subscale measures feelings of functional competence and efficacy. The adaptability subscale indicates a willingness to try out new devices and to take risks. The self-esteem subscale includes questions on topics such as self-esteem, security, sense of power and control, and self-confidence. A higher score in each subscale determines a positive impact of the AT used on the psychosocial life of the individual. The PIADS is reported to be a valid tool for measuring assistive technology impact when combined with a semi-structured interview (Jutai, 2000).

3.6 DATA REDUCTION AND ANALYSIS

3.6.1 Data Reduction

The raw data stored on the flash memory chip of the data logging device were transferred to a personal computer. The raw data files were decompressed and analyzed using a custom designed MATLAB program (R2006a, The MathWorks Inc). The program computed basic mobility variables including daily distance traveled, average speed, and accumulated driving time. Other secondary variables such as the number of starts/stops per thousand meters, maximum period of continuous activity between consecutive stops, maximum distance traveled between consecutive stops, and percentage of time when driving below 0.5 m/s, between 0.5-1.0 m/s, and over 1.0 m/s were also calculated. Wheelchair users were considered to be idle or stopped if the amount of time between the two consecutive time stamps exceeded seven seconds.

3.6.2 Data Analysis

Descriptive statistics were used to analyze the demographic factors associated with the subjects including gender, age, years of injury, years of utilizing the current wheelchair, type of injury/level, ethnic origin, veteran status, and wheelchair type and model. Descriptive statistics were also performed to determine basic mobility variables and secondary variables over two two-week trials. All data were examined for normalcy.

All statistical analysis was completed using SPSS v13.0[b] software (SPSS, Inc.). The significance level was set at $p < 0.05$. To test *Hypothesis 1a-1c*, we conducted three comparisons on basic mobility variables shown in the diagram below, i.e., (1) the PAPAW versus the personal chair during the PAPAW trial, (2) the PAPAW versus the personal chair during the own chair trial, and (3) the combined mobility during the PAPAW trial and the own chair trial (Figure 4).

PAPAW Trial (2-week)			Own Chair Trial (2-week)
PAPAW	Personal Chair	Total	Personal Chair

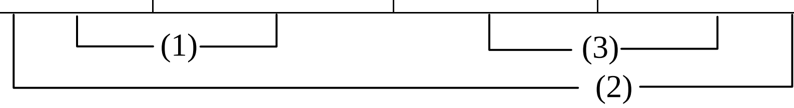

Figure 4: Diagram of mobility variables

Based on the normalcy of data distribution, a Wilcoxon Signed Ranks test was used to determine the difference on the daily distance and accumulated driving time. A paired t-test was used to determine the difference on the average speed.

To test *Hypothesis 2a-2c*, we compared the PAPAW trial with the own chair trial. A paired t-test was used to determine the difference on the number of places visited and the variety of places. A Wilcoxon Signed Ranks test was used to determine the preference in terms of comfort, and a paired t-test was used to determine the difference regarding maneuverability. Accessibility was not statistically analyzed since it was added to the daily questionnaire starting with the 10^{th} participant, but the result was reported.

To test *Hypothesis 3a*, a Wilcoxon Signed Ranks test was used to determine the difference regarding competence and adaptability, and a paired t-test was used to determine the difference on self-esteem between the PAPAW trial and the own chair trial.

4.0 RESULTS

4.1 PARTICIPANTS

This study received prior approval by the appropriate institutional review boards. Each participant was provided with information about the safety and purpose of the study, and signed informed consent was obtained prior to any testing. Fifteen full-time manual wheelchair users with tetraplegia participated in the study. All participants were Caucasian and two of them were Veterans. They ranged in age from 18 to 59 years old with a mean of 38.3 ± 10.5 years old. The majority of the participants (80%) were male. The injury level among participants varied from C-3 to C-7 with a higher percentage of C-5 (53%). The years of injury ranged from 2 to 27 years with a mean of 15.8 ± 9.0 years. Seven participants used the titanium frame and six the ultra lightweight frame, and the rest of three participants used the lightweight frame. Table 2 shows the injury levels and characteristics of participants' personal wheelchairs.

Table 2: Injury levels of participants and characteristics of their personal wheelchairs

ID	Injury Level	Years with injury	Type of WC	Transportation
1	C6	5	Ti Lite TRA	Own-ass both
2	C5-6	7	Quickie GP	Own- ass PAPAW
3	C5-6	21	Invacare Top End	Own- ass PAPAW
4	C5-6	22	Quickie GPV	Own
5	C5-6	25	Quickie 2	Own
6	C5	4	Invacare Ti A4	Own -ass both
7	C4	4	Quickie Ti	Own -ass both
8	C3-4	28	Invacare 9000 XT	Own- ass both
9	C5-6	20	Quickie Ti	ACCESS
10	C6-7	27	Quickie Ti	Own –(lift)
11	C7	16	InvacareUltralight X4	Own- ass PAPAW
12	C6	7	Quickie Ti	Own- ass both
13	C7	27	Quickie 2	Own- ass PAPAW
14	C5-6	11	Quickie 2	ACCESS
15	C5-6	13	Quickie 2	Own –(lift)

4.2 MOBILITY CHARACTERISTICS

The basic mobility variables including daily distance traveled, average speed, and accumulated driving time were calculated based on the time stamps recorded by the data logging device. These variables for the PAPAW and the personal wheelchair during the PAPAW trial, and the personal wheelchair during the own chair trial were first analyzed with repeated measurements to determine if there was any significant differences between the first week and second week. As no significant differences were found, we concluded that there was no sudden behavior change during the study period and all the variables were averaged over 14 days for comparison. Table 3 summarizes the basic mobility variables during the two 14-days trials.

Table 3: Summary of basic mobility variables of the PAPAW and personal wheelchair over the two 14-day trials

Basic Mobility Variables	PAPAW Trial (2-week)			Own Chair Trial (2-week)
	PAPAW	**Personal Chair**	**Total**	**Personal Chair**
Daily Distance (m)	1518.3±1620.0	711.7±967.4	2230.0±2120.9	1816.7 ±1730.1
Average Speed (m/s)	0.74±0.31	0.59±0.23		0.62±0.18
Daily Accumulated Movement Time (min)	33.7±33.0	16.6±18.6	50.8±32.8	43.7±24.4

When comparing the daily distance traveled and the accumulated driving time when using the PAPAW during the 2-week PAPAW trial versus the personal wheelchair during the 2-week own chair trial, no significances were found (p=0.33 for distance, p=0.15 for time). Participants traveled a daily average of 1518.3 ± 1620.0 meters for a total of 33.7 ± 33.0 minutes with the PAPAW during the PAPAW trial, and 1816.7 ± 1730.1 meters for a total of 43.7 ± 24.4 minutes with the personal wheelchair during the own chair trial. When comparing the total mobility (the PAPAW and the personal wheelchair) during the PAPAW trial with the mobility during the own chair trial, there were no significance found as well (p=0.15 for distance, p=0.33 for time). No significant differences were found on the distance and time between the PAPAW and the personal wheelchair during the PAPAW trial where the participant could choose to use either the PAPAW or their personal wheelchair according to their preference (p= 0.08 for distance, p= 0.17 for time). Participants chose to use the PAPAW for 10.4 ± 4.7 days and the personal wheelchair for 9.0 ± 5.5 days over this 14-day period. However, subjects did travel further and spent longer time with the PAPAW than with the personal wheelchair during the same trial (1518.3 ± 1620.0 meters versus 711.7 ± 967.4 meters, and 33.7 ± 33.0 minutes versus 16.6 ± 18.6 minutes). Figure 5-7 shows the number of days, daily distance, and accumulated driving time traveled with the

PAPAW and the personal wheelchair of each individual participant during the PAPAW trial, respectively.

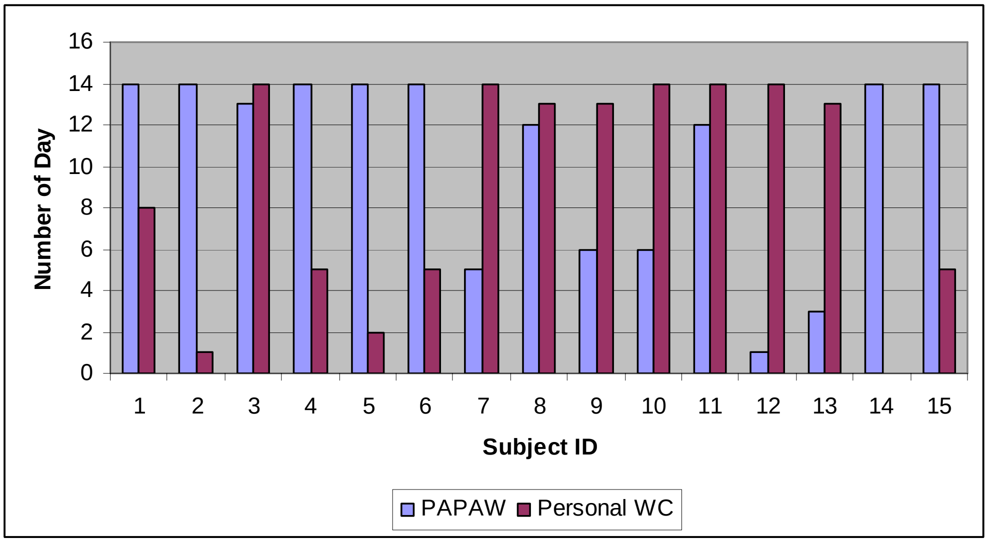

Figure 5: Number of days using the PAPAW and the personal wheelchair for each subject

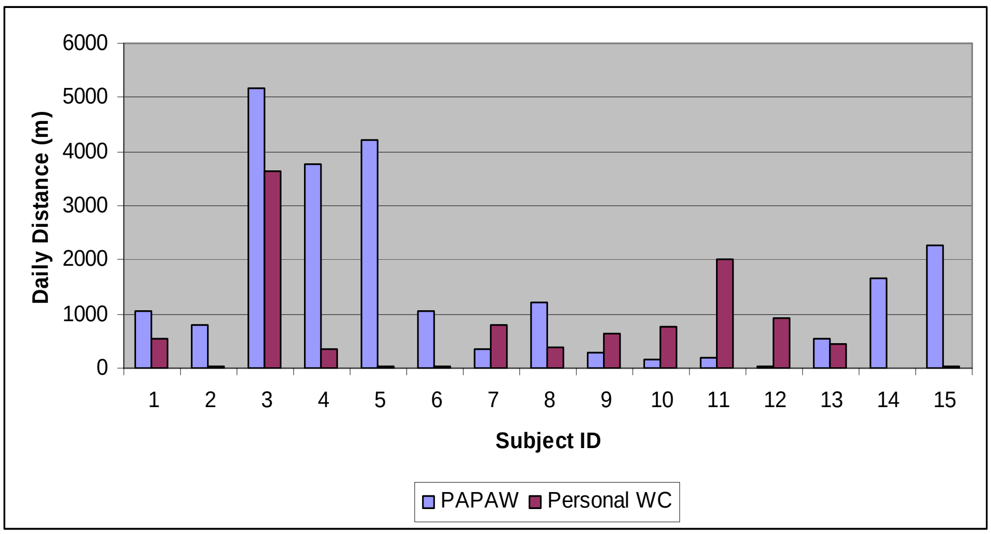

Figure 6: Daily distances with the PAPAW and the personal wheelchair for each subject

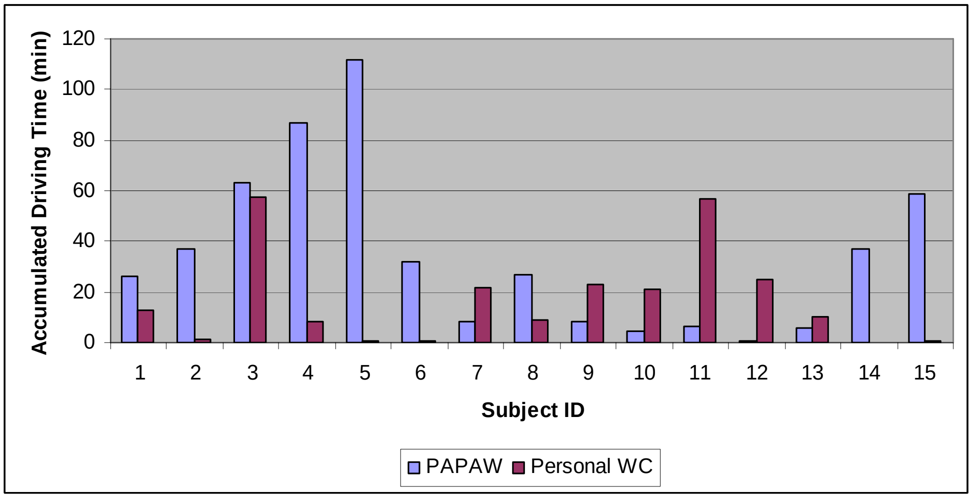

Figure 7: Driving time with the PAPAW and the personal wheelchair for each subject

In terms of the speed traveled, a significant difference (p=0.04) was found between the PAPAW and the personal wheelchair during the PAPAW trial. They traveled at an average speed of 0.74 ± 0.30 m/s with the PAPAW and 0.59 ± 0.23 m/s with their personal wheelchair during the PAPAW trial. Figure 8 show the average speed traveled with the PAPAW and the personal wheelchair for each individual participant during the PAPAW trial. They also drove significantly faster with the PAPAW during the PAPAW trial than with the personal wheelchair during the own chair trial (p=0.035).

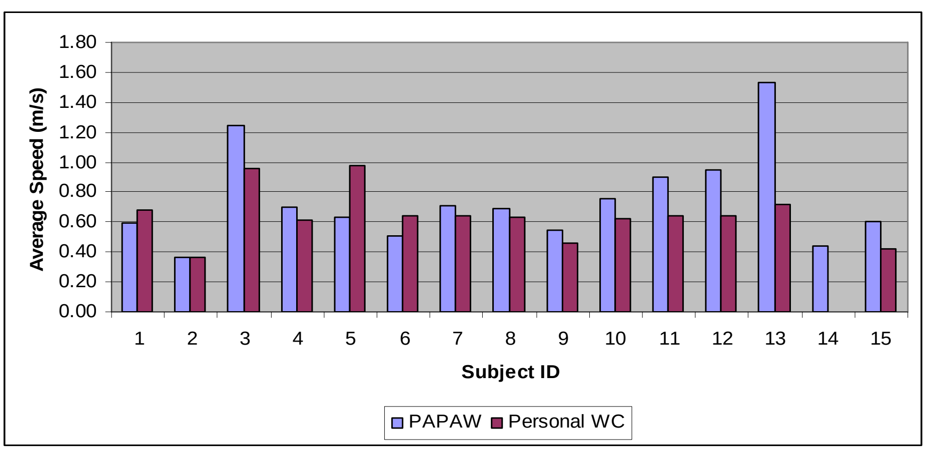

Figure 8: Driving speed with the PAPAW and the personal wheelchair for each subject during the PAPAW trial

The secondary mobility variables including the number of starts/stops per thousand meters, maximum period of continuous activity between consecutive stops, maximum distance traveled between consecutive stops, and percentage of time when driving below 0.5 m/s, between 0.5 and 1.0 m/s, and over 1.0 m/s were also calculated based on the time stamps recorded by the data logging device. Table 4 summarizes these secondary variables during the two 14-day trials.

Table 4: Summary of secondary mobility variables of the PAPAW and personal wheelchair over the two 14-day trials

Secondary Mobility Variables	PAPAW Trial (2-week)		Own Chair Trial (2-week)
	PAPAW	Personal WC	Personal WC
Number of Starts/Stops (per thousand meters)	65.4±25.7	78.3±21.8	75.2±22.7
Maximum period of continuous movement (min)	3.0±2.4	2.1±2.7	3.3±4.6
Maximum distance of continuous movement (m)	229.2±289.4	135.4±248.7	229.8±409.3
Percentage of time below 0.5 m/s	38.5%±32.6%	49.8%±26.2%	42.5%±27.8%
Percentage of time between 0.5 m/s and 1.0 m/s	45.0%±28.8%	39.4%±20.6%	46.5%±24.6%
Percentage of time over 1.0 m/s	16.5%±24.2%	10.8%±18.7%	11.0%±20.4%

4.3 COMMUNITY PARTICIPATION AND PREFERENCE

Table 5 shows the frequency and variety of places visited during the own chair trial and the PAPAW trial. No significant differences were observed on the number and variety of places visited between the two trials. During the PAPAW trial, participants visited a total of 6 ± 3 places and went out for a total of 13 ± 7 times. During the own chair trial, participants visited a total of 8 ± 5 places and went out for a total of 15 ± 8 times. Figure 9 and 10 shows the number and variety of placed visited by the individual participant, respectively.

Table 5: Frequency and variety of places visited during the two trials

Variables (avg. per person)	PAPAW Trial	Own Chair Trial	p-value
Number of places	13 ± 7	15 ± 8	0.27
Variety of places	6 ± 3	8 ± 5	0.22

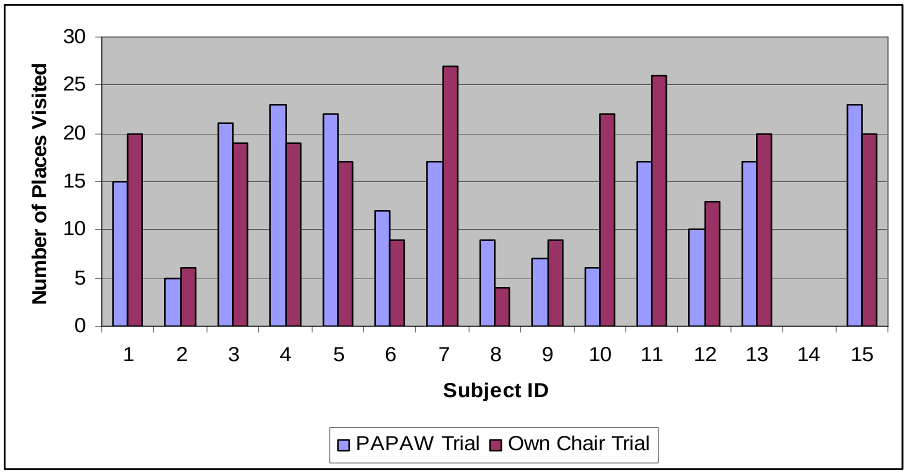

Figure 9: The number of places visited during the two trials for each participant

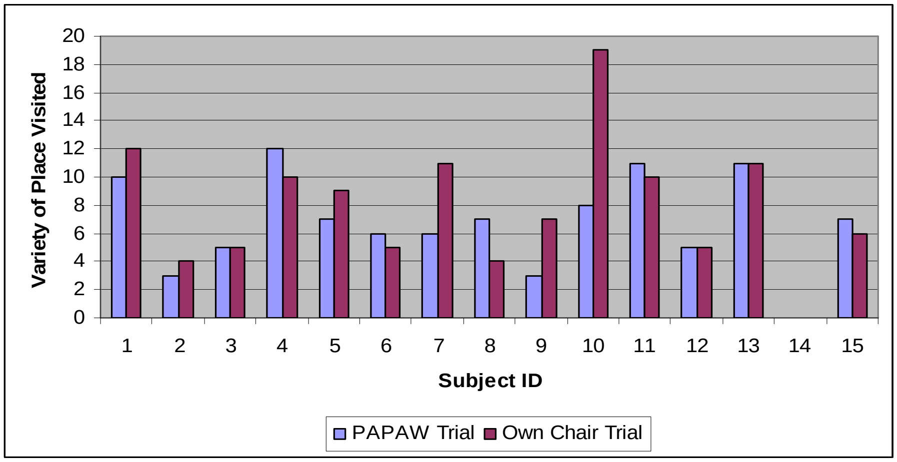

Figure 10: The variety of place visited during the two trials for each participant

Figure 11 shows the frequency of visit to a variety of places for all the participants during both trials. These places are 1) grocery stores, 2) theatre, 3) mall, 4) friend residence, 5) restaurants, 6) church, 7) work, 8) school, 9) doctor, 10) other stores such as pharmacy, hardware stores etc., 11) hiking and sports, 12) necessity (bank, post office, etc.), 13) recreational activities including museum, concert, festival, party, park, camping, fishing, etc., 14) other such as therapy, etc.

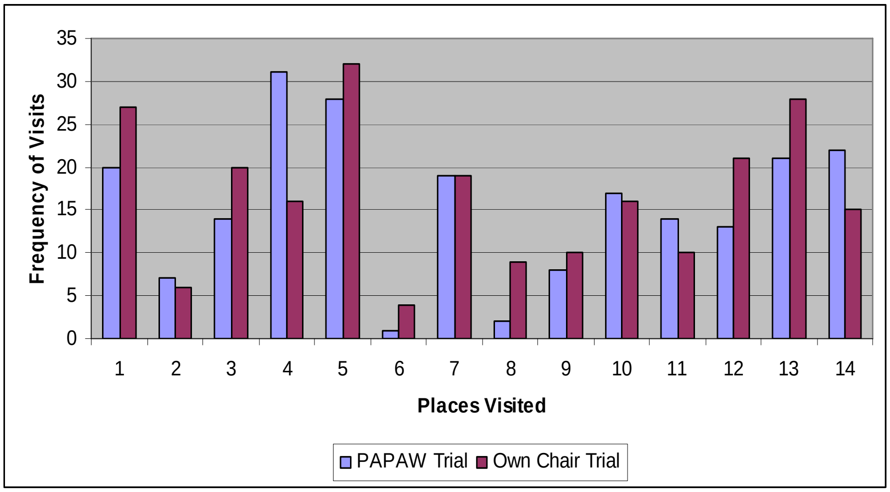

Figure 11: Frequency of visit to a variety of places during both trials

Participants satisfaction with comfort, maneuverability and accessibility of the PAPAW and the personal wheelchair were recorded on the daily basis via a visual analog scale where participants placed a mark along the line from poor (0mm) to very good (100mm). Table 6 shows the ratings on comfort, maneuverability, and accessibility of the two chairs. Although the average comfort ratings with the PAPAW were higher (77.2 ± 12.6 mm) than with the personal wheelchair (71.9 ± 22.0 mm), no significant difference was found on comfort between the two wheelchairs ($p=0.91$). No significant difference was seen on maneuverability as well ($p=0.17$), where the rating on the PAPAW was 82.0 ± 13.3 mm and on the personal wheelchair was 65.4 ± 25.3 mm. The accessibility at home was added to the protocol starting with the 10th participant. The rating on the PAPAW was 84.6 ± 10.3 mm and on the personal wheelchair was 79.4 ± 10.5mm. No significant differences were found (p=0.43). Figure 12-14 shows the ratings on comfort, maneuverability, and accessibility of the two chairs from each individual participant, respectively.

Table 6: Ratings on comfort, maneuverability, and accessibility of the two chairs

	Comfort (mm)	Maneuverability (mm)	Accessibility(mm)
Personal WC	71.9 ± 22.0	65.4 ± 25.3	79.4 ± 10.5
PAPAW	77.2 ± 12.6	82.0 ± 13.3	84.6 ± 10.3
P Value	0.91	0.17	0.43

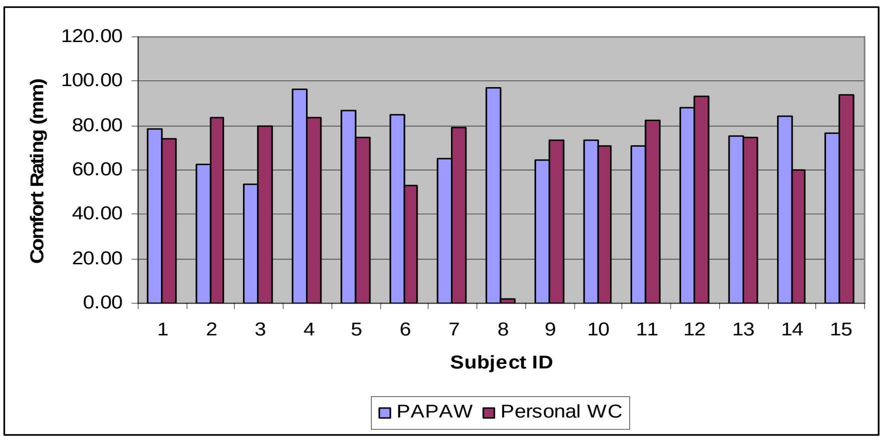

Figure 12: Comfort ratings on both wheelchairs by each individual participant

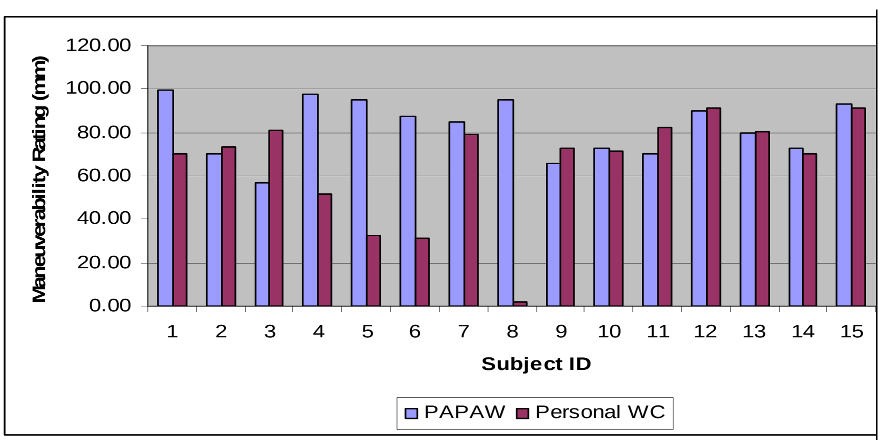

Figure 13: Maneuverability ratings on both wheelchairs by each individual participant

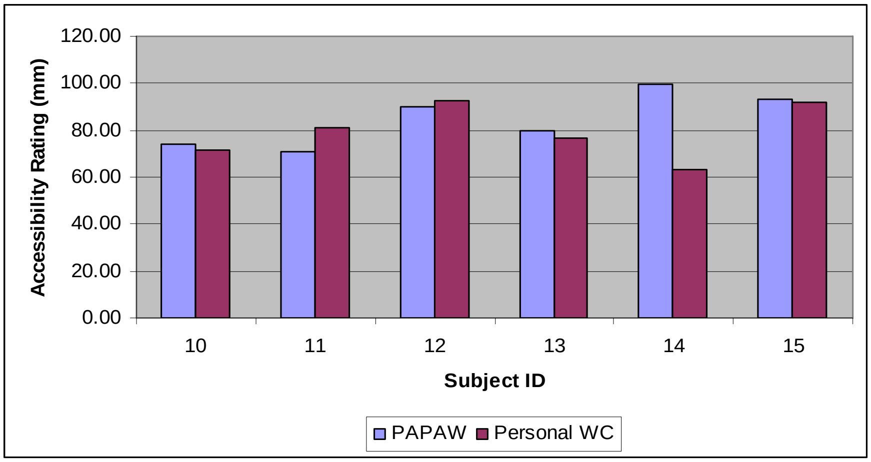

Figure 14: Accessibility at home ratings on both wheelchairs by some participants

In the daily questionnaire, we also asked two open-ended questions regarding the benefits and limitations of the PAPAW. The benefits reported include easy propulsion (11), increased independence (6), good performance in difficult terrains (3), increased quality of life (4), faster speed (4), and other benefits such as decreased upper-limb pain, easy to carry shopping bags, comfortable, feel stronger, good braking, and easy turning. The limitations reported include difficulty in disassembly (4), difficulty in maneuvering in small rooms and inside the house (3), fitting problem (3), and other problems such as heavy wheels, hard to load into the trunk, not fast enough, hard to change battery independently, difficult to propel when the battery dies, hard to go up curb cuts.

4.4 PIADS

Results from the PIADS survey were summarized in Table 7. No significant differences were found on all three subscales, i.e. competence, adaptability, and self-esteem.

Table 7: PIADS subscale scores

	Competence	Adaptability	Self-Esteem
Personal WC	1.69 ± 1.01	1.54 ± 1.08	0.98 ± 1.29
PAPAW	1.65 ± 1.21	1.15 ± 1.26	0.91 ± 1.29
P Value	0.95	0.44	0.57

Figure 15-17 plots the PIADS scores on competence, adaptability, and self-esteem at the end of each trial from each individual participant, respectively.

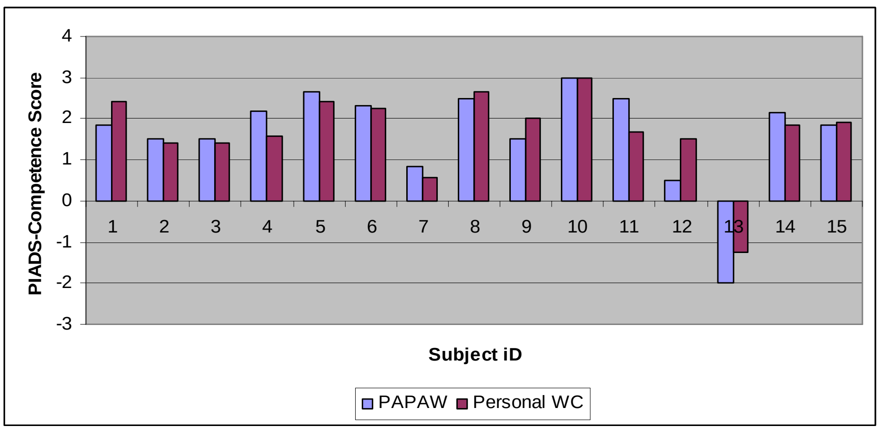

Figure 15: PIADS-competence score for the two trials by each individual participant

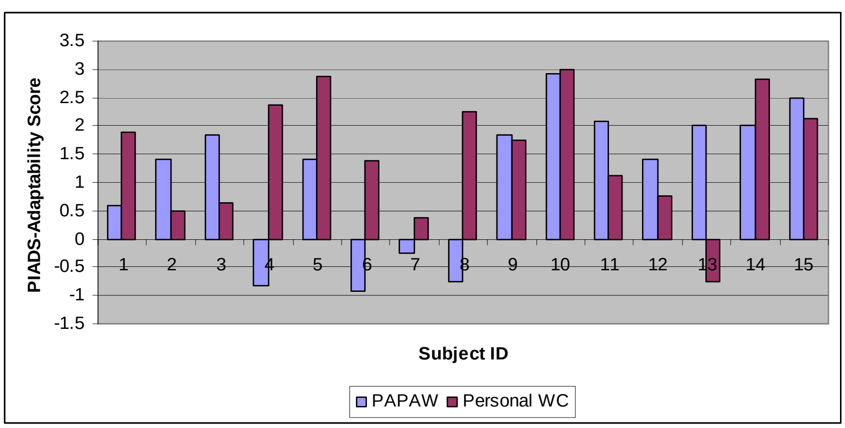

Figure 16: PIADS-adaptability score for the two trials by each individual participant

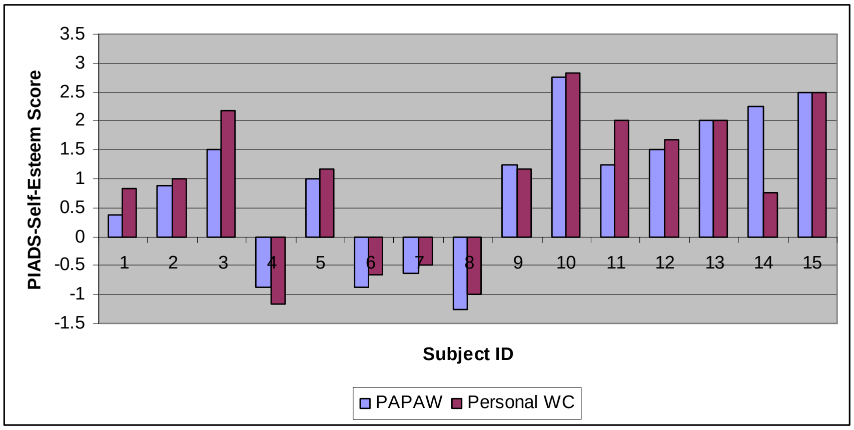

Figure 17: PIADS-self-esteem score for the two trials by each individual participant

5.0 DISCUSSION

Previous studies showed that the PAPAW operates much like a manual wheelchair with less effort, decreasing strains on the upper extremities while performing activities of daily living (Arva *et. al.*, 2002; Cooper *et. al.*, 2001; Fitzgerald *et. al.*, 2003). Most studies were conducted in laboratory settings among individuals with reduced capabilities such as the elderly, individuals with SCI, and other disabilities (Algood, 2003; Arva *et. al.*, 2001, Levy *et. al.*, 2004). The only field study was conducted by Fitzgerald et al. (2003) who compared the usage of the PAPAW and MWC among individuals with paraplegia in a four-week protocol. Our study represented another such study that investigated the usage of the PAPAW in real-life environments and its impact on activities of daily living among individuals with tetraplegia.

The participants in this study completed two 2-week trials, i.e. the PAPAW trial where they were given the PAPAW for two weeks, but they could choose to use either the PAPAW or their personal wheelchair for the activities of daily living, and the own chair trial where they used their personal wheelchair alone for another two weeks. We hypothesized that they would drive more miles, longer durations, and faster with the PAPAW than their personal wheelchair. However, our results showed no significant differences on the distance and driving time between the two wheelchairs during the same PAPAW trial, the two wheelchairs during separate trials, and the combined mobility (the PAPAW and personal wheelchair) during the PAPAW trial and the mobility during the own chair trial. One of the reasons that we didn't observe significant differences between the two wheelchairs during separate trials, and between the PAPAW trial and the own chair trial could be due to the life styles people usually maintain. Within such a short period of time (2-week), their activity levels may not be subject to drastic changes. They may not have sufficient period of time to acclimatize to the PAPAW and achieve effective operation. Furthermore, most people may exhibit a temporary reduction in performance when introduced to a new technology (Cooper *et. al.*, 2000). Fitzgerald *et. al.* (2003) suggested the two-week period used in their study comparing MWC and PAPAW usage in the community among individuals with paraplegia may not have been sufficient to uncover significant changes or allow participants to alter habits of use. However, when comparing the mobility between the two wheelchairs during the same trial where they had the freedom to select the wheelchair to use, we found that they chose to use both wheelchairs at similar frequency (10.4 ± 4.7 days for the PAPAW and 9.0 ± 5.5 days for the personal wheelchair), but they traveled further and spent longer time with the PAPAW than their personal wheelchair (1518.3 ± 1620.0 meter versus 711.7 ± 967.4 meters, and 34.2 ± 33.0 minutes versus 16.6 ± 18.6 minutes), although no significant differences were found (p= 0.08 for distance, p= 0.17 for time). Only one participant (14^{th}) didn't travel during both trials, mostly because he usually doesn't go out unless he has a doctor appointment. Previous studies (Arva *et. al.*, 2001, Corfman *et. al.*, 2003, Algood, 2003) have concluded that subjects needed to generate more power when propelling their personal wheelchair than the PAPAW. Studies have also shown that in order to preserve an active lifestyle, it is common to see upper extremity pain and repetitive strain injuries among individuals who self propel their manual wheelchairs (Boninger *et. al.*, 2002), and more than two thirds of individuals with SCI report suffering or have suffered some kind of shoulder pain since becoming manual wheelchair users (Sie *et. al.*, 1992). Therefore, it is possible that participants in this study may have preferred the PAPAW to their personal wheelchair as they were able to drive further with less physical strain to their upper extremities. Participants in this study also reported that it was easier to traverse difficult terrains and obstacles such as going up ramps, gravel, grass, and carpet with the PAPAW than their personal wheelchair. This capability may facilitate more outdoor travels, and four participants actually reported to take bike trails in the park with the PAPAW but not during their own chair trial. In terms of the driving speed, significant differences were found between the two wheelchairs during the same trial and the separate trial as well. It seems natural that with the power assist function, the PAPAW would allow participants to move faster than a regular MWC. One participant reported the PAPAW increased his independent mobility especially on his working environment where he needs to go to different places during the day, and decreased his driving time between places and with higher speed. He also reported he could accomplish more throughout the day compared to his personal wheelchair. From the summary table of the secondary mobility variables (Table 4), we could see that the percentage of time traveling over 1 m/s was higher with the PAPAW than with their personal chair. We could also observe that the increased percentage of time traveled with higher speed allowed participants to reach a normal walking speed required to safely cross the streets (1.2m/s) compared to participants personal wheelchair (Lerner-Frankiel & colleagues, 1986). Being able to propel faster and more efficiently is very important especially for individuals with tetraplegia since they usually require more physical strain and longer time to perform their activities of daily living compared to individuals with paraplegia. The PAPAW also allows the participants to travel further and longer without unnecessary stops for rests, saving individuals time while accomplishing more during the day, indicating that the PAPAW could be beneficial to those who have endurance problems, who couldn't produce continuous strokes and couldn't accomplish more due to fatigue and longer time to rest between activities.

The number and variety of places visited were not statistically different between the two trials, indicating that participants in this study were able to maintain their lifestyles with the PAPAW despite the learning curve and adjustment process within a short time period, and other problems such as difficulties with transportation, maneuverability in small rooms, and fitting issues reported with the PAPAW. On the other hand, we didn't see the hypothesized outcome that the PAPAW could enable participation in more and larger variety of activities than their personal wheelchair. The reason could be that a lifestyle change may take much longer than two weeks, and there are usually many more factors such as personality that contribute to such a change as well. We had some difficulties in recruiting participants for this study, as individuals with tetraplegia within a productive age range were either already using a power wheelchair, or had such an active lifestyle that did not want to try a new device for such a short period of time. Another reason could be that the PAPAW can outperform a regular manual wheelchair for certain activities, but may have similar performance or even less convenient to use under other situations. From Figure 11, we observed that the PAPAW seems to have more advantages when visiting friends or family, and during outdoor activities such as hiking. As mentioned earlier, four participants reported to take bike trails in the park with the PAPAW but not during their own chair trial. One participant particularly requested to enroll in the study at the time when he planned a visit to a local amusement park where he could use the PAPAW to reduce the amount of propulsion and save his energy.

In terms of the user's preference regarding comfort, maneuverability, and accessibility at home, we didn't find any significant differences between the two wheelchairs, although the PAPAW received higher ratings in all three aspects than the personal wheelchair. The PAPAW was setup based upon measurements taken from the personal wheelchair of each participant. More than half of the participants used a Quickie frame manual wheelchair, which allows the investigators to configure the PAPAW with the same or similar frame. However, two subjects reported problems with the PAPAW they received such as lower footrest, and other comfort problems, which may prevent us seeing a significant difference as expected. Participants reported an increased independent maneuverability with the PAPAW not only in the home, but also in uneven terrains such as carpet, grass, and gravel. These results are similar Algood (2003) where subjects rated 10 out of 18 obstacles as easier to complete with the PAPAW. However, three participants also reported measurability problems with the PAPAW specifically around tight corners and in small rooms. The rating for accessibility at home was added to the protocol for the last six subjects out of the concern about the added width of the PAPAW. However, the PAPAW received a higher rating on the accessibility at home than their personal wheelchair. One of the reasons could be the home environments for the last six subjects were already modified to be wheelchair accessible and could accommodate the added width of the PAPAW. Though accessibility at home seems a lesser issue, transportability was reported by the majority of participants as a reason for not using the PAPAW more often. Transferring the PAPAW to their vehicles independently was not possible due to weight of the wheels. Some of the participants had to rely on the availability of their friends or family members in order to go out. Other related complaints included difficulty in disassembling the wheels, and changing the battery independently.

We chose the PIADS to measure the degree to which the two wheelchair influenced participants' perception of self and disability, considering the fit between the person and the social context. The PIADS scores received in this study demonstrated that both wheelchairs have a positive impact on the participants' perceptions of competency, adaptability, and self-esteem, but no significant differences were found on three subscales between the two wheelchairs. The small sample size and limited duration of experimental trials may prevent us from seeing a higher score with the PAPAW than their personal wheelchair, especially considering half of the participants in this study reported to use a regular manual wheelchair for 11.33 ± 5.16 years. Users of a new device must develop skills and aptitudes with the device, and this occurs usually through a process of experience and learning. Six participants reported that the PAPAW increased their independency, and four of them reported improvement in their quality of life, where the PAPAW enhanced their mobility especially outside their home. This is also compliant to what was found by Fitzgerald *et. al.* (2003), where participants rated that the PAPAW enhanced their self-perception as the chair went faster resulting in getting more accomplished in a day. Despite the benefits mentioned by participants about the PAPAW, they also mentioned its disadvantages such as transportability, maneuverability in small rooms, and battery location etc., which may affect their ratings of the PAPAW. The self-esteem scores were lower than the other two subscales for both wheelchairs, which is consistent with the previous study by Devitt *et. al.* (2003), who compared the use of a PWC versus a MWC among individuals with multiple sclerosis and found mean scores were lower for the MWC users on all subscales and the self-esteem scores were lower than the other subscales. The self-esteem subscale deals more directly with emotional response and self-perception, while the adaptability and competence subscales consider issues of independence, performance, and opportunity. It may be that, with the short study period, participants did not have sufficient time to feel confident in using the PAPAW. Psychological feelings of frustration and sadness could arise due to the hassles occurred while learning to use the PAPAW and trying to adjust their routines with the PAPAW. The same feeling of frustration may also exist with the personal wheelchair for some ADLs. The PAPAW and personal wheelchair received similar scores on the competence scale. However, we observed that one of the subjects gave negative scores on both wheelchairs. He reported it was difficult to independently transfer the PAPAW into his car as it was a standard four doors sedan and he usually loads the chair behind the passenger seat, which he usually take some time to do, but is was much difficult with the PAPAW. Disassembling the PAPAW wheels was very difficult for him due to their heavy weight so he either needed assistance to load the PAPAW or, in some case chose not to use it; therefore it was a hassle for him to transport not only the PAPAW but also his personal wheelchair. The ratings on adaptability were lower for the PAPAW than the personal wheelchair. Four participants actually gave negative ratings for the PAPAW but positive ratings for their personal wheelchair. The same four participants gave negative ratings for both wheelchairs on the self-esteem subscale. Interestingly to note that although they showed an active lifestyle such as going to concerts, hiking, and gym, they reported to require assistance to load the wheelchair to their cars. As previously stated, one of the drawbacks of PAPAW was related to transportation such as its transportability, heavy wheels, and difficulty of disassembly. The dependency on others for loading their wheelchairs may increase their frustration and lowering their self-esteem. One of those four participants has a higher injury level (C3), and with the decreased hand function, loading any wheelchair is a challenge.

Individuals usually consider many variables in selecting a mobility device. It was observed that injury level, lifestyle, as well as transportation status can influence clinicians and individuals' choice of mobility device especially among those with higher level of injury (such as tetraplegia). The decision to use a manual wheelchair, a power wheelchair, or a PAPAW may not rest solely on the performance of the device, but also on the user's experience using the device, particularly in the social context. When choosing between a PAPAW, manual wheelchair or a power wheelchair, it is important to consider not only individuals physical condition and preferences, but also their home environment, including outdoor factors such as steps to get into the home, and also indoor factors such as steps in the home, doorways and maneuvering spaces. Transportation has to be considered, as a PAPAW is heavier than manual wheelchair and therefore more difficult to lift into a vehicle if a ramp or lift system is not available. Power wheelchairs can offer an independent means of mobility, however, they are bigger and heavier, and also in some models require more space for maneuvering, and driving through narrow spaces may be a barrier for some users resulting n them being confined at home and unable to go to some places. PAPAWs on the other hand, provide not only independent mobility indoors and outdoors, but also provide some cardiopulmonary fitness, upper extremity exercise and can maneuver more effectively than power wheelchairs especially in the home (Somers & Wlodarczyk, 2003). In our study although no statistical significant differences were seen, the PAPAWs were scored higher not only on maneuverability, but also on comfort and accessibility in the home. For individuals with tetraplegia who can propel a wheelchair efficiently and want to maintain physical exercise, PAPAWs are possibly a more appropriate option of mobility device prior to using a power wheelchair.

5.1 LIMITATIONS & FUTURE WORK

The results of this study may provide some insights for clinicians prescribing the PAPAW and manufacturers advancing the PAPAW technology. However, there are a few limitations that need to be addressed. The small sample size increased the possibility of a type II error that differences between the PAPAW and the personal wheelchair in terms of mobility, community participation, and psychosocial well-beings that truly exist were not uncovered. The time period for using the PAPAW was two weeks; this may not have been a sufficient period of time to acclimatize to the PAPAW and achieve effective operation, and uncover significant changes or allow participants to alter habits of use as well. A longer trial period may have resulted in a better reference point for evaluation of performance, and it would be easier to capture the types and number of new activities and environments that users might attempt with the PAPAW. The training session for the PAPAW was short where the investigators went over all the features of the PAPAW in one time and participants then practiced with the PAPAW for about 10-20 minutes only. The learning curve, adjustment process, and development of experiential knowledge of the PAPAW all happened during the 2-week experimental trial, so the PAPAW might not be evaluated based upon a fair ground that participants were fully familiar with the features and usage of this new device. Again future studies should consider a longer period of use, or at least a longer period of adjustment before commencing evaluation. More information could be collected by the questionnaire such as the satisfaction with the current personal wheelchair, specific problems encountered with the current wheelchair, upper-extremity pain status, and baseline life styles, which will help better interpret the ratings of the PAPAW. A more controlled subject pool including those who are in the waiting list for a PAPAW would provide more insights into the impact of a PAPAW.

The impact of the PAPAW among individuals with tetraplegia was only evaluated using the PIADS from the perspectives of self-perceived disability in the social contexts. Other outcome measures could be considered to evaluate the impact of the PAPAW from different perspectives such as users' satisfaction with the PAPAW and its attributes using QUEST (Demers *et. al.*, 2002), or users' ability to perform activities using FEW (Functional Evaluation in a Wheelchair) (Mills *et. al.*, 2002). We also had difficulties in recruiting participants for this study, as individuals with tetraplegia within a productive age range were either already using a power wheelchair, or had such an active lifestyle that did not want to try a new device for a short period of time. A multi-center collaboration study would significantly increase the subject pool as well as provide a more heterogeneous population. Future work should also include more rigorous analysis based on a larger sample size. Between-subject comparison would allow us to examine who may be better suited to using the PAPAW than others. A closer examination of impairment degrees among users and its relationship to the PAPAW use may be worthy of investigation. Within-subject comparison would provide a better picture of the circumstances where the PAPAW might be more beneficial than a regular manual wheelchair such as hiking, or other activities that requires significant amount of movement.

APPENDIX A

Take Home Questionnaire: Phase III (Daily form)

Date______________

1.**Number of Trips taken today** (trip=leaving and returning home)____

2. Amount of Time away today (e.g. 2 hours 45 minutes) __________

3. Type of Wheelchair Used Today

____ Own Wheelchair

____ PAPAW

---

4. Was today a typical day?

____ Yes

____ No

Only if you said no:
____ more active than usual
____ less active than usual

5. Were there any reasons that prevented you from traveling outside the home today?

____ Yes, please check all that apply:

_____ weather (raining, snowing, heat)

_____ was not feeling well (illness, fatigue)

_____ problems with transportation (automobile problems, etc)

_____ problems with wheelchair

_____ other (please explain) ______________________________

____ No

For the next three questions place an X on the line according to your satisfaction with the wheelchair you used today*:*

Example

Poor ——X—————————— Very good

6. How would you rate the overall ride comfort in this wheelchair?

Poor ______________________________ Very good

7. How would you rate the maneuverability in this wheelchair?

Poor ______________________________ Very good

8. How would you rate the accessibility of this wheelchair in your home?

(e. g. access doorways, rooms in you home)

Poor ______________________________ Very good

9. Only answer the next questions *if you left your home today*. If you did not leave your home please go to question 10:

Type of Transportation (you may check more than one, if applicable)

____ ACCESS

____ Public transportation, such as bus

____ Own vehicle (car, van)

____ No transportation (going out by wheelchair)

Type of loading

____ Loaded wheelchair independently

____ Loaded wheelchair with assistance

____ Not applicable

Places Visited Today (check all that apply)

____ Grocery store

____ Movie theatre

____ Mall

____ Family/Friends' residence

____ Restaurant

____ Church

____ Work

____ School

____ Doctors appointment

____ Others, Please specify________________________

Choose the obstacles encountered and how did you manage to trespass it *(check all that apply)*

	Traversed Independently	Required Assistance	Avoided Obstacle
Up ramp	_______	________	________
Down ramp	_______	________	________
Grass	_______	________	________
Gravel	_______	________	________
Curb cuts	_______	________	________
Small curb	_______	________	________
Door threshold	_______	________	________
Carpet	_______	________	________
Snow	_______	________	________

10. Only answer the next questions *if you used the PAPAW today*. If you did not use the PAPAW, Thank you very much!!!

Did you have any technical problems with the PAPAW wheelchair?

____ Yes, please explain: ____

____

____

Were you able to resolve the problem?

____ Yes

____ No

____ No

Was there anything that you liked most about the PAPAW wheelchair?

____ Yes, please explain: ____
____
____

____ No

Was there anything that you disliked about the PAPAW wheelchair?

____ Yes, please explain: ____
____
____

____ No

Thank you for completing this questionnaire!

APPENDIX B

Psychosocial **I**mpact of **A**ssistive **D**evices **S**cale (PIADS) Today's Date: ____________________
month/day/year

Client Name:___________________________ ☐ male ☐ female
(last name, then first name)
Diagnosis:______________________ Date of Birth:_________________________
month/day/year

The form is being filled out at (choose one) **1.** ☐ home **2.** ☐ a clinic **3.** ☐ other (describe):_____________

The form is being filled out by (choose one) **1.** ☐ the client, without any help **2.** ☐ the client, with help from the caregiver (e.g., client showed or told caregiver what answers to give) **3.** ☐ the caregiver on behalf of the client, without any direction from the client **4.** ☐ other (describe): ______________________

Each word or phrase below describes how using an assistive device may affect a user. Some might seem unusual but it is important that you answer every one of the 26 items. So, for each word or phrase, put an "X" in the appropriate box to show how you are affected by using the __________________________ (device name).

	Decreases	-3	-2	-1	0	1	2	3	Increases
1)	competence	☐	☐	☐	☐	☐	☐	☐	
2)	happiness	☐	☐	☐	☐	☐	☐	☐	
3)	independence	☐	☐	☐	☐	☐	☐	☐	
4)	adequacy	☐	☐	☐	☐	☐	☐	☐	
5)	confusion	☐	☐	☐	☐	☐	☐	☐	
6)	efficiency	☐	☐	☐	☐	☐	☐	☐	
7)	self-esteem	☐	☐	☐	☐	☐	☐	☐	
8)	productivity	☐	☐	☐	☐	☐	☐	☐	
9)	security	☐	☐	☐	☐	☐	☐	☐	
10)	frustration	☐	☐	☐	☐	☐	☐	☐	
11)	usefulness	☐	☐	☐	☐	☐	☐	☐	
12)	self-confidence	☐	☐	☐	☐	☐	☐	☐	
13)	expertise	☐	☐	☐	☐	☐	☐	☐	
14)	skillfulness	☐	☐	☐	☐	☐	☐	☐	
15)	well-being	☐	☐	☐	☐	☐	☐	☐	
16)	capability	☐	☐	☐	☐	☐	☐	☐	
17)	quality of life	☐	☐	☐	☐	☐	☐	☐	
18)	performance	☐	☐	☐	☐	☐	☐	☐	
19)	sense of power	☐	☐	☐	☐	☐	☐	☐	
20)	sense of control	☐	☐	☐	☐	☐	☐	☐	
21)	embarrassment	☐	☐	☐	☐	☐	☐	☐	
22)	willingness to take chances	☐	☐	☐	☐	☐	☐	☐	
23)	ability to participate	☐	☐	☐	☐	☐	☐	☐	
24)	eagerness to try new things	☐	☐	☐	☐	☐	☐	☐	
25)	ability to adapt to the activities of daily living	☐	☐	☐	☐	☐	☐	☐	
26)	ability to take advantage of opportunities	☐	☐	☐	☐	☐	☐	☐	

Revised August 14, 2000 (Office Use Only – ID# ____________) Version 3.0

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