PRESCRIPTION, OUTCOMES, AND RISK ASSESSMENT OF WHEELCHAIRS FOR AGING POPULATION

by

Amol Mahadeo Karmarkar

Bachelor of Science, Government Medical College, Nagpur University, India, 2000

Masters of Science, University at Buffalo, Buffalo, New York, 2005

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This dissertation was presented

by

Amol Mahadeo Karmarkar

It was defended on

June 18th, 2009

and approved by

Alicia Koontz, PhD, Adjunct Assistant Professor, Rehabilitation Science and Technology

Diane M. Collins, PhD, Visiting Assistant Professor, Rehabilitation Science and Technology

Judith Matthews, PhD, MPH, RN, Assistant Professor, Health and Community Systems

Stephanie Studenski, MD, MPH, Professor, Geriatric Medicine

Dissertation Director: Rory A. Cooper, PhD, Distinguished Professor, Rehabilitation Science and Technology

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Older adults are the largest and fastest growing users of wheeled mobility devices (wheelchairs). Research in the areas of: utilization; and outcomes is very limited. Lack of evidence based research often results in the provision of lower quality of wheelchairs to aging adults. This problem is more predominant for those living in Nursing Homes (NH) or other institutional settings. The goal of this dissertation work was to present a continuum of research studies, conducted with older adults that emphasized on: the development of a methodology (utilization review); measurement of outcomes; and identification of problems associated with use of wheelchairs that may pose a threat to the health, and safety of older adults.

We anticipate that the overall outcomes of this work will help rehabilitation professionals to move towards performing utilization reviews through appropriate use of clinical environment. Such research will help in both the development of standard of care guidelines, and proving effectiveness and efficiency of service provision. We also expect to see this work influencing the outcomes research for older adults using wheelchairs. This will help in needs assessment of potential users (of wheelchairs) and will also help to evaluate: quality of services (devices) provided, and impact of types of wheelchairs on mobility and safety of users. Finally, we anticipate to see application use of the Wheelchair Assessment Checklist (WAC) by clinicians in detection of problems associated with wheelchairs and prevention of component failures, which in turn, will control (to some extent) the occurrence of unintentional (acute and chronic) injuries.

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PREFACE

I would like to express my sincere gratitude to Dr. Rory Cooper, for his mentorship and guidance throughout my doctoral program and this research process. His positive encouragement and constructive feedback kept me motivated and focused throughout this process. I would also like to thank Dr. Diane Collins for her tremendous support and guidance in my early days of the doctoral program. Sincere thanks to Dr. Stephanie Studenski for providing me the opportunity of joining the Pepper fellowship program. It made me excited and driven to work in the field of geriatrics research. Many thanks to Dr. Alicia Koontz for providing critical feedback on my work and her queries helped me to produce a high quality work. My sincere appreciation for Dr. Judith Matthews, for providing a valuable and thorough feedback on of my dissertation.

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I would like to share this accomplishment with my family, especially my parents, Aai and Baba, who have always been my greatest inspiration and who have taught me to be humble and grateful for every aspect of life. Finally, I owe everything that I have achieved so far to my wife, Kshitija. Her selfless and unconditional love kept me inspired and motivated throughout the pursuit of this goal.

1.0 INTRODUCTION

There is a growing number of older adults within both the community (home) as well as institutional settings (nursing homes (NH), assisted living centers). Wheeled mobility devices (including wheelchairs) provide some of these individuals with a means of achieving functional independence and improving participation, and thus have a positive impact on their quality of life. In spite of older adults being the largest consumer group of wheelchair users, little is known about the appropriateness of the wheelchairs provided to older adults. Unknown factors include, but are not limited to; factors that impact the provision of one type of wheeled mobility device over all of the others, and outcomes related to the use of standard versus customized device options.

Wheelchair-related incidents (falls and other injuries) are common among older adults. These incidents results from the interaction of multiple factors. Out of all of these factors, wheelchair failures (i.e., component and mechanical failures) may be preventable through proactive risk assessment and safety management.

The majority of research conducted previously on this topic has focused exclusively on the very active, community-dwelling, manual wheelchair users. Thus, the application of findings from those studies for improving clinical practice of wheelchair provision and management for older adults is limited. Problem identification is always the first step in finding appropriate solutions. In case of older adults using wheelchairs, studies focusing on problem identification do not exist widely, thus limiting the ability of researchers and clinicians to find appropriate solutions. This dissertation work consists of a series of pilot research studies, aimed at identifying problems related to: (a) provision of wheelchairs for older adults; (b) the negative outcomes associated with use of inappropriate wheelchairs; and (c) the occurrence of unintentional injuries that arise due to the use of such inappropriate wheelchairs.

This proposed dissertation is a continuum of research studies focusing on older adults using wheelchairs as their primary means for mobility. The anticipated outcomes of this work will identify problems associated with use of wheelchairs by older adults in both the community (home environment) and institutional settings (nursing homes). This will eventually aid in the development of a standard of care for the provision of wheelchairs for the aging adults. The subsequent six chapters are based on four individual research studies, and on the data from the registry at the Human Engineering Research Laboratories (HERL), as mentioned in the Table 1.1 below.

Table 1.1 Research Studies

1.	Wheelchairs Obtained by Older Adults from the Center for Assistive Technology: A Retrospective Analysis
2.	Wheelchair User Registry*
3.	Wheelchair Driving Characteristics During and Post National Veterans Wheelchair Games
4.	How Does Wheelchair Use in Extended-Care Facilities Affect Safety, Participation, and Quality of Life?
5.	Assessment of Repairs and Maintenance Issues of Manual Wheelchairs for Residents in Nursing Care Facilities (NCF)

* not a research protocol

The second chapter of the dissertation utilized data from studies 1, 4, and from the wheelchair user registry. The objective of this paper was to identify the association between demographic characteristics, health-related factors for older adults (age>60 years), and types of wheeled mobility devices used. Specifically we wanted to explore the utilization of the types of wheeled mobility devices (manual wheelchairs, power wheelchairs, and scooters) by older adults. This was done in order to identify the demographics (age, and gender), health-related factors (primary diagnosis), and living settings (home versus institutional settings) that may be associated with the types of wheeled mobility devices being used.

The third chapter of the dissertation was a subsequent analysis of the second chapter utilizing the data collected for study 1. The objectives of this chapter were: (a) to identify the factors that impact the prescription of wheeled mobility devices for older adults at the Center for Assistive Technology (CAT) at the University of Pittsburgh Medical Center (UPMC), and (b) to determine the relationship between living settings (home versus institutional) and the types of devices that older adults receive. Specifically, the objective of this study was to determine the clinical decision making process employed by the center and factors that contribute to the provision of one type of wheeled mobility device versus the others, for older adults.

The fourth chapter of the dissertation described a study designed to determine the outcomes related to the use of different wheeled mobility devices by older adults living in both community and institutional settings. The objective of this chapter was to analyze satisfaction related to wheelchair use (manual and power wheelchairs) from three cohorts of older individuals: one living at VA-affiliated nursing homes, the second living in private nursing homes, and the third was comprised of individuals living in community (individual home) settings. We hypothesized that: (a) the quality of wheelchairs possessed by community dwelling older adults will be better than those living in NH; and (b) the levels of satisfaction related to wheelchair use will be higher for community dwelling older adults as compared to those living in NH.

The fifth chapter of the dissertation utilized an objective method to determine wheelchair-related mobility patterns for older adults living in community settings. This chapter used the data from study 3. The objectives of this study were: to determine wheelchair mobility patterns for community dwelling older adults; and to identify whether age has an impact on wheelchair use, or self-reported physical activities. We proposed that: (a) older adults will be more active during the games than their home environment; (b) there will be differences in self-reported activity levels between manual and power wheelchair users; and (c) factors such as age, self-reported physical activities levels, and wheelchair mobility, will be correlated.

The sixth chapter of the dissertation utilized the same objective method described in the fifth chapter for identifying the extent of wheelchair use by older adults in nursing homes. This chapter utilized data from the fourth study. The objectives of this study were to quantitatively assess wheelchair-related mobility in older adults living in NH, and to identify the factors that may be contributing to the differences in wheelchair-related mobility characteristics.

The seventh chapter of the dissertation was based on data from the fifth research study. The objectives of this chapter were: to describe the development and standardization of a wheelchair assessment checklist that could determine the risks associated with use of wheelchairs by older adults in a nursing home; and to describe the impact of wheelchair conditions on wheelchair-related mobility, safety and satisfaction related to wheelchair use. The study was conducted in two phases: Phase I – development and standardization of a wheelchair assessment checklist (WAC); Phase II – utilization of the developed checklist for the assessment of quality (conditions) of wheelchairs in nursing homes and to identify the impact of wheelchair condition on the mobility, satisfaction, and safety related to wheelchair use.

The final chapter (conclusion) of the dissertation describes the compiled results from all the studies, and attempts to describe evidence related to all the areas for standardization of wheelchair prescription, delivery, and maintenance practices, for the older adult population.

2.0 DEMOGRAPHIC PROFILE OF OLDER ADULTS USING WHEELED MOBILITY DEVICES

AUTHORS: Amol M. Karmarkar[1-2], PhD(c), MS; Brad E. Dicianno[1-3], MD; Emily Teodorski[1-2], BS; Rory A. Cooper[1-2], PhD

AFFILIATIONS: [1]Human Engineering Research Laboratories, VA Pittsburgh Healthcare System; [2]Department of Rehabilitation Science and Technology, University of Pittsburgh; [3] Department of Physical Medicine and Rehabilitation, University of Pittsburgh

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CORRESPONDENCE

Rory A. Cooper, PhD,

VAPHS-Human Engineering Research Laboratories,

7180 Highland Dr., Bldg. 4, 2nd Floor, 151R1-HD,

Pittsburgh, PA 15206,

rcooper@pitt.edu

2.1 ABSTRACT

The purpose of this study was to determine the relationship between demographic and health-related factors and use of wheeled mobility devices among older adults. Data from a cohort of 723 older adults using wheeled mobility devices were analyzed. It was found that the factors including age, gender, diagnosis, and living settings were associated with differences in use of manual versus powered mobility devices. Differences were also noted with respect to the use of sub-types of manual (depot, standard, and customized) and those of powered (scooter, standard, and customized) mobility devices. A consideration of these factors during the prescription process may assist in identifying the most appropriate mobility device for the user, which, in turn, will help define standards of care.

KEYWORDS: Older adults, Wheeled mobility devices, Wheelchairs, Standard of care,

2.2 BACKGROUND

The data from recent population statistics have indicated a global exponential growth in the number of older adults (aged >65 years). This number, in the US alone, is projected to be approximately 40 million by the year 2010, and 87 million by 2050.[1] About 5% of all older individuals in the US are currently living in institutional settings. The increasing trend of life expectancy has been directly proportional to the increase in disability. This increase has resulted in growing need by this population for either human or technology support for performing daily activities.[1] Wheeled Mobility Devices (WhMD) are commonly used by older adults, and these devices have been found to increase independence in Activities of Daily Living (ADLs) by reducing the need for human help.[2] Assistive Technology (AT) devices, in general, are reported to decrease the residual difficulty in daily activities of older adults, and thus decrease the need for personal assistance; in turn, reducing the probability of placement in long term care facilities.[3-5] However, a mismatch between the needs of the end-users and the types of devices used results in an increased need for personal assistance in spite of the use of the devices.[6]

In the US, an estimated 1 million WhMD users are aged 65 years and above, with the majority being manual wheelchair (MWC) users.[7] Several factors are reported to be associated with the use of WhMD by ambulatory older adults in skilled nursing facilities: (a) fear of falling during walking, (b) faster and efficient mobility with wheelchairs, and (c) physical limitations that impede walking ability (such as weakness, balance issues, pain, visual impairment, etc.).[8] A cross-sectional study, representing the Canadian population of community dwelling older adults aged 65years and above, described that factors including gender (men>women), level of functional limitation (greater functional limitation>lesser functional limitation), and living status (alone>living with someone) are some of the indicators for increased wheelchair use.[9]

Utilization of WhMD for older adults differ by living settings (situation) differs. While clinicians view WhMD as a way to improve independent mobility, wheelchairs are often also provided to residents of nursing homes (NH) to meet their positioning needs or merely for improving transportation efficiency.[10] In one study, the residents of a NH reported that use of wheelchairs improved their level of independence in functional mobility, their efficiency and their safety during mobility.[8] In general, a wide gap exists between the perspectives of clinicians and those of the end-users, with respect to the use of wheelchairs. The utilization of a prescribed WhMD depends on several factors such as: the user's demographics (e.g., age, gender etc.); their health factors (e.g., physical impairments, functional limitations, co-morbid conditions); the characteristics of their wheelchair (e.g., condition, type of wheelchair, etc.); the environmental facilitators and barriers (e.g., accessible living situation); and the quality of service delivery (the process of wheelchair prescription by a specialist in AT as opposed to that by a non-specialist).[11-13] Demographics and health-related characteristics of the end-users are significant determinants of the extent to which they use their wheelchairs.

In spite of such a high prevalence of wheelchair possession by older adults, they frequently report difficulties using their wheelchairs. Sixty one percent of the sample in a recent study reported difficulty during wheelchair propulsion.[14] The study suggested the impact of factors other than the user characteristics, such as environmental barriers and professional intervention as possible determinants for the extent of wheelchairs use.[14] This fact raises the question as to whether or not the mobility devices being provided to older adults meet their needs.

A number of descriptive and exploratory studies have focused on disparity in provision of WhMD, such as how demographics, health, and socio-economic characteristics impact the utilization of AT and WhMD. Hunt and colleagues reported that low socio-economic status was a key determinant of use of standard manual wheelchairs instead of customized wheelchairs by individuals with spinal cord injury (SCI).[15] And older age of the end-user was related to their use of a standard power wheelchair rather than a customized power wheelchair.[15] A study by Hubbard and colleagues reported that racial origin of the end-user: white versus non-white, determined the type of power wheelchair used: customized versus standard.[16] Yet, research is lacking in the area of extent of use of WhMD specifically in older adults. The studies that exist for this population emphasize racial and ethnic disparities, rather than on other factors that are clinically relevant for the prescription and use of the WhMD. A study by Cornman and Freedman suggested that the racial and ethnic disparities in use of wheelchairs and walkers, in their sample population, could be explained by the differences in human and environmental factors.[17] Another study suggested an underlying effect of the difference in age to explain the difference in the use of mobility devices by white versus non-white older adults.[18]

Although it is important to understand how factors such as race and socioeconomic status play a role, it is also essential to determine the factors that are clinically relevant in the use of different WhMD by older adults. Understanding these clinical factors may have great impact on analyzing the ‘matching’ process that is used to provide devices to users based on their needs. The objectives of the current exploratory study were to determine the utilization of the types of wheeled mobility devices (MWC, PWC, and scooters) by older adults, and to identify the demographic and health-related factors that may be associated with the types of WhMD being used.

2.3 METHODS

2.3.1 Study Design

The study was a secondary analyses of data that were compiled from nursing homes (NH), from the Center for Assistive Technology (CAT), and from the research participants' registry at the Human Engineering Research Laboratories (HERL) (Appendix A). The CAT is a multi-disciplinary specialty clinic of the University of Pittsburgh Medical Center (UPMC) for provision of Assistive and Rehabilitation Technologies. The CAT is comprised of a team of medical professionals experienced in assistive technology prescription who assist the client and caregivers in the process: physiatrists, occupational and physical therapists, a rehabilitation engineer, and rehabilitation technology suppliers.

2.3.2 Data

Data were collected from older adults aged > 60 years who used WhMD while living in a NH or the community. The data were obtained from three different cohorts: (a) NH, (b) medical chart review from CAT, and (c) the research participants' registry at HERL. The data from the individuals with the availability of the details regarding the make, model and other features of their WhMD were used for the final analyses. The data related to the wheelchairs that were used as positioning devices, power-assist (power add on) wheelchairs, and wheelchairs that were temporary (e.g., rental) were excluded from the analyses.

The first cohort (from NH) included individuals who were participants of research studies that focused on wheelchair-related mobility and wheelchair-related incidents. Residents of five different NH were part of this study. Two of the five NH were VA-affiliated facilities, and three were private. These participants were provided with WhMD as part of their long-term care plan at their respective NH. However, only two participants reported using their personally owned power wheelchairs in a NH. The resultant data included 109 individual NH participants.

The medical charts for clients who received a new wheeled mobility device (either a manual wheelchair, a power wheelchair, or a scooter) through CAT during the years 2007 and 2008 were reviewed. Prescription of WhMD in the CAT is based on 'medical necessity' and follows a pathway of: interdisciplinary assessment, WhMD prescription, and follow-up assessment. This review yielded records for 334 unique individuals.

The participants' registry at HERL has data related to the demographics, health-related characteristics, and the WhMDs utilized by individuals across the US (Appendix). However, no information is available related to the WhMD procurement process. The data obtained from this source provided information on 280 unique individuals.

All of the above individual studies received Institutional Review Board (IRB) approvals prior to their respective data collection. The study involving participants living in the NH was approved by the VA IRB and by the Pennsylvania Department of Health. The study conducted on the data related to patients receiving WhMD from the CAT was approved by the University of Pittsburgh IRB: Exempt protocol. The HERL registry was approved by the VA IRB.

2.3.3 Classification of Wheeled Mobility Devices

The WhMD were classified into three main groups on the basis of their make and model, manual wheelchairs, power wheelchairs, and scooters. For identifying sub-types of manual wheelchairs (depot versus standard versus customized), and power wheelchairs (standard versus customized), we used the Health Care Common Procedure Coding System (HCPCS) of the Center for

Medicare and Medicaid Services (CMS). For the manual wheelchairs, we used the criteria including the weight of the wheelchairs, adjustability features (axle positions, seat height), and CMS codes for the categorization into subtypes: (a) depot, (b) standard, and (c) customized. For the power wheelchairs, we used the criteria including: controls programmability (based on the make and model), seating base, customized features (tilt, recline, seat-elevator etc.), type of the wheelchair motor (standard versus heavy duty), and the weight capacity (< 250 lbs and > 250 lbs); for the categorization into standard and customized power wheelchairs. This coding system has been used and published in the previously conducted research studies.[15, 16, 19, 20]

- Group 1: intended for light use, no power option and seating system (wheelchair product codes: K0813-K0816)
- Group 2: consumer rehabilitation, no power, single power, or multiple power option, and intended for individuals with limited use throughout a day (wheelchair product codes: K0820-K0843)
- Group 3: complex rehabilitation, no power, single power or multiple power option, and intended for all day use (wheelchair product codes: K0848-K0864)
- Group 4: high activity use, heavy duty (wheelchair product codes: K0868-K0886).

2.3.4 Data Analyses

Descriptive statistics were computed for the entire data set. The data were then classified into those individuals using manual wheelchairs versus those using powered mobility devices (scooters and power wheelchairs). This was labeled as the tier 1 classification (Figure 1). As part of the tier 2 classification, the manual wheelchair group was further classified into: those using depot manual wheelchairs, and those using other types of manual wheelchairs (standard and customized manual wheelchairs). The latter group was further classified (tier 3) into: those using standard manual wheelchairs and those using customized manual wheelchairs. Tier 4 classification involved categorization of the individuals using powered mobility devices into two groups, one using scooters and the other using power wheelchairs. The group of power wheelchair users was further classified, as part of the tier 5 classification, into: those using standard power wheelchairs, and those using customized power wheelchairs (Figure 2.1).

At all tiers, the continuous variable, namely age, was compared between groups using the independent t-test. For categorical variables including gender, diagnosis, and living setting, the association between the types of WhMDs were determined using the chi-square statistics (Fisher exact statistics for cells with less than 5 observations). All statistical analyses were computed using SPSS 16.0 with a significance level set at .05. Also, *p* values less than .1 were noted as a significant trend.

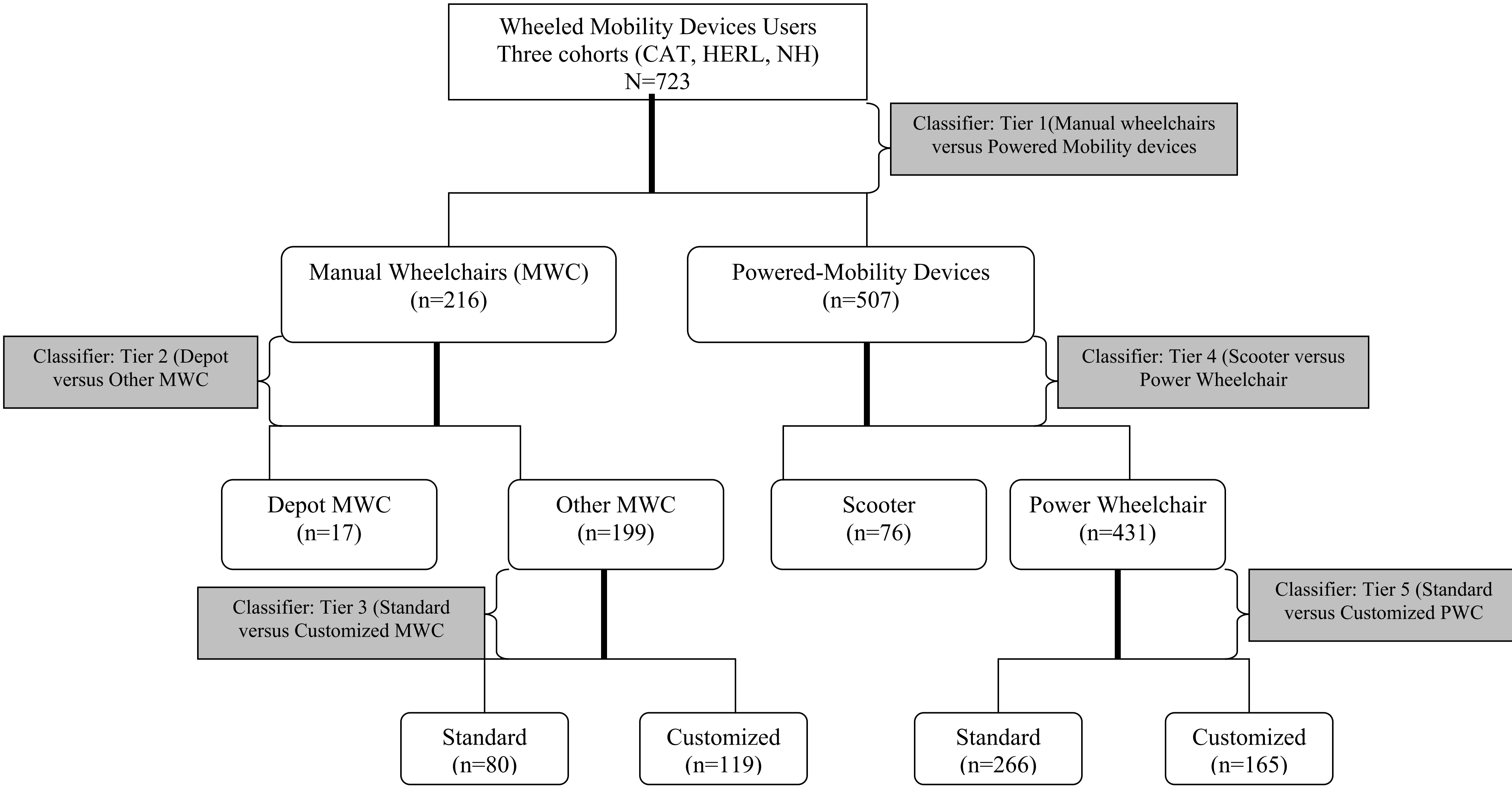

Figure 2.1. Stratification and Segmentation Chart

2.4 RESULTS

2.4.1 Demographics

The data from 723 older adults were analyzed for this paper. Out of these, 401 were males (56%) and 322 were females (44%). Neurological conditions (n=285) was the most common category of primary medical diagnosis, followed by spinal cord conditions (n=144), and orthopedic conditions (n=140). Among the neurological conditions, cerebral vascular accidents (including hemiplegia and hemiparesis) (n=86) were most prevalent, followed by multiple sclerosis (n=73), and movement disorders (n=35). Spinal cord injury was the most prevalent diagnosis (n=144) among the spinal cord conditions (which also included conditions like spinal stenosis etc.). Arthritis-related conditions were the most prevalent (n=82) followed by amputations (n=40) in the orthopedic conditions. While a majority of individuals were living in their homes (n=576), only 147 were living in other settings (including NH, assisted living facilities, and independent living centers). All other details are provided in Table 2.1.

Table 2.1. Demographics Characteristics of the Sample Population

Demographic Characteristics of Wheeled Mobility Devices Users (N=723)		
Age (y)		70.2±8.6
Gender	Male	401 (56%)
	Female	322 (44%)
Medical Diagnosis§		
Neurological Conditions n=285 (39%)	Cerebral Vascular Accident (hemiplegia, and hemiparesis)	86 (30%)
	Multiple Sclerosis	73 (26%)
	Movement Disorders (Parkinson's, and Ataxia)	35 (12%)
	Post-polio Syndrome	32 (11%)
	Cerebral Palsy	22 (8%)
	Other	37 (13%)
Orthopedic Conditions n= 140 (19%)	Arthritis (Osteoarthritis, Rheumatoid Arthritis, Fibromyalgia, and Systemic Lupus Erythematosus)	82 (58%)
	Amputation	40 (29%)
	Other	16 (11%)
Spinal Cord Conditions n= 173 (24%)	Spinal Cord Injury	144 (82%)
	Other	29 (17%)
Cardiovascular and Pulmonary (CVP) Conditions n= 73 (10%)	Chronic Obstructive Pulmonary Disease	55 (75%)
	Other	18 (25%)

Other Conditions **n= 49 (7%)**		49 (100%)
Living Settings	Home	576 (80%)
	Other (Nursing Homes, Assisted Living Centers, Independent Living Centers)	147 (20%)

§ indicates missing data (n=3)

2.4.2 Tier 1: Factors Associated with Manual versus Powered Wheeled Mobility Devices

For tier 1, individuals who were older (t=-3, P=.003), of male gender (χ^2=37, P<.001), with spinal cord conditions (χ^2=22.4, P<.001), and living settings other than their home (χ^2=102.2, P<.001) were more likely to use manual wheelchairs than powered mobility devices. (Table 2.2)

Table 2.2. Tier 1: Factors Associated with Manual versus Powered Mobility Devices Utilization

		Manual Wheelchair (n=216)	Powered Mobility Devices (n=507)	P-value
Age (y)		71.8±9.5	69.5±8.1	.003*
Gender	Male	157 (73%)	244 (48%)	<.001*
	Female	59 (27%)	263 (52%)	
Medical Diagnosis	Neurological Conditions	86 (40%)	199 (39%)	<.001*
	Orthopedic Conditions	26(12%)	114 (22%)	
	Spinal Cord Conditions	70 (33%)	103 (20%)	
	CVP Conditions	14 (7%)	59 (12%)	
	Other	17 (8%)	32 (6%)	
Living Settings	Home	122 (56%)	454 (90%)	<.001*
	Other	94 (44%)	53 (10%)	

* indicates a statistically significant difference or association

2.4.3 Tier 2: Factors Associated with Depot versus Other Manual Wheelchairs

For tier 2, individuals who were older (t=2.6, P=.009), and female (χ^2=6.1, P=.01) were more likely to use depot style manual wheelchairs as compared to other types of manual wheelchairs. The results also suggest a positive trend for an association between cardiovascular and pulmonary diagnoses (χ^2=8.5, P=.05) and not living at home (χ^2=3.4, P=.07) and the use of depot style wheelchairs (Table 2.3).

Table 2.3. Tier 2: Factors Associated with Depot versus Other Manual Wheelchairs Utilization

		Depot Manual Wheelchair (n=17)	Other Manual Wheelchair (n=199)	P-value
Age (y)		77.5±9.9	71.3±9.4	.009*
Gender	Male	8 (47%)	149 (75%)	.01*
	Female	9 (53%)	50 (25%)	
Medical Diagnosis	Neurological Conditions	5 (31%)	81 (41%)	.05†
	Orthopedic Conditions	2 (12%)	24 (12%)	
	Spinal Cord Conditions	3 (19%)	67 (34%)	
	CVP Conditions	4 (25%)	10 (5%)	
	Other	2 (12%)	15 (8%)	
Living Settings	Home	6 (35%)	116 (58%)	.07†
	Other	11 (65%)	83 (42%)	

* indicates a statistically significant difference or association † indicates a positive trend

2.4.4 Tier 3: Factors Associated with Standard versus Customized Manual Wheelchairs

For tier 3, individuals who were older (t=9, $P<.001$), female ($\chi^2=8.8$, $P=.003$), with neurological or cardiovascular and pulmonary conditions ($\chi^2=66.7$, $P<.001$), and not living at home ($\chi^2=97.2$, $P<.001$) were more likely to use standard manual wheelchairs compared to customized manual wheelchairs (Table 2.4).

Table 2.4. Tier 3: Factors Associated with Standard versus Customized Manual Wheelchairs Utilization

		Standard Manual Wheelchair (n=80)	Customized Manual Wheelchair (n=119)	P-value
Age (y)		77.4±8.5	67.1±7.5	<.001*
Gender	Male	51 (64%)	98 (82%)	.003*
	Female	29 (36%)	21 (18%)	
Medical Diagnosis	Neurological Conditions	47 (60%)	34 (29%)	<.001*
	Orthopedic Conditions	10 (13%)	13 (12%)	
	Spinal Cord Conditions	4(5%)	63 (53%)	
	CVP Conditions	10 (13%)	0	
	Other	7 (9%)	8 (7%)	
Living Settings	Home	13 (16%)	103 (87%)	<.001*
	Other	67 (84%)	16 (13%)	

* indicates a statistically significant difference or association

2.4.5 Tier 4: Factors Associated with Scooters versus Power Wheelchairs

For tier 4, individuals with a primary diagnosis of cardiovascular and pulmonary conditions (χ^2=28.6, *P*<.001) and living in their homes (χ^2=4, *P*=.04) were more likely to use scooters as compared to power wheelchairs. No difference with respect to age was observed between the two categories (t=.02, *P*=.98), and no association was found between gender and the use of either scooters or power wheelchairs (χ^2=.01, *P*=.92) (Table 2.5).

Table 2.5. Tier 4: Factors Associated with Scooters versus Power Wheelchairs Utilization

		Scooter (n=76)	Power Wheelchair (n=431)	P-value
Age (y)		69.5±8	69.5±8.1	.98
Gender	Male	37 (49%)	207 (48%)	.92
	Female	39 (51%)	224 (52%)	
Medical Diagnosis	Neurological Conditions	24 (32%)	175 (40%)	<.001*
	Orthopedic Conditions	17 (22%)	97 (22%)	
	Spinal Cord Conditions	8 (10%)	95 (22%)	
	CVP Conditions	22 (29%)	37 (9%)	
	Other	5 (7%)	27 (6%)	
Living Settings	Home	73 (96%)	381 (88%)	.04*
	Other	3 (4%)	50 (12%)	

* indicates a statistically significant difference or association

2.4.6 Tier 5: Factors Associated with Standard versus Customized Power Wheelchair

For tier 5, individuals who were older (t=3.5, $P<.001$), female (χ^2=16.2, $P<.001$), with a primary diagnosis of orthopedic or cardiovascular and pulmonary conditions (χ^2=52.7, $P<.001$) were more likely to use standard power wheelchairs compared to customized power wheelchairs. No associations were found between the living setting and the use of standard or customized power wheelchairs (χ^2=.33, P=.56) (Table 2.6).

Table 2.6. Tier 5: Factors Associated with Standard (Group 1 and 2) versus Customized (Group 3 and 4) Power Wheelchairs Utilization

		Standard Power Wheelchair (n=266)	Customized Power Wheelchair (n=165)	P-value
Age (y)		70.5±8.6	67.8±7	<.001*
Gender	Male	107 (40%)	100 (61%)	<.001*
	Female	159 (60%)	65 (39%)	
Medical Diagnosis	Neurological Conditions	90 (34%)	85 (52%)	<.001*
	Orthopedic Conditions	79(30%)	18 (11%)	
	Spinal Cord Conditions	46 (17%)	49 (30%)	
	CVP Conditions	35 (13%)	2 (1%)	
	Other	16 (6%)	11 (7%)	
Living Settings	Home	237 (89%)	144(87%)	.56
	Other	29 (11%)	21 (13%)	

* indicates a statistically significant difference or association

2.5 DISCUSSION

This study examines what was prescribed, but not necessarily the appropriateness of that equipment. Future work should aim at determining whether the demographic factors that influence prescription in this type of setting are different than those seen in the overall older adult population. However, understanding the clinical factors that contribute to selection and provision of one type of WhMD over others in all settings is the first step in the future development of guidelines for prescription of WhMD in older adults, much like the guidelines for prescription of wheelchairs for the SCI population.[15]

A significant difference may exist in the severity of medical conditions and the extent of functional limitations in those individuals using WhMD, which could confound other associations or relationships. Hence, it is critical to use a stratification approach and to compare similar segments for identifying relationships. We used the classification approach of dividing the entire sample into different tiers, and making comparisons of segments at each tier for identifying factors that could have a significant impact on use of one type of device over the others. Clinically, this method is valuable for WhMD provision in older adults since the broad question for this population is whether manual or powered devices were appropriately. For this study, we were only interested in using this analytical approach to focus on the association of the demographics and health-related factors, with the use of individual types of WhMD.

For the tier 1 classification, not living at home was the most significant factor associated with the use of manual wheelchairs. For our study most of the individuals not living at home were living in NH. The use of powered mobility devices is uncommon within NH. This can be attributed to several reasons, one of them being the risk associated with driving powered mobility devices. Studies have demonstrated that many individuals within institutional settings do not receive power mobility devices because they were never referred for a proper, objective mobility device evaluation.[21-23] We also found that more females were using manual wheelchairs, and more males using powered mobility devices. This issue needs to be explored with a larger and more diverse sample size to determine whether this may be related to gender differences with respect to diagnoses that result in functional impairments that may make these devices more appropriate, or whether a true disparity exists in their provision. The diagnosis of a spinal cord condition was also found to be associated with use of manual wheelchairs rather than powered mobility devices. This group was not stratified into paraplegia versus tetraplegia, but a higher number of individuals with functional use of the upper limbs may explain why most were manual wheelchair users. Finally, age was found to be negatively associated with the use of powered mobility devices in our sample. Age alone should not be a determining factor as to whether an individual should receive a power mobility device. Rather, cognitive status and functional ability to operate the device are important considerations in the evaluation.[24] Indeed, a subsequent analysis indicated that higher age was associated with living in settings other than home, which, in turn, may indicate some of these other variables were important in provision in this cohort.

From the tier 2 classification in our study, a negative association was found to exist between age and the use of lightweight or ultra-lightweight manual wheelchairs. Our results resemble those suggested by Hunt and colleagues, who also demonstrated greater likelihood of use of standard manual wheelchairs by older individuals as compared to their younger counterparts.[15] Our study also found that women were more likely to use depot style manual wheelchairs than men. Generally, although depot manual wheelchairs may be appealing because of low cost, they are not appropriate for individuals who will use a mobility device for extended periods or who require special seating requirements. Depot chairs, due to their weight and lack of customizability should only be used for temporary transport of individuals on a short-term basis. All of the 17 depot chairs in this study were used by individuals in NH settings and were not prescribed at CAT and not from the HERL registry. In NH, it is common to see individuals receiving wheelchairs that are already available rather than a customized solution based on their needs and requirements.

For the tier 3 classification of the study, it was found that institutional living had a negative association with the use of customized manual wheelchairs. Within the NH settings, residents are often provided with a standard rather than with a customizable manual wheelchair. Limited use by residents and the consideration of wheelchairs primarily as positioning devices rather than mobility devices influence this practice.[10] Although research shows the positive impact of provision of customizable wheelchairs on the level of functional performance and on the quality of life of the residents of institutional settings[25], not all individuals in these settings always use or receive these devices. This may be due to several reasons. First, institutions may not recognize that devices should be custom fit to individual users, and even if an older adult receives a customized device, caregivers at these places may use the equipment for other residents. Second, although state programs known as the Home and Community Based Services (HCBS) program, or the Medicaid waiver program, is designed specifically to assist institutional settings (nursing homes) in acquiring specialized services including more expensive mobility devices for residents,[26] not all institutions are able or willing to send residents for a proper evaluation or to complete the necessary documentation to receive the devices. This has resulted in underutilization of that program in several states[26] and use of inappropriate WhMD by the older adults living in such settings.

Our study found that the proportion of individuals with spinal cord conditions was the highest among the users of customized manual wheelchairs, whereas that of the individuals with other neurological conditions was the highest among the users of standard manual wheelchairs. This is concerning, especially since having certain progressive neurological conditions may warrant a customized device. No other research to date has focused on profiling the wheelchair users based on their medical diagnosis, which would be important in identifying the disparities and differences in the provision of different wheelchairs. The individuals with older age were also found to be using standard wheelchairs more often than customizable ones, which resembles the findings from a previous study.[15]

For the tier 4 classification of the study, the individuals who were using scooters had a higher proportion of cardiovascular and pulmonary conditions, as compared to those using power wheelchairs. For using a scooter, higher functional levels and the ability to transfer independently, are required. Although this information was not categorized for our sample, it is possible that scooter users had higher functional levels, as compared to those who used power wheelchairs, on the bases of their respective medical diagnoses. This concept needs to be analyzed further by collecting data on functional performance level and transfer ability status of individuals. Also, very few individuals living in institutional settings used scooters. Limited maneuverability of scooters and higher physical capacity required on the part of the user are some of the drawbacks associated with scooter use. In institutional settings physical space is usually limited. Accommodation of a scooter in such an environment, therefore, may become very problematic.

Finally, for the tier 5 classification of the study, the results indicated higher proportions of individuals with neurological and spinal cord conditions were in the customized power wheelchair user group. The standard power wheelchair user group, on the other hand, was found to have users with higher proportions of orthopedic, and cardiovascular and pulmonary conditions. It is interesting that the need for customized power wheelchairs was recognized for those with neurological diagnoses but not the need for customized manual wheelchairs. Our study also found that the older the age of the user of the WhMD, the greater was the likelihood for them to use a standard power wheelchair rather than a customizable power wheelchair, similar to what has been pointed out in a previous study.[15]

This study has some limitations to the current study. Some information related to the make and model of WhMD was missing from the registry data. Out of 321 registry participants who met the inclusion criterion of age>60 for this study, we could only use complete data points for 280 participants. Therefore 41 cases were excluded from the present study. Also, some of the information available on the participants from the HERL registry were collected for classification purposes for recruitment for other studies. Therefore, there could be a possibility of miscoding of the raw data (data entry errors) prior to all analyses. This, however, is one of the limitations of any secondary analysis study, which needs to be acknowledged. It would also be important to acknowledge statistical versus clinical significance in interpreting the results. We realize that the small samples in some of the tiers (such as the number of individuals using depot manual wheelchairs and that of the individuals using scooters) may limit external validity. Finally, the study did not take into account the environmental and contextual factors, the preferences of the users, and availability of resources (health-care insurance, access to wheelchair and seating clinics etc.), which are important in influencing the types of WhMD used.

In the future, analyses of the human, environmental, technological factors, and their interaction, need to be conducted to better understand WhMD device prescription and their use by older adults. The study was a cursory analyses of data compiled from three sources. Future work should look at development of statistical models that can predict use of particular types of WhMD by individuals controlling for cohort they belong to, their demographics, and health characteristics.

2.6 CONCLUSION

Older adults, who utilize WhMD for achieving functional independence, represent a diverse cohort. The diversity lies in the differences that exist in the demographic characteristics, health-related factors, and living situation, of the users of WhMD. Understanding these factors has a tremendous value in identifying a match (or mismatch) between types of mobility devices used, and the users' needs and requirements. The classification method implemented in our study could also assist clinicians in making the appropriate decisions when prescribing a certain type of WhMD: manual or powered, and the subtype: standard or customized. This, in turn, will be helpful in defining the standard of care for the provision of WhMD for older adults.

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2.8 APPENDIX A

Wheelchair Users Registry

Questionnaire

Date ____________

First Name ______________________ **Last Name** ______________________

Street Address ____

City ______________________ **State** ________ **Zip Code** ______________

Home Phone ______________ **Alternate Phone** ______________

E-mail Address ______________________________

I prefer to be contacted by: ☐ No preference ☐ Telephone Call ☐ Mail ☐ E-mail

How did you hear about us? ☐ Newsletter ☐ Internet ☐ Brochure ☐ Games ☐ Expo ☐ Other

Would you like to receive the HERL newsletter? (typically sent 2-3 times per year) ☐ Yes ☐ No

---

Date of Birth ____________

Gender ☐ Male ☐ Female

Are you a veteran? ☐ Yes ☐ No

Race/Ethnicity ☐ Black or African American ☐ Asian ☐ White or Caucasian ☐ Hispanic or Latino

☐ American Indian or Alaskan Native ☐ Native Hawaiian or other Pacific Islander ☐ Two or more races

---

Do you use a computer? ☐ Yes ☐ No

Do you use adaptive computer equipment or software? ☐ Yes ☐ No

Do you use a communication device? (speech output device) ☐ Yes ☐ No

Do you (or have you ever) build and use assistive technology of your own design? ☐ Yes ☐ No

Do you (or have you ever) modified commercially available assistive technology to better suit your needs? ☐ Yes ☐ No

If yes, what types of assistive technology have you modified or designed?

☐ Wheelchair related (accessories, etc) ☐ Automobile related (hand controls, etc) ☐ Home

☐ Personal Care (grooming, eating) ☐ Work place (tools, computer access) ☐ Other

Office Use Only ________

V6.1

Injury or Diagnosis (please check all that apply)

Date of Injury or Diagnosis ____________________

Spinal Cord Injury: ☐ Paraplegia ☐ Tetraplegia/Quadriplegia

Level of Injury (e.g. T2, C4-6) ____________________

Is your injury: ☐ Complete ☐ Incomplete

☐ Upper Extremity Amputation ☐ Spina Bifida ☐ Traumatic Brain Injury

☐ Lower Extremity Amputation ☐ Muscular Dystrophy ☐ Stroke

☐ Osteo/Rheumatoid Arthritis ☐ Cerebral Palsy ☐ Other ____________________

☐ Post Polio Syndrome ☐ Multiple Sclerosis

What date did you start using a wheelchair or scooter? ____________________

What type of chair do you currently use as your primary means of mobility?
(please choose one)

☐ Manual Wheelchair ☐ Pushrim Activated Power Assist

☐ Power Wheelchair ☐ Scooter

Make (Brand) of your Primary Wheelchair

☐ Action/Invacare ☐ Everest & Jennings

☐ Kuschall ☐ Ottobock

☐ Permobil ☐ Pride

☐ Sunrise/Quickie ☐ TiLite

☐ Other ____________________

Model of your Primary Wheelchair
(if unsure, please look for a label on your wheelchair) ____________________

If you use a power wheelchair, does your wheelchair have any of the following...
(please check all that apply)

☐ Tilt-in-Space ☐ Elevating legrests

☐ Backrest Recline ☐ Seat Elevator

When using transportation, do you... ☐ Transfer into the vehicle ☐ Use your wheelchair as a seat

What is your primary means of transportation?
(please choose one)

☐ Non-modified private vehicle ☐ Modified private vehicle (hand controls, lifts, ramps, etc)

☐ Public transportation (bus, metro, train, etc) ☐ Paratransit service (van, demand response) ☐ Other

Office Use Only ________

3.0 FACTORS IMPACTING PROVISION OF WHEELCHAIRS IN OLDER ADULTS: ANALYSIS OF DECISION MAKING PROCESS

AUTHORS: Amol M. Karmarkar[1-2], PhD (candidate), MS; Brad E. Dicianno[1-4], MD, MS; Rosemarie Cooper[1-3], MPT, ATP; Annmarie Kelleher[1-3], MS, OTR/L, ATP; Haishin Ozawa[1,4], MS; Rory A. Cooper[1-2], PhD

AFFILIATIONS: [1]Human Engineering Research Laboratories, VA Pittsburgh Healthcare System; [2]Department of Rehabilitation Science and Technology, University of Pittsburgh; [3] Center for Assistive Technology, University of Pittsburgh Medical Center; [4] Department of Physical Medicine and Rehabilitation, University of Pittsburgh

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CORRESPONDENCE

Rory A. Cooper, PhD,

VAPHS-Human Engineering Research Laboratories,

7180 Highland Dr., Bldg. 4, 2nd Floor, 151R1-HD,

Pittsburgh, PA 15206,

rcooper@pitt.edu

3.1 ABSTRACT

Objective: The objectives of this study were: (a) to identify the factors that impact prescription of wheeled mobility devices for older adults, and (b) to determine the effect that living setting has on the types of devices that older adults receive.

Design: Retrospective medical chart review.

Setting: Center for Assistive Technology, University of Pittsburgh Medical Center.

Participants: Data were gathered from medical charts on 337 older individuals. These individuals were aged >60 years, and each of them received a new wheeled mobility device from the Center for Assistive Technology during 2007 and 2008.

Methods: Data were analyzed in three tiers: tier 1 (manual versus powered mobility devices); tier 2 (motorized scooters versus power wheelchairs); and tier 3 (customized versus standard power wheelchairs).

Results: For tier 1, the factor associated with higher odds for receipt of manual wheelchairs versus powered were: cognitive limitations (OR=.03). For tier 2, diagnosis of cardio-vascular and pulmonary conditions were associated with prescription of motorized scooters (OR=3.9). For tier 3, neurological conditions (OR=3.1), male gender (OR=.37), institutional living (OR=.23), and lower age (OR=.96) were associated with receipt of customized power wheelchairs.

Conclusion: This study objectively describes the clinical decision making process used for prescription of wheeled mobility for older adults. This information can aid in development of guidelines and improving standards of practice for prescription of wheelchairs for older adults.

Keywords: Wheelchair Prescription, Older Adults, Decision Making

3.2 BACKGROUND

Clinical decision making is a goal-oriented process with the expected outcome of improved quality of life for clients. The clinical decision making process is reported to be comprised of, but is not limited to: (a) clinical reasoning (which involves a needs assessment of the client), (b) evidence-based reasoning (which involves determining the most effective and efficient intervention), and (c) pragmatic reasoning (which involves determining what would work best for the client given all the individual circumstances).[1] When this process is applied to the prescription of wheeled mobility devices including wheelchairs, a clinician needs to apply the above listed types of reasoning in evaluating the interaction between person-activities-environment-technology within the available resources.[2] Several conceptual models have described essential aspects to be considered for prescription of wheelchairs.[2] However, testing of these models to evaluate factors that may determine the selection of one type of device over another have not been done extensively. This has resulted in a lack of guidelines for standards of care, leading to disparities and discrepancies in the provision of wheelchairs.[3-5]

Older adults form the largest group among users of wheeled mobility devices. It is estimated that approximately one million older adults (age 65 years and above) in the United States use some type of wheelchair.[6] In spite of this fact, the prescription of wheelchairs and the types of wheelchairs provided to the aging population vary significantly. Although clinicians view prescription of wheelchairs to be a way of promoting independent mobility, wheelchairs are also provided to older adults to meet their seating and positioning needs, or even to improve transportation efficiency (in institutional settings).[7] The assumption of limited use or mobility often results in prescription of non-customizable standard wheelchairs for older adults, as compared to the wheelchairs prescribed to their younger counterparts.[5] Hubbard and colleagues have suggested that a negative relationship existed between the quality of the wheelchair prescribed and the age of the recepient.[3] This study indicated that older veterans were more likely to receive standard manual wheelchairs (MWC) when compared to their younger counterparts, who were more likely to receive customized power wheelchairs (PWC), scooters, or ultralightweight wheelchairs.[3] This finding emphasizes the need for development and establishment of a standard of care guideline that can direct a clinician through the steps to conduct accurate needs assessment. This will not only ensure prescription of the most appropriate wheelchair to meet the requirements of the client, but also prevention of secondary injuries from accidents or improper wheelchair setup. Such guidelines are already established and available to use for the professionals involved in the rehabilitation of individuals with spinal cord injury.[8] The outcomes from the prescription of wheelchairs in absence of such guidelines, therefore, depend greatly on the clinical expertise and professional judgment-making ability of the individual therapist.[9] When clients with diverse clinical manifestations are assessed within institutional settings by multiple healthcare providers, the selection of a wheelchair for an individual client is based on the clinical judgment of the healthcare providers and on the availability of resources for that client, rather than on his or her disability levels, needs, and requirements.[10]

Research has suggested use of an in-depth assessment process for older adults who are candidates for receiving wheeled mobility devices. This assessment includes evaluation of: (a) personal characteristics (age, gender, diagnosis, physical impairments, and functional status); (b) environmental factors (environment of use, accessibility, transportation); (c) interface with technology (for example, arm versus feet propulsion in MWC, or the operability and safety in

PWC driving); and (d) goals for the use of the wheelchair.[11] A client-centered approach for the prescription of wheelchairs has also been emphasized for this population.[12] Yet no study has been conducted to identify the most and least significant factors that influence the prescription of a certain type of wheeled mobility devices over the others. Some population-based studies that have not specifically focused on the aging population have assessed the impact of demographics and socio-economic factors on quality of the wheelchair that the user received.[3-5] These studies have answered some questions related to wheelchair disparity and differences in specific populations. However, the factors that influence the selection of one mobility device over others and the complex decision making process utilized by a healthcare provider for prescription of wheelchairs have not been addressed.

For optimal prescription of wheelchairs, the development of an expert system that can aid providers in the decision making process for selection of a type of wheelchair is crucial since many individualistic and extrinsic factors may vary from one person to another. There have been attempts in the past to establish such a system.[13] However, these systems mainly emphasize on machine learning and other artificial intelligence, and their feasibility and utilization in daily clinical operations is unknown.

The primary objective of this exploratory study was to identify the types of wheeled mobility devices (MWC, PWC, and scooters) that were prescribed for older adults during 2007 and 2008 at the Center for Assistive Technology (CAT), to determine factors associated with decision making by these providers in the selection of certain types of wheeled mobility devices over others. The secondary objective was to identify whether living setting (home or institution) had an impact on the types of mobility devices prescribed.

3.3 METHODS

3.3.1 Study Design

This study was a retrospective medical chart review of clients who received new wheelchairs from the Center for Assistive Technology (CAT), a multi-disciplinary specialty clinic of the University of Pittsburgh Medical Center (UPMC) for provision of assistive and rehabilitation technologies. The CAT is comprised of a team of medical professionals experienced in assistive technology prescription who assist clients and caregivers in the process: physiatrists, occupational and physical therapists, a rehabilitation engineer, and rehabilitation technology suppliers. This study was approved by the University of Pittsburgh Institutional Review Board prior to data collection.

3.3.2 Data

Medical charts for clients who received a new wheeled mobility device (manual wheelchair, power wheelchair, scooter) through CAT during 2007 and 2008 were reviewed. Only records of individuals age 60 years or older at the time of visit to CAT were reviewed. This resulted in records for 347 unique individuals. Data for 10 of these clients were excluded due to: 1=power assist wheelchair (Pushrim Activate Power Assist Wheelchair), 2=rental wheelchairs, 2=data missing related to make/model of the prescribed wheelchairs, 5=positioning wheelchairs. The list and descriptions for all independent and dependent variables for which data were collected is provided in Table 3.1.

Table 3.1 Variables (All Tiers)

	Variables	Description	Classification
Predictors (IV)	**Age**	Age in Years	Continuous
	Age[§]	Age in Years	0= Age <69 1= Age >69
	Gender	Male and Female	0= Male 1= Female
	Body Weight (Self-reported)	Body Weight in Kg	Continuous
	Body Weight[§]	Body Weight in Kg	0= Weight <84 1= Weight >84
	Diagnosis (Primary Medical Condition)	Neurological Conditions Orthopedic Conditions Spinal Cord Conditions Cardio-Vascular-Pulmonary Conditions Other Systemic conditions	0= No 1=Yes
	Education	Number of Years	Continuous
	Employment	Employment Status	0= No 1=Yes
	Transportation	Availability of Transportation	0= No 1=Yes
	Living Setting	Types of Living Arrangement	0= Other 1= Home
	Living Situation	Co-dwelling Situation	0= Alone 1= Other
	Home Accessibility	Living Situation	0= Not Accessible 1=Accessible
	Functional Status	ADL Independence	0= No 1= Modified 2= Yes
	Cognition Status	Screening of Comprehension Abilities (Medical Records)	0= Impairment 1= No Impairment
Outcomes (DV)	**Tier 1**	Manual wheelchairs versus Powered Mobility Devices	0= Powered (Power Wheelchairs and Scooters) 1= Manual Wheelchairs
	Tier 2	Power Wheelchairs versus Scooters	0= Power Wheelchairs 1= Scooters
	Tier 3	Standard Power Wheelchairs (Group 1 and 2) versus Customized (Group 3 and 4) Power Wheelchairs	0= Standard 1= Customized

3.3.3 Wheelchair Classification

Wheeled mobility devices were classified by make and model. The first tier of classification divided the group into manual wheelchairs and powered mobility devices (scooters and power wheelchairs) (Figure 3.1). For second tier of classification, we omitted all manual wheelchairs and divided the group into scooter and power wheelchairs based on their make and model. For the third tier, we omitted all scooters and further divided the group into standard power wheelchairs and customized power wheelchairs. The standard power wheelchairs are operationally defined as group 1 and group 2 categories of power wheelchairs. Customized power wheelchairs were operationally defined as group 3 and group 4 categories of power wheelchairs. This group coding was based on Centers for Medicare and Medicaid (CMS) codes and those published by Dicianno and Tovey (2007).[14] For conducting this classification, we used control programmability (from make and models), seating base, power options (tilt, recline, seat-elevator, etc.), wheelchair motor (standard versus heavy duty), and weight capacity (<250 lbs and >250 lbs). The classification was done by the first author with the help from two of the clinicians (RC and AK) involved in the study.

- Group 1: intended for light use, no power option and seating system (wheelchair product codes: K0813-K0816) (Note: We did not find any Group 1 power wheelchairs prescribed to clients in CAT, since these wheelchairs are not appropriate for driving on surfaces that a typical wheelchair user encounters in daily mobility)
- Group 2: consumer rehabilitation; no power, single power, or multiple power option (up to two seat functions); and intended for limited use throughout a day (wheelchair product codes: K0820-K0843)

- Group 3: complex rehabilitation; no power, single power or multiple power options; and intended for all day use (wheelchair product codes: K0848-K0864)
- Group 4: high activity use; heavy duty (wheelchair product codes: K0868-K0886).

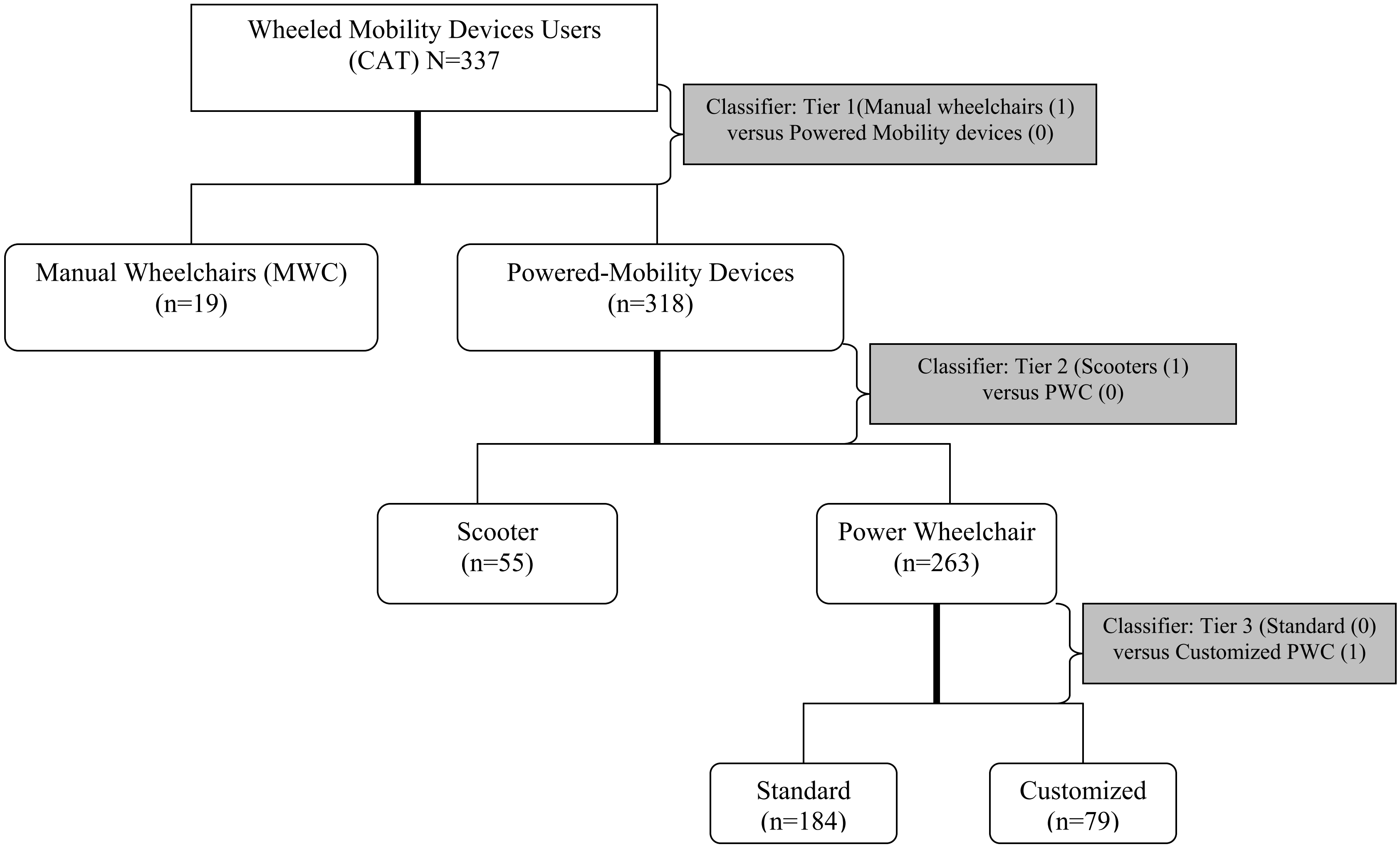

Figure 3.1 Stratification and Segmentation Chart

3.3.4 Data Analyses

Data were analyzed in three tiers for identifying factors that may have affected prescription of one type of wheeled mobility device over others by the clinicians at CAT. For tier 1, the objective was to identify factors that impacted prescription of manual wheelchairs over powered mobility devices (power wheelchairs and scooters). For tier 2, the objective was to identify factors that could determine prescription of scooters over power wheelchairs. For tier 3, the objective was to identify factors related to prescription of customized power wheelchairs (Group 3 and Group 4) over standard power wheelchairs (Group 2). Screening was done for all tiers to select variables that were significantly associated with types of wheelchairs prescribed using Chi-square statistics and t-tests. A cutoff value of 0.1 was selected for inclusion/exclusion of variables for further analyses. Associations between independent variables were identified, to avoid inflation of the model fit. In case of significant association, the variable with the higher association with the dependent variable was selected. Sequential logistic regression models were used to identify factors that affect the prescription of wheeled mobility devices at each tier. Model selection is based on a backward stepwise selection process with exclusion criteria of $p>0.1$. This method starts with all predictors in the model and removes ones that do not meet the criteria. We also forced a living setting variable into all the regression models, irrespective of the screening results. For tier 1, independent variables entered in the model were: body weight, neurological conditions, orthopedic conditions, living situation, cognitive status and living setting. (Cognitive ability to operate a mobility device is routinely evaluated as part of the CAT assessment and impairments are recorded in the chart.) For tier 2, variables entered were: neurological conditions, cardio-vascular and pulmonary conditions, and living settings. For tier 3, the independent variables were: neurological conditions, orthopedic conditions, age, gender, and living setting. Details regarding screening and selection of independent variables for the regression models are provided in Tables 3.2 and 3.3. All statistical analyses were computed with SPSS 16.0 and Answer Tree 3.1 with a significance level set *a-priori* .05 (trend level was set at .1).

Table 3.2 Significant Categorical Variables

	Variables	χ^2	**df**	***P***
Tier 1 (n=337) Manual versus Powered Mobility Devices	Neurological Conditions	11.1	1	.001*
	Orthopedic Conditions	5.7	1	.02*
	Living Situation	4.2	1	.04*
	Cognition	36.4	1	.001*
	Living Setting	.29	1	.48
Tier 2 (n=318) Scooters versus Power Wheelchairs	Neurological Conditions	5.5	1	.02*
	CVP Conditions	15.6	1	<.001*
	Transportation	14.5	1	<.001*
	Living Setting	4.1	1	.04*
	Transfer Status	15.1	2	<.001*
Tier 3 (n=263) Standard versus Customized Power Wheelchairs	Neurological Conditions	23.8	1	<.001*
	Orthopedic Conditions	11	1	.001*
	CVP Conditions	6.8	1	.009*
	Gender	14.3	1	<.001*
	Living Setting	14.1	1	<.001*
	Living Situation	10.5	1	.001*
	Functional Status	67.9	2	<.001*

* indicates significant association between wheelchair types

Table 3.3 Significant Continuous Variables

	Variables	**t**	**df**	***P***
Tier 1 (n=337)	Body Weight	2.3	333	.02*
Tier 2 (n=318)				
Tier 3 (n=263)	Age	2.2	261	.03*

* indicates significant between wheelchair types

Finally, an exhaustive Chi-Square Automated Interaction Detection (CHAID) algorithm was used to identify the role of each significant predictor from the results of logistic regression models for segmentation and classification at each tier. This method was also used to plot a decision tree and to identify the nesting effect of the independent variables in classifying outcome variables. Utilization of this method for decision making analysis has been suggested in previously conducted clinical research studies.[15-17] All computations were done using SPSS 16.0 and Answer Tree 3.1 software programs.

3.4 RESULTS

Examination of records of 337 individuals revealed a mean age of 70 years (±8.5) for wheelchair recipients through CAT. The majority of clients were female (60%) who lived in the home (88%). Clients not living at home were living in skilled nursing facilities (SNF), assisted living (AL) centers, and independent living centers (ILC). A majority of participants were diagnosed with neurological disorders (33%), followed by orthopedic (22%) and cardio-vascular pulmonary

(CVP) conditions (18%). Detailed description of demographic characteristics is given in Table 3.4.

Table 3.4 Demographic characteristics

Variables	Sub-variables	N=337
Age (Years)		70.5±8.5
Gender	Male	137 (40%)
	Female	200 (60%)
Body Weight (Kg)		88.2±26.1
Diagnosis[‡]	Neurological Conditions	127 (38%)
	Orthopedic Conditions	100 (30%)
	Spinal Cord Conditions	49 (14%)
	Cardio-Vascular and Pulmonary Conditions	71 (21%)
	Other Medical Conditions	6 (2%)
Education Completed	Years of Formal Education Received	12.74±3.4
Employment	Unemployed	313 (93%)
	Employed	22 (7%)
Living Settings	Home	297 (88%)
	Other (Skilled Nursing Facility, Assisted Living, Independent Living Center)	40 (12%)
Living Situation	Living Alone	127 (38%)
	Living with others	207 (62%)
Home Accessibility	Not Accessible	11 (3%)
	Accessible	325 (97%)
Transportation	Not Available	58 (17%)
	Available	277 (83%)
Functional Status	ADL Dependence	83 (25%)
	ADL Modified Independence	203 (60%)
	ADL Independence	50 (15%)
Cognition	Impairments	4 (1%)
	Intact	331 (99%)

[‡] Some clients were presented with dual-primary diagnoses

A significantly large cohort of clients (21%) did not use any form of mobility device, including assistive ambulatory aids (walkers, canes, etc.), upon their initial evaluation at CAT, prior to prescription of wheeled mobility device. For those who reported using devices, manual wheelchairs were the most common form of mobility devices possessed prior to their visit to the CAT. Further classification determined that the majority of individuals (57%) were using a standard lightweight wheelchair (most commonly the Invacare 9000 XT), while only 11 individuals (8%) were using ultralightweight manual wheelchairs. For power wheelchairs, the Pride Jazzy family of wheelchairs was the most common form used by clients (37.5%). For scooters, Pride Victory was the most common make/model used by clients (26.3%). Detailed description of all the mobility devices is provided in the table 3.5.

Table 3.5 Utilization of Mobility Devices Prior to CAT Visit

Variables	**Categories**	**N=336[§]**	**Specific Details**
Types of Mobility Devices	**None**	71 (21.1%)	NA
	Cane	26 (7.7%)	NA
	Walker	35 (10.4%)	NA
	Manual Wheelchair	127 (37.7%)	Invacare 9000 XT (56.7%)
	Power Wheelchair	56 (16.6%)	Pride Jazzy (37.5%)
	Scooter	19 (5.6%)	Victory (26.3%)
	Positioning Wheelchair	2 (0.6%)	NA

[§] indicates missing data

Results from the regression model for tier 1 (manual versus powered devices) determined that odds for individuals with greater body mass were .98 times less likely to receive manual wheelchairs (*B*= -0.02, *P*= 0.06, exp (*B*) =.98) compared to those with lower body mass. A trend was found indicating that clients with medical diagnosis other than orthopedic conditions were least likely to be prescribed manual wheelchairs (*B*=-1.8, *P*= 0.07, exp (*B*) =.15). Living setting was not a significant predictor for receipt of manual or powered mobility devices *B*= .77, *P*= 0.34, exp (*B*) =2.2. Cognitive screening status was the most important predictor, as those without documented cognitive impairments were significantly more likely to receive power wheelchairs versus those with documented cognitive problems who were more likely to receive manual wheelchairs (*B*= -3.5, *P*= 0.004, exp (*B*) =.03). The model fit was good, as no significant difference was noted between observed and predicted group membership (Hosmer-Lemeshow χ^2 (8) = 6.7, *P* = 0.56).

Results from the exhaustive CHAID model for tier 1, indicated that the most significant factor associated with prescription of manual wheelchairs was the clients cognitive status (χ^2 (1) = 36.6, *P* <.001) with the sample categorized as clients with intact cognitive status (n =333) and clients with cognitive impairment (n = 4). Ninety five percent (n=317) of clients without cognitive limitations were provided powered mobility devices, as compared to 5% receiving manual wheelchairs (n=16). Among clients with cognitive impairment, the ratio of being prescribed powered mobility devices (25%) versus manual wheelchairs (75%) was 1:3. Orthopedic medical conditions only had a significant impact for the cognitively intact group (χ^2 (1) = 4.5, *P*=.03) dividing the sample into those with orthopedic medical conditions (n=100) and those without (n=233). The proportions of powered devices versus manual wheelchairs in the orthopedic conditions group were 99% and 1% respectively, while they were 94% to 6% respectively in the non-orthopedic conditions group. No significant effect of body weight on classification of types of mobility devices prescription. The overall risk estimate for this model was .05, *SE*=.01, indicating 95% accuracy of the model in classification. Details are provided in Table 3.6 and Figure 3.2.

Results from the regression model for tier 2 (scooter versus power wheelchair) revealed that the odds for clients with cardio-vascular and pulmonary (CVP) conditions were 3.4 times higher for receiving a scooter as compared to those without CVP conditions (*B*= 1.2, *P*<.001, exp (*B*) =3.4). For those living at home, the odds for receiving scooters were almost 4 times higher than for those living in other settings (*B*= 1.4, *P*= 0.07, exp (*B*) =3.96). The overall model fit was acceptable as no significant difference between observed and predicted group membership (Hosmer-Lemeshow χ^2 (2) = 1.4, *P* = 0.50).

Results from the exhaustive CHAID model for tier 2 indicated that the most significant factor associated with prescription of scooters was the clients' diagnosis (presence of CVP conditions) (χ^2 (1) = 15.6, *P*<.001), dividing the sample into those without CVP conditions (n=253) and clients with CVP conditions (n = 65). Eighty-seven percent (n=220) of clients without CVP conditions were prescribed power wheelchairs as compared to 13% received scooters (n=33). However, 66% (n=43) of clients with CVP conditions were provided with power wheelchairs as compared to 34% receiving scooters (n=22). Living setting showed a trend only for those clients with CVP conditions (χ^2 (1) = 3.4, *P*=.06) dividing the sample into those living at home (n=59) to other settings (n=6). The proportions of power wheelchairs versus scooters prescribed for those living at home was 63% and 37%, respectively. For clients living in other settings, none received scooters, and 100% received power wheelchairs. The overall risk estimate for this model was .17, *SE*=.02, indicating 83% accuracy of the model in classification. Details are provided in Table 3.6 and Figure 3.3.

Results from the regression model for tier 3 (standard power wheelchair to customized power wheelchair) determined that odds for clients with neurological conditions to receive customized power wheelchairs were three times higher than those individuals without neurological conditions (*B*= 1.1, *P*= <.001, exp (*B*) =3.1). Also, females were .37 times less likely to receive customized wheelchairs than their male counterparts (*B*= -.99, *P*= 0.001, exp (*B*) =.37). Those living at home were .23 times less likely to receive customized wheelchairs as compared to individuals living in institutional settings (SNF, AL, or ILC) (*B*= -1.5, *P*= 0.001, exp (*B*) =.23). Finally, those of older ages were .96 times less likely to receive customized power wheelchairs than those with younger ages (*B*= -0.04, *P*= 0.04, exp (*B*) =.96). The model fit was good as there was no significant difference between observed and predicted group membership (Hosmer-Lemeshow χ^2 (8) = 6.9, *P* = 0.55).

Results from the exhaustive CHAID model for tier 3 indicated that the most significant factor associated with prescription of customized power wheelchair was clients' diagnosis (presence of neurological conditions) (χ^2 (1) = 25.7, *P*<.001) dividing the sample into those diagnosed with neurological conditions (n =102) and clients without (n = 161). Eighty one percent (n=131) of clients without neurological conditions were prescribed standard power wheelchairs, as compared to 19% who received customized power wheelchairs (n=30). However, 48% of clients (n=49) with neurological conditions were provided with customized power wheelchairs as compared to 52% receiving standard power wheelchairs (n=53). For those without neurological conditions, living setting significantly classified the group further (χ^2 (1) = 11.5, *P*=.007). For those living at home (n=145), 15% received customized wheelchairs (n=22) versus 85% who received standard wheelchairs (n=123). For those living in other settings (n=16), 50% received customized wheelchairs (n=8) and 50% received standard wheelchairs (n=8). Gender had a significant impact on clients living at homes and other settings. For clients living at home, gender significantly classified the group (χ^2 (1) = 7.4, *P*=.006). For males (n=49), 27% received customized wheelchairs (n=13) versus 73% who received standard wheelchairs (n=36). For females (n=96), only 9% received customized wheelchairs (n=9) versus 91% who received standard power wheelchairs (n=87). For clients living at other settings, gender significantly classified the group (χ^2 (1) = 4.3, *P*=.04). Among males (n=6), 83% received customized wheelchairs (n=5) versus 17% who received standard wheelchairs (n=1). Among females (n=10), only 30% received customized wheelchairs (n=3) versus 70% who received standard power wheelchairs (n=70). Age showed a trend in female clients living at home without neurological conditions, classifying the group further (χ^2 (1) = 3.3, *P*=.07). For those aged more than 69 years (n=49), 4% received customized wheelchairs (n=2) versus 96% who received standard wheelchairs (n=47). For those aged less than 69 years (n=47), 15% received customized wheelchairs (n=7) versus 85% who received standard wheelchairs (n=40).The overall risk estimate for this model was .28, *SE*=.02, indicating 72% accuracy of the model in classification. Details are provided in Table 3.6 and Figure 3.4.

Table 3.6 Predictors related to Types of Wheelchair

	Variables	**β**	**SE**	***P***	**Exp β (OR)**	**CI Exp β**
Tier 1 Manual versus Powered	**Body Weight**	-.02	.01	.06†	.98	(.95-1)
	Orthopedic Conditions	-1.9	1	.07†	.15	(.02-1.2)
	Cognition	-3.5	1.2	.004*	.03	(.003-.32)
	Living Setting	.77	.82	.34	2.2	(.44-10.7)
Tier 2 Scooters versus Power	**Cardiovascular and Pulmonary Conditions**	1.2	.32	<.001*	3.4	(1.8-6.4)
	Living Setting	1.4	.75	.07†	3.9	(.91-17.2)
Tier 3 Standard versus Customized	**Age**	-.04	.02	.04*	.96	(.92-.99)
	Neurological Conditions	1.1	.30	<.001*	3.1	(1.7-5.7)
	Gender	-.99	.31	.001*	.37	(.20-.67)
	Living Setting	-1.5	.43	.001*	.23	(.10-.53)

* indicates a significant predictor variable

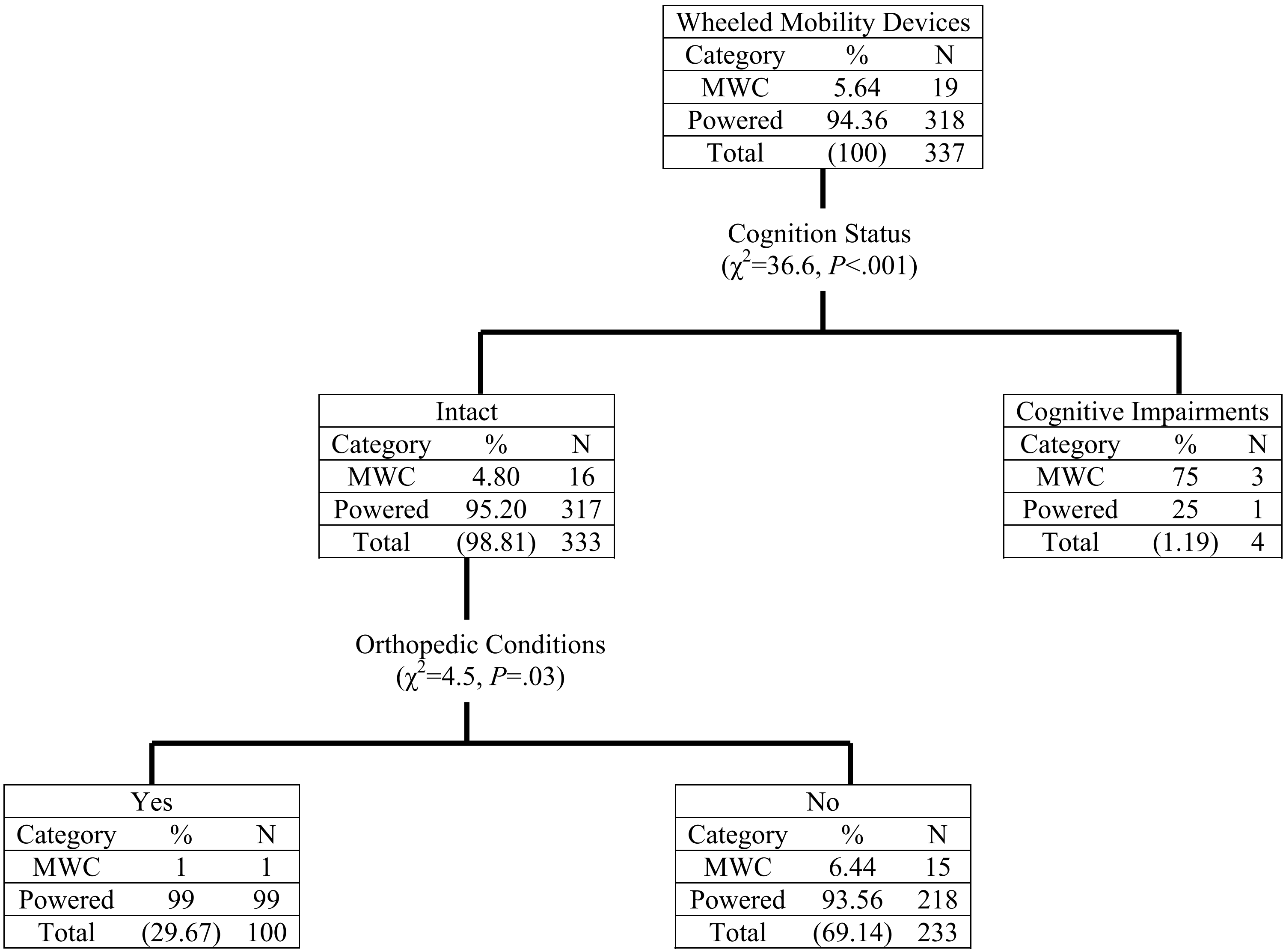

Figure 3.2 Decision Tree Exhaustive CHAID (Tier 1: Manual versus Powered Wheeled Mobility Devices)

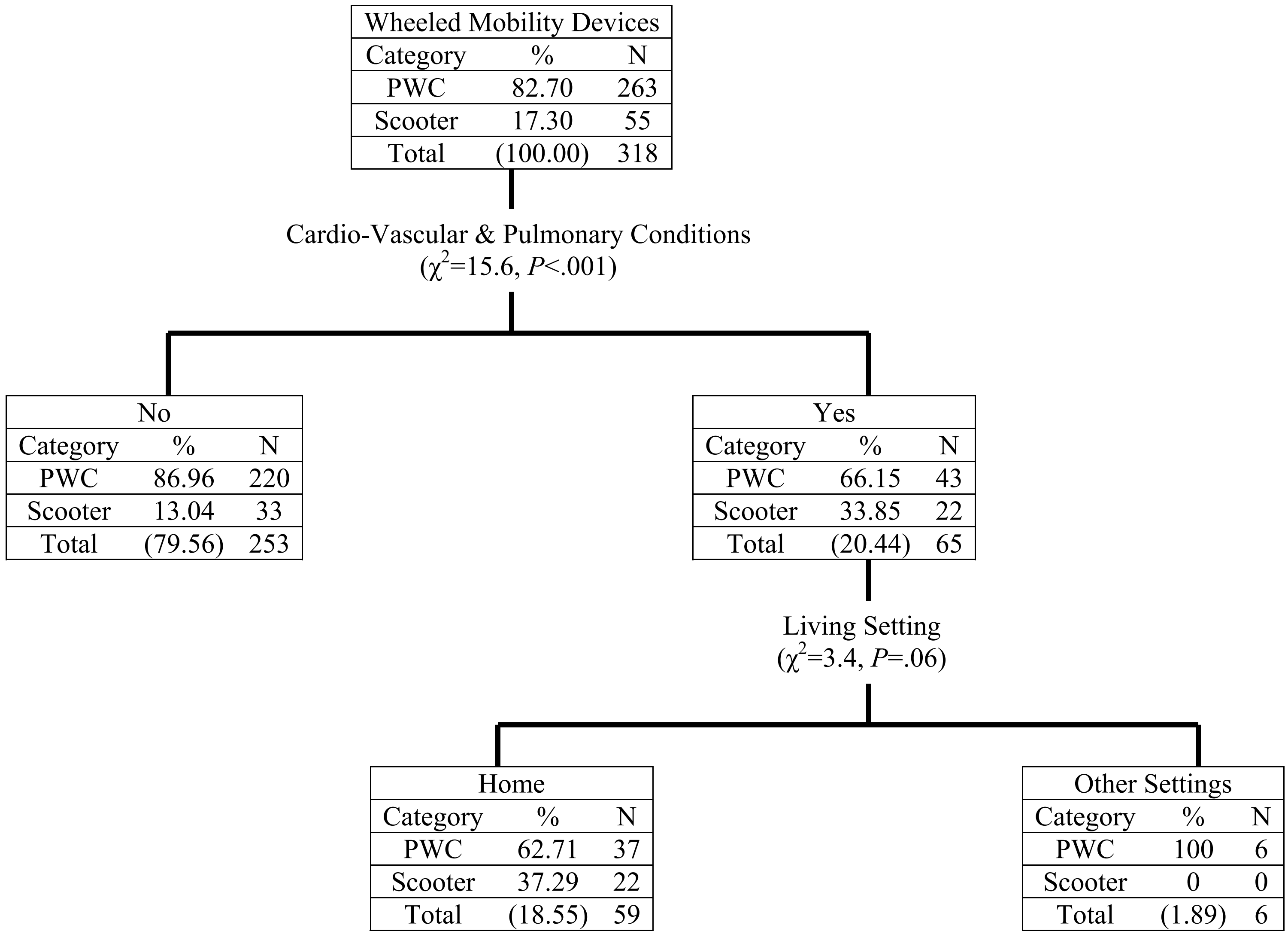

Figure 3.3 Decision Tree Exhaustive CHAID (Tier 2: Scooters versus Power Wheelchairs)

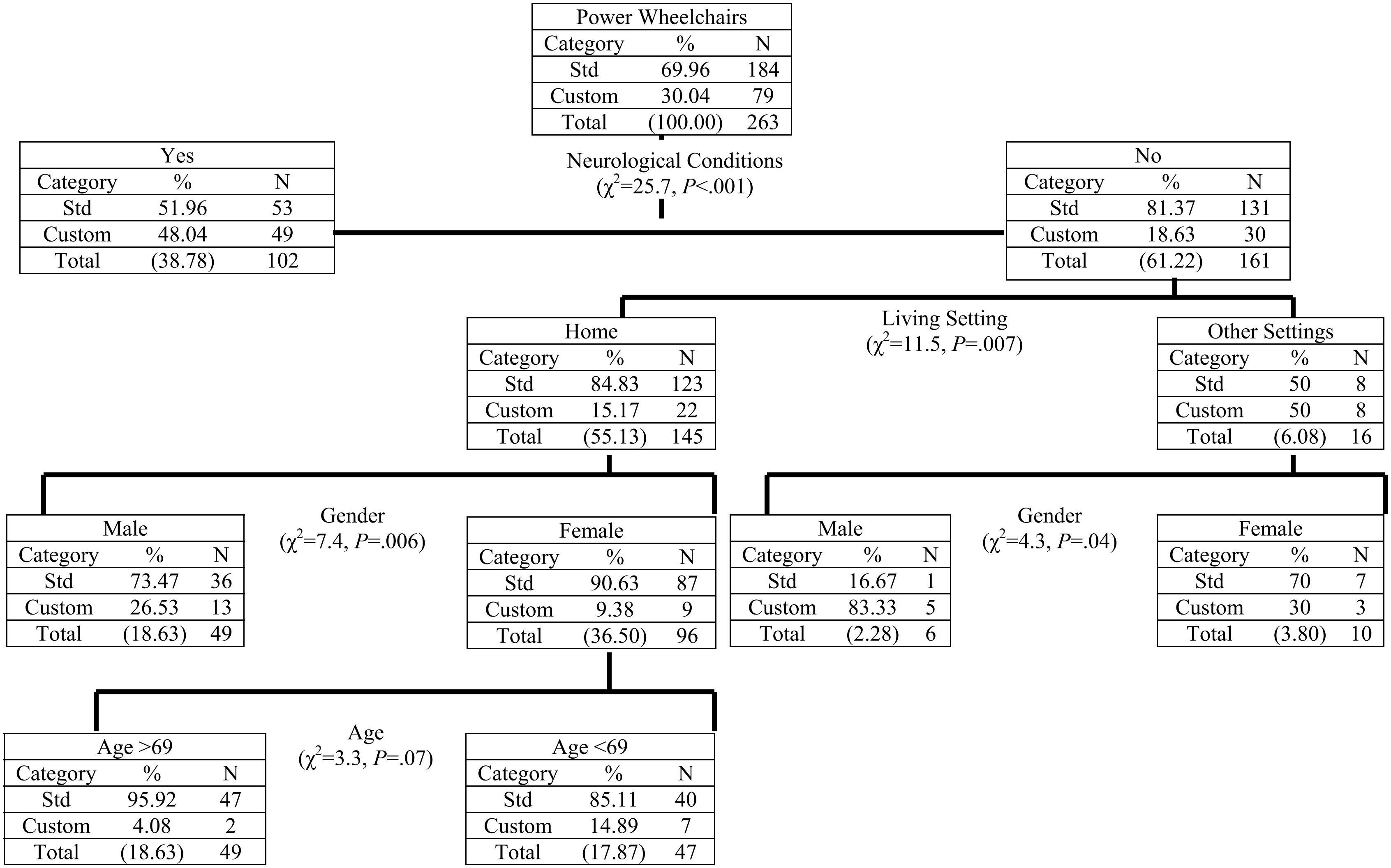

Figure 3.4 Decision Tree Exhaustive CHAID (Tier 3: Standard versus Customized Power Wheelchairs)

3.5 DISCUSSION

Assistive technology (AT), including wheeled mobility devices (wheelchairs), has a significant impact on the ability to achieve functional independence and reduces the need for human assistance in older adults with disabilities.[18] In spite of being the largest group of consumers for utilization of wheeled mobility devices, standard guidelines are lacking for prescription of these devices for older adults.

For tier 1 of the current study, we found that cognitive impairment is the most significant predictor for the selection of manual wheelchairs versus power wheelchairs among our sample. An evaluation of the cognitive ability to operate a device can prove to be a more accurate predictor of the readiness of an older adult to use a powered mobility device than a neuropsychological assessment.[19] The existing practice at CAT involves a detailed driving assessment including the evaluation of safety, reaction time, and maneuverability. Safety assurance is the most important criterion from the clinicians' perspective when prescribing power wheelchairs. A previous report has indicated cognitive function as a significant predictor for assessing the readiness of children with cerebral palsy to transition to using power mobility.[20] Likewise, there exists a positive correlation between cognitive function and power wheelchair use in older adults.[21] Cognitive impairments are suggestive of decreased safety and increased risk of falls and/or injuries in older adults using power wheelchairs within institutional settings.[22, 23] The presence of cognitive impairment could be the major reason to deem an older adult to be an 'unsafe driver' of a power wheelchair.[22, 23]

Our study also found a negative association between the body weight of clients and the prescription of manual wheelchairs. One reason for receipt of power devices may be that overweight individuals are not able to exert the effort required to propel a manual wheelchair to complete functional tasks. Another reason may be that overweight individuals are more likely to develop shoulder pain and pathology.[24] Body weight is a significant predictor of increased shoulder forces (anterior, posterior, inferior, and lateral) that could result in overuse injuries during manual wheelchair propulsion.[25] Some of the possible interventions suggested include maintenance of “ideal” body weight and adjustments in the position of the axle for decreasing rolling resistance.[25, 26] When higher body mass confounds aging, some of the possible interventions may include transition to manual wheelchairs with a power-assist add on, or consideration of the user for powered mobility devices.

We forced ‘types of living settings’ into the regression model. This factor, however, did not prove to be a significant predictor for the selection of a certain type of wheeled mobility device over the others within the regression model. On the other hand we found higher odds for those older adults living within institutional settings to receive powered devices over manual wheelchairs. However, due to lack of statistical significance, the results need careful interpretation. There exists evidence-based research focusing on the readiness of children for use of power mobility and the factors that determine the selection between manual versus powered mobility devices.[27] However, such studies are lacking in older adult populations. Lack of such evidence results in the inevitable criticism that the selection process for types of wheelchairs is arbitrary, with an emphasis placed primarily on the availability of resources and the clinicians’ judgment, rather than on the needs of the clients.[10] Lack of evidence also raises the concern about over-utilization and abuse of power wheelchair prescription, without accurately assessing the needs and level of disability of the end-users.[28, 29]

For tier 2, we found that the odds of receiving scooters for clients with cardiovascular and pulmonary (CVP) conditions were higher, whereas individuals with other medical conditions (neurological, orthopedic, and spinal cord conditions) were more likely to receive power wheelchairs. We found no evidence suggesting a difference in the physical and cognitive demand for driving a motorized scooter versus a power wheelchair. However, scooters do not provide the amount of postural support that a power wheelchair does; and if prolonged use is warranted, this fact could be a critical deciding factor when prescribing. We also found that strong relationship among the medical condition (diagnosis), functional status, and their ability to transfer (in/out of device). Therefore, we included only the medical conditions in the regression model. Ability to transfer independently into and out of a motorized scooter is necessary to be able to use a scooter safely, and it is one of the required criteria for prescription specified by the CMS. The 'type of living arrangement' was also a significant factor only in the case of the individuals with CVP conditions. None of the clients living in nursing homes or assisted living centers were provided with scooters. Scooters require a larger turning radius and more space for maneuverability compared to power wheelchairs. Space constraints and accessibility may be of concern within institutional settings. The risk involved in driving a scooter in institutional settings given its size and speed and the presence of other older adults, is therefore significantly higher when compared to driving a power wheelchair.[22, 23, 30] Research has shown that scooter use is also associated with higher risk of injuries and accidents.[31]

For tier 3 of the study, the presence of neurological conditions was found to be the most significant predictor for prescription of customized versus standard power wheelchairs. Funding source is likely a key contributor here. One of the CMS criteria for funding a Group 3 power wheelchair is having a neurological diagnosis.[14] However, this is often also clinically appropriate because customized power wheelchairs can be fitted with power seat functions (tilt-in space, recline) and other power options (seat elevators, elevating leg rests, etc.). Power seat functions are medically appropriate for a number of purposes, and are especially necessary for those who lack the ability to independently reposition themselves and who may be at risk for skin breakdown.[32] Those with neurological conditions are more likely to fall into this group. Customized power wheelchairs also offer an option for retrograde fitting of power seat functions for those who may have a progressive condition.

In our sample, we found a discrepancy in gender, with male clients more likely to be prescribed customized power wheelchairs compared to their female counterparts. This is surprising since some progressive neurological conditions like multiple sclerosis (MS) are more common in women.[33] Other studies have shown an association between the demographic characteristics of clients and the types (quality) of wheelchairs prescribed, but none have shown differences based on gender of the end-user.[3-5] These studies analyzed data from veterans and individuals with spinal cord injuries. Both of these populations have significantly higher proportions of male individuals.[3-5] Our results, however, need to be interpreted with great caution, as several other mediating factors impacting the prescription of specific devices exist.

We also found a significant association with the type of living setting on the type of power wheelchair prescribed. However, these results were only significant for males and not for female clients in our sample. The proportions of clients who received customized power wheelchairs and were living within institutional settings were only higher among those without neurological conditions. This interesting finding could be of great significance for the prescription process implemented for mobility devices among older adults in institutional settings. Current clinical practice within institutional settings primarily focuses on providing standardized manual wheelchairs to all the residents, since the goal, most often, is positioning rather than achieving independent mobility.[7, 30] In these scenarios, lack of financial resources are often cited as barriers to provision of powered mobility for these individuals. However, independent mobility should also be a primary goal for individuals who are capable of operating a mobility device. The Home and Community Based Services (HCBS) program, also known as the Medicaid waiver program, is designed specifically to assist institutional settings in acquiring specialized services including wheelchairs. Not only can this program provide wheelchairs within an institutional setting, but improved mobility may in some cases enable discharge of individuals from institutional environments to their home settings.[34] Kitchener and colleagues indicated an underutilization of this program in the procurement of AT devices including wheelchairs for older adults within the institutional settings.[34]

Future research should focus on determining the impact of availability or lack of funding resources, on the prescription of devices for older adult populations. Finally, we found a negative effect of age of the end-user on the types of power wheelchairs prescribed. Similar to gender, age was mediated and nested within all the other variables. The results from the CHAID analysis for tier 3 of the study did not reveal any significant associations between age and types of power wheelchair prescribed within any of the groups or sub-groups. Thus, our results do not fully support the notion that there is a negative association between age and quality of wheelchairs prescribed.[3-5] However, our study used age as one of the cutoff criteria for selection of records for the sample, possibly resulting in a sample that was relatively homogenous (with respect to age) compared to those used by other studies. In future studies, the inclusion of records from a younger client population will be helpful in accepting or rejecting this hypothesis.

There were several limitations of this study worth noting. First, we had a small sample size for manual wheelchairs and scooters prescribed through the CAT. We limited our data collection to only two years (2007 and 2008). This limits our ability to generalize the findings to the entire population of older adults. Future work needs to expand on these findings with studies over a longer time period and inclusion of individuals from all age ranges, and not just older adults. This will also enable identification of trends in the prescription of mobility devices from one year to the next. Secondly, some variation in data is expected during secondary analyses when multiple investigators are involved. However, all of the data for this study were collected by the first author (AMK) using a pre-determined definitions for classifying variables (e.g functional independence: 0=dependent, 1=modified independent, and 2=independent). Thus, we were able to control for a large amount of variation. Third, since the medical records were designed for prescription of devices and not for research purposes, we experienced some incomplete and missing data points. Insurance availability for clients was one of the confounding factors for which we did not control. We collected the related data for our sample, and feel that future work should replicate this study and utilize the current data collected to determine the interaction between clinical and reimbursement factors for prescription of wheeled mobility devices. Finally, but perhaps most importantly, the preferences of the users and of the family members in the selection of one type of mobility device over the others was not included in this study. The (informed) opinion of the end-user and history of devices use (manual versus powered) could have a significant impact on the prescription process (especially on the prescription of scooters), and therefore always needs to be acknowledged as part of the final decision making process.

3.6 CONCLUSION

Prescription of mobility devices involves consideration of many factors, including diagnosis, prognosis, and the social and living environment. Prescription of an inappropriate device can have a negative impact on mobility and quality of life for older adults. Our results suggest that cognitive status is a significant determinant of the selection of manual versus powered mobility devices. The medical condition of the individual influences the selection between a motorized scooter and a power wheelchair, and also between a customized and a standard power wheelchair. No differences were observed with respect to institutional versus non-institutional living and the types of wheelchairs prescribed. Future research, replicating the same design with a larger sample size, will enable the development of a clinical decision making process and a tool for conducting utilization reviews, which will help with the justification process for the prescription of wheelchairs for older adults.

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4.0 SATISFACTION RELATED TO WHEELCHAIR USE IN OLDER ADULTS IN BOTH NURSING HOMES AND COMMUNITY DWELLING

Amol M. Karmarkar, MS[1-2]; Diane M. Collins, PhD[1-2]; Annmarie Kelleher, MS OTR/L ATP[1-2]; Rory A. Cooper, PhD[1-2]

[1]Human Engineering Research Laboratories, VA Pittsburgh Healthcare System;

[2]Department of Rehabilitation Science and Technology, University of Pittsburgh

In Press: *Disability and Rehabilitation: Assistive Technology*

CORRESPONDENCE:

Rory A. Cooper, PhD

VAPHS-Human Engineering Research Laboratories

7180 Highland Dr., Bldg. 4, 2nd Floor, 151R1-HD

Pittsburgh, PA 15206

Work: 412-954-5287

Fax: 412-954-5340

rcooper@pitt.edu

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4.1 ABSTRACT

Problem Statement: Older adults commonly use wheelchairs for mobility impairments regardless of their living situations. However, limited outcomes data are available to determine quality of the wheelchairs that older Americans are receiving, as well as their satisfaction with wheelchair service delivery programs. The purpose of this paper was to analyze satisfaction data collected from three cohorts of older individuals living at nursing homes and in community settings.

Methods: One hundred thirty two older adults completed the standardized Quebec User Evaluation of Satisfaction with Assistive Technology. Ninety participants were residents in VA (n=30) or private nursing homes (n=30), and 42 were community dwelling participants. Those enrolled were either independent manual or power wheelchairs users.

Results: The community dwelling group reported significantly higher levels of satisfaction with their manual wheelchairs and service delivery as compared to the private nursing home participants (4.3 versus 2.9, P=.002). The satisfaction was also higher for VA nursing homes than private (3.9 versus 2.9, P=.004). No significant differences were reported for satisfaction levels regarding powered wheelchairs use between three groups.

Conclusion: Level of satisfaction should be incorporated as an outcomes measure for evaluating wheelchair prescriptions and service delivery programs. This study also supports the establishment of a re-evaluation process of wheelchair fit as the users age, to aide in provision of the best quality wheelchairs and service delivery programs.

KEYWORDS: Wheelchairs, Older Adults, Satisfaction

4.2 INTRODUCTION

Data from recent population statistics indicate a rapid growth rate for older Americans (aged >65 years). This number is projected to be approximately 46 million by the year 2010, with older veterans currently constitute approximately 22% of the entire older population in the US [1]. About 5% of the overall population of older individuals are currently living in institutional settings [1]. The increase in life expectancy is also proportional to growth in disability, with proportional change in the need for either human or technological support for performing daily activities. Assistive Technology (AT) devices, especially mobility devices (canes, walkers, wheelchairs), are very often used by older adults for improving functional independence while reducing need for physical assistance [2]. Recent numbers indicate that approximately 2.2 million community dwelling individuals use wheelchairs, with 58% of this population being manual wheelchair (MWC) users [3]. In NH, the number of older individuals using wheelchairs is reported to be over 50% of the total population [4]. Utilization of prescribed wheeled mobility devices depends on: user's demographics, health factors, wheelchair characteristics, environmental factors, and quality of service delivery [5-7]. In addition, involvement of users in the selection process of mobility devices as well as their satisfaction related to the devices play important role in use/abandonment of the devices [8, 9].

Abandonment of prescribed mobility devices is a huge problem resulting in non-use, particularly in the first year of ownership of the device. Devices that were obtained easily, poor fit, and prescribed without taking into consideration the views of the users, were more likely to be abandoned [9]. Several studies indicate that consumer satisfaction is the strongest determinant of acceptance or rejection of AT devices. Therefore, greater involvement of consumers in the device prescription process, and establishment of a client-centered approach, can reduce premature abandonment of AT devices [8, 10-14] [15] [16].

A moderate positive relationship, between the level of satisfaction associated with wheelchair use and the overall quality of life, was indicated in Chinese MWC users with spinal cord injury (SCI) [17]. Many studies have used satisfaction with AT devices as a variable, to gather feedback on AT devices, and also to relate it to AT service delivery. A study by Samuelsson and Wressle compared the level of satisfaction, using the Quebec User Satisfaction with Assistive Technology (QUEST), between users of manual wheelchairs and those of wheeled walkers [18]. Their study found a significant positive relation between the extent of use of both the wheelchairs and the wheeled walkers, to the level of satisfaction with these devices [18]. For older adults, Evans et al. reported moderate level of satisfaction with power wheelchairs (PWC) use, in spite of environmental barriers [19]. Their study also identified consumers' problems related to the service delivery of wheelchairs due to significant waiting times needed to obtain a wheelchair [19]. Another study, from the Netherlands, used satisfaction related to wheelchair service delivery, to determine problems related to the delivery time of wheelchairs for 503 individuals [13].

One of the limitations of previous research is that it has primarily targeted community dwelling populations, with limited emphasis placed on older adults, who form the biggest group of wheelchair users within NH settings. Therefore, the level of satisfaction, in older adults living in NH settings, related to their wheelchairs is relatively unknown. The objectives of this study were to describe the population of older adults living in NH and their community dwelling counterparts. The study also aimed to compare level of satisfaction (device and service-related) for older adults who used either MWC or PWC and resided in VA NH, private NH facilities, or in community settings. We hypothesized that

1. Quality of wheelchairs possessed by community dwelling older adults will be better than those living in NH.
2. Levels of satisfaction related to wheelchair use will be higher for community dwelling older adults as compared to those living in NH.

4.3 METHODS

4.3.1 Study Design

The study was cross-sectional in nature. All subjects provided written informed consent prior to enrollment in the study, which was approved by the VA Pittsburgh Healthcare System Institutional Review Board (IRB) and by the State of Pennsylvania Department of Health (DOH).

4.3.2 Subjects

A convenience sample of 132 older adults completed the study questionnaire. Participants represent three cohorts: older adults living in two VA-affiliated NH facilities; older adults living in three private NH facilities, and from community dwelling older adults who participated in the 28th National Veterans Wheelchair Games (NVWG) in Omaha, Nebraska. The NH facilities are all located in Southwestern Pennsylvania and part of a multi-site research protocol looking at wheelchair use and wheelchair-related incidents for this population. The NVWG is the largest annual wheelchair sports event in the world, and attracts participants from all across the United States. The inclusion criteria for this study were: age 55 years and above and currently using a MWC or PWC. The NH cohort underwent a screening procedure prior to enrolling in the study, to ensure enrollment of individuals who did not have cognitive impairments. This screening procedure consisted of administration of the Mini Mental Status Examination (MMSE), a standardized assessment to determine presence of cognitive impairment [20]. The exclusion criterion for the study was presence of pressure ulcer in the gluteal/sacro-coccygeal area. Demographic information of all participants is presented in Table 4.1.

4.3.3 Outcome Measurement

All participants completed a demographics questionnaire, and study investigators noted type of wheelchairs including make/model of wheelchairs they were using. Satisfaction related to MWC and PWC was determined using the Quebec User Evaluation of Satisfaction with Assistive Technology Version 2.0 (QUEST 2.0). The QUEST 2.0 assesses satisfaction of individuals who use AT by allowing them to rate their device (wheelchair) and also the service delivery of the device (wheelchair) on a five point Likert scale (1 to 5). A score of 1 indicates 'Not satisfied at All' and a score of 5 indicates being 'Very satisfied' (Appendix). The QUEST 2.0 is designed to measure satisfaction with a broad range of AT devices in a structured manner. The QUEST consists of 12 items, of which 8 items are related to device characteristics and 4 are related to the service delivery (Appendix B). Previous research studies have determined validity and reliability of the QUEST, and also indicated its sensitivity in determining satisfaction levels with use of AT devices in various populations [10-12].

4.3.4 Data Analyses

Data were analysed separately for manual wheelchair and power wheelchair group. Demographics and the wheelchair characteristics data were analysed using descriptive statistical methods (independent t test and Chi-square statistics). The composite QUEST scores (device, service delivery, and total score) were compared between three cohorts using Univariate Analysis of Covariance (ANCOVA) controlling for differences in age, gender, and diagnosis between the three cohorts followed. All statistical analyses were computed using SPSS 16.0 with α level of .017 (.05/3) set *a-priori*.

4.4 RESULTS

For both the MWC and PWC groups, participants in the private NH group were the oldest cohort (83.8 years and 82.4 years), and the community dwelling group was the youngest cohort (63.2 years and 67.8 years). Also, the private NH group represented the highest non-veteran female participants, compared to male veterans from both the VA NH and the community dwelling cohort. The proportion of individuals with SCI was higher among the community dwelling cohort (71%) compared to larger proportions of individuals with CVA in the VA NH group (43%).

Table 4.1. Demographic and Health-Related Characteristics

		VA NH (n=60)		Private NH (n=30)		Community Dwelling (n=42)	
		MWC (n=48)	PWC (n=12)	MWC (n=25)	PWC (n=5)	MWC (n=27)	PWC (n=15)
Age (years)		73.9±8.1†	77.5±5.8	83.8±5.4	82.4±4.9	63.23±5.6†† ‡	67.87±7.4†† ‡
Gender §§	**Male**	42	10	6	2	27	13
	Female	6	2	19	3	0	2
Veterans Status	**Yes**	44	10	2	1	27	15
	No	4	2	23	4	0	0
Diagnosis§ §§	**SCI**	0	0	0	0	19	11
	CVA	21	5	7	1	1	0
	Other	25	7	18	4	6	4

†= Statistically significant difference between VA NH group and Private NH group;
††=Statistically significant difference between VA NH group and Community Dwelling group;
‡= Statistically significant difference between Private NH group and Community Dwelling group; CVA=Cerebral Vascular Accident, SCI= Spinal Cord Injury, PD=Parkinson's Disease;
§=Indicates missing data
§§ = indicates significant differences between three groups by Chi-Square (Fisher Exact statistics)

With respect to the type of MWC used, a notable proportion of participants from the VA facilities were using an Invacare 9000 XT (60%), while those from the private NH were using an Invacare Tracer SX5 (28%). A significant proportion of the community dwelling cohort was using a Quickie 2 (23%). A significant difference was identified between groups regarding quality of MWC. The community dwelling group was using more ultralightweight MWC, the VA cohort who were using lightweight MWC, and last the private NH group was primarily using the depot style wheelchairs (Table 4.2a). With respect to use of PWC, a large proportion of the VA NH group and the private NH group reported using the same type of wheelchair (Jazzy 1113 ATS), whereas the community dwelling group was typically using the Invacare Arrow (Table 4.2b).

Table 4.2a. Manual Wheelchair Characteristics

		VA NH	Private NH	Community Dwelling
Most Common Wheelchair Make # (%)		Invacare 9000 XT 29 (60%)	Invacare Tracer SX5 7 (28%)	Quickie2 6 (23%)
Wheelchair CMS k-codes # (%)	Depot (K01)	4 (8%)	11 (44%)	0
	Lightweight (K04)	44 (92%)	14 (56%)	3 (11%)
	Ultralightweight (K05)	0	0	24 (89%)

Table 4.2b. Power Wheelchair Characteristics

		VA NH	Private NH	Community Dwelling
Wheelchair Make	Most Common	Jazzy 1113 ATS (25%)	Jazzy 1113 ATS (20%)	Invacare Arrow Action Storm (40%)

For manual wheelchairs users, the level of satisfaction related to wheelchairs was found to be significantly different between the three cohorts. Satisfaction levels for the community dwelling cohort was highest and that for the private NH cohort was the lowest (4.3 versus 2.9, *P*=.003). The VA NH cohort also reported higher levels of satisfaction as compared to the Private NH cohort (3.9 versus 2.9, *P*=.004). For the wheelchair service delivery a positive trend towards significant difference was observed with the community dwelling cohort reported higher levels of satisfaction as compared to both Private NH cohort (4.4 versus 2.8), and the VA NH cohort (4.4 versus 3.6). No notable differences were observed between the VA NH cohort to those of Private NH cohort (3.6 versus 2.9)

Table 4.3a. Satisfaction-Related to Manual Wheelchair Use

	VA NH (n=48)	**Private NH (n=25)**	**Community Dwelling (n=27)**
Satisfaction-Related to Wheelchair			
Dimensions	3.9±1.1	3.5±1.2	3.7±1.3
Weight	3.8±1.1	2.9±1.3	3.9±1.1
Adjustment	3.8±1.3	3.2±1.5	3.8±1.1
Safety	4±1.2	4.2±.98	4±.9
Durability	4.2±1	3.8±1.3	4±1
Ease of Use	3.8±1.4	2.8±1.2	4.1±1.1
Comfort	3.7±1.4	2.9±1.2	3.9±.9
Effectiveness	3.8±1.3	3.2±1.4	3.9±1.2
Satisfaction-Related to Wheelchair Service Delivery			
Service Delivery	4±1.2	3.7±1.3	3.9±1.2
Repairs and Services	3.4±1.6	2.5±1.4	3.8±1.1
Professional Services	3.7±1.4	3.1±1.3	4.1±1.2
Follow-up Services	3.3±1.5	2.4±1.1	4.1±1.3

	VA NH (n=48)	**Private NH (n=25)**	**Community Dwelling (n=27)**	***p* (ANCOVA)**
QUEST Composite Scores				
Device Combined	3.9±.15†	2.9±.28	4.3±.25‡	.009*
Services Combined	3.6±.18	2.8±.38	4.4±.29	.020
QUEST Total	3.9±.15†	2.9±.30	4.3±.25‡	.006*

*= overall statistical significance between groups;
†= Statistically significant difference between VA NH group and Private NH group; ‡= Statistically significant difference between Private NH group and Community Dwelling group

For powered wheelchairs users, the community dwelling cohort reported higher levels of satisfaction without significant differences related to both wheelchairs (4.1 versus 3.7, *P*=.53) and service delivery (4 versus 2.3, *P*=.21) as compared to the Private NH cohort. No differences were observed between the community dwelling cohort to that of VA NH cohort related to both powered wheelchairs and to the service delivery aspects.

Table 4.3b. Satisfaction-Related to Power Wheelchair Use

	VA NH (n=12)	Private NH (n=5)	Community Dwelling (n=15)
Satisfaction-Related to Wheelchair			
Dimensions	4.2±.7	4.2±.9	4.2±.9
Weight	4±.8	2.5±.7	4.1±1.2
Adjustment	4.2±.8	3.2±1.7	4.1±.9
Safety	4.5±.6	3.7±.9	4.3±.9
Durability	4.5±1.2	3.1±1.9	4.1±.9
Ease of Use	4.5±.6	4.4±1.3	4.5±.9
Comfort	3.4±1.4	3.6±1.7	4.1±.9
Effectiveness	3.9±1.5	3.8±.8	4.3±.9
Satisfaction-Related to Wheelchair Service Delivery			
Service Delivery	3.5±1.8	3.5±.7	4.1±.8
Repairs and Services	3.4±1.8	2.3±1.5	4.1±1.2
Professional Services	3.7±1.8	1.7±.5	4.4±.7
Follow-up Services	3.6±1.9	2.3±1.5	3.9±1.3

	VA NH (n=12)	Private NH (n=5)	Community Dwelling (n=15)	*p* (ANCOVA)
QUEST Composite Scores				
Device Combined	4.1±.23	3.7±.39	4.1±.22	.53
Services Combined	3.8±.43	2.3±.81	4±.37	.21
QUEST Total	4.1±.22	4±.37	4.1±.26	.47

4.5 DISCUSSION

The results showed differences in level of satisfaction related to wheelchair use and related to service delivery of the wheelchairs between the three groups. For manual wheelchair group satisfaction related to wheelchairs were highest for the community dwelling cohort and lowest for the Private NH cohort. Some of the contributors for these differences were: weight of wheelchairs, ease of use, and comfort related to wheelchair use. Satisfaction levels were related to the type of the MWC that the participants were using, with the community dwelling participants using mostly the ultralightweight wheelchairs, whereas a significant portion of the private NH group using the depot style wheelchairs. The difference between the weight of an ultralight weight MWC and that of a depot style MWC is approximately 30 pounds, which explains the lower satisfaction rates with the latter [21]. Also, the VA NH group reported significantly higher level of satisfaction compared to that reported by the private NH group, which can be attributed to the wheelchair weight difference between the lightweight and the depot style wheelchairs - approximately 25 pounds. There was no significant difference between the satisfaction levels among the VA NH group, which was using mostly lightweight wheelchairs (92%), and the community dwelling group. The ultralight and lightweight wheelchairs have a marginal difference in their weights. This is reflected by the fact that no significant difference exists between the reported satisfaction scores related to weight for the two types of wheelchairs. Another major difference was observed for ease of use, with participants from the community dwelling group reported highest satisfaction ratings, compared to those for the VA NH group and the private NH group. However, the difference was only significant between the community dwelling group and the private NH group. A previously conducted study by Trefler and colleagues indicated a positive impact of newly prescribed wheelchairs on improving propulsion efficiency of older adults in NH facilities [22]. In our study, since the community dwelling participants were using better quality wheelchairs, with adjustable axle positions to improve set up and propulsion, compared to those from the private NH group, the results were similar to the findings of the study by Trefler and colleagues [22]. Another factor was comfort related to wheelchair use, our results confirmed previous study results, indicating a positive relationship between quality of wheelchairs and satisfaction related to comfort or perceived comfort [22, 23]. Despite differences in the types of MWC used, no significant differences in comfort were found between the community dwelling and the VA NH group. This finding contradicts the one reported by DiGiovine, who reported a higher level of riding comfort for ultralightweight wheelchairs users as compared to lightweight wheelchair users [23].

Satisfaction related to manual wheelchair service delivery was highest for the community dwelling cohort followed by the VA NH cohort, and lowest for the Private NH cohort. The differences were notable for repairs, professional services, and follow-up services delivery. Since all the participants from the community dwelling cohort were veterans, the results indicate greater access to specialized professional care related to wheelchairs and AT services compared, to those available to the participants living in private NH facilities. The Veterans Health Administration (VHA) has established Wheelchair and Seating Clinics within VA Pittsburgh Healthcare System (VAPHS). These clinics provide specialized services related to wheelchair provision, and also provide routine wheelchair repairs/maintenance services. These clinics are held twice a month in the participating VA NH facilities. However, lack of permanent presence of these specialty clinics at the VA NH facilities could have resulted in lower satisfaction levels with respect to wheelchair service delivery between the VA NH group as compared to the community dwelling cohort. A previous report suggested low rates of wheelchair repairs in their population and a positive relationship between wheelchair repairs and maintenance to satisfaction related to wheelchair use [24]. This is represented in our study, which identified overall low satisfaction related to this aspect of wheelchair service delivery in all three cohorts.

With respect to powered wheelchair user, levels of satisfaction were higher for both the community dwelling cohort and the VA NH cohort as compared to the Private NH, without significant differences. The differences were notable regarding the service delivery for repairs, professional services, and follow-up services. Access to specialized wheelchairs and seating clinics is limited in the private NH setting. The majority of the PWC used by the residents in private NH settings were also personally owned, with an outside Durable Medical Equipment (DME) supplier as a point of contact for all wheelchair-related services. Better access to these specialized clinics could be a possible explanation for greater satisfaction with all service related areas for veterans in both the NH setting and those living in the community.

Due to the small sample size for (especially for the PWC users) in both the VA and private NH facilities, generalization of the results may not be applicable to a broader population. Also, the study excluded older adults with cognitive impairments, which is the largest user group for manual wheelchairs. Since procedure for obtaining informed consent from a legal representative was not set-up for this study with the IRB, we had to only recruit individuals who could provide their consent after understanding the study process. Limitation also applicable for subjects recruited from the NVWG, which does not represents all community dwelling wheelchair users thus limits generalization to the entire community dwelling older adults using wheelchairs for their mobility. Also, this paper did not look at the association between satisfaction as an outcome determinant and the utilization of the prescribed wheelchairs. An outcomes indicator such as satisfaction may be critical to understand the similarities and differences in the prescription process, and to develop a standardized quality for wheelchair prescription and service delivery across the continuum of skilled nursing care.

4.6 CONCLUSION

The results of this study indicate that differences do exist in the perceived level of satisfaction related to both manual and power wheelchair use in older adults related to their living settings. The study also suggests use of satisfaction as an outcomes indicator for determining pros and cons in both wheelchairs and their service provision for older adults. Due to the consumer-centered nature of wheelchair related services, satisfaction could also be viewed as an important quality indicator for changing course of services provision. The current clinical practice within NH does not focus on providing individualized wheelchairs, which, conversely, is the norm for community dwelling recipients of wheelchairs. Our results could also suggest improvement and reevaluation of NH wheelchair service provision programs that could results in prescription of better quality wheelchairs, with more emphasis placed on sharing more information with the NH residents and providing a follow-up care program.

4.7 ACKNOWLEDGEMENT

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4.9 Appendix B: QUEST

1	2	3	4	5
Not satisfied at all	Not very satisfied	More or less satisfied	Quite Satisfied	Very satisfied

ASSISTIVE DEVICE ***How satisfied are you with,***					
1. the **dimensions** (size, height, length, width) of your assistive device? *Comments*:	1	2	3	4	5
2. the **weight** of your assistive device? *Comments*:	1	2	3	4	5
3. the **ease in adjusting** (fixing, fastening) the parts of your assistive device? *Comments*:	1	2	3	4	5
4. how **safe and secure** your assistive device is? *Comments*:	1	2	3	4	5
5. the **durability** (endurance, resistance to wear) of your assistive device? *Comments*:	1	2	3	4	5
6. how **easy** it is to use your assistive device? *Comments*:	1	2	3	4	5
7. how **comfortable** your assistive device is? *Comments*:	1	2	3	4	5
8. how **effective** your assistive device is (the degree to which your device meets your needs)? *Comments*:	1	2	3	4	5

5.0 ANALYZING WHEELCHAIR-MOBILITY PATTERNS OF COMMUNITY DWELLING OLDER ADULTS

AUTHORS: Amol M. Karmarkar[1-2], PhD (Candidate); Rory A. Cooper[1-2], PhD; Hongwu Wang[1-2], MS; Annmarie Kelleher[1-2,] MS, OTR/L, ATP; Rosemarie Cooper[1-2], MPT, ATP.

AFFILIATIONS: [1]Human Engineering Research Laboratories, VA Pittsburgh Healthcare System; [2]Department of Rehabilitation Science and Technology, University of Pittsburgh

SEND CORRESPONDENCE TO:

Rory A. Cooper, PhD

VAPHS-Human Engineering Research Laboratories

7180 Highland Dr., Bldg. 4, 2nd Floor, 151R1-HD

Pittsburgh, PA 15206

Work: 412-954-5287

Fax: 412-954-5340

rcooper@pitt.edu

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5.1 ABSTRACT

Objective: To determine wheelchair mobility patterns for community dwelling older adults. To identify age influences on wheelchair mobility, or other self-reported physical activities.

Design: Prospective Cohort Design

Setting: National Veterans Wheelchair Games (Omaha, Nebraska) and participants' natural living environment.

Participants: Thirty nine veterans participating in the wheelchair games. Twenty six were manual wheelchair and 13 were power wheelchair users.

Outcomes: Wheelchair data logging devices, Physical Activity Scale for Elderly (PASE), and participation in sporting events.

Results: Participants using manual wheelchairs were significantly more physically active during the games compared to when they used their wheelchairs at their homes, in terms of distance traveled (4466.2 versus 1367.4 meters, $P<.001$) and average speed of propulsion (.76 versus .64 meter/second, $P<.001$). The trend was the same for power wheelchair users, with a difference in the extent of use during games and at home, with respect to distance (7306.2 versus 3450.5 meters, $P=.004$) and average speed (.90 versus .70 meter/second, $P=.002$). Power wheelchair users reported higher levels of work-related activities than manual wheelchair users ($P=.04$). The difference in the level of participation, in the sporting event, for manual and power wheelchair users, was not significantly different.

Conclusion: An objective evaluation is important for understanding the factors associated with wheelchair use and for the development of strategies for improving wheelchair mobility, thus enhancing overall participation on the part of wheelchair users.

Key Words: Older Adults, Wheelchair Use, Physical Activity

5.2 INTRODUCTION

The rate of participation in "regular physical activity" is reported to be only 22% in individuals 65 years and above, while this percentage drops to 8% for those over 85 years of age.[1] "Regular physical activity" is defined by the US Surgeon General as engaging in moderate intensity activities for 30 minutes for at least five times a week[2]. When aging is coupled with the presence of disability, restriction in physical activity becomes a significant problem.[3] Physical inactivity is also considered a major contributing factor for increased level of disability and mortality in the older population.[4] One study reports three times higher odds of mortality for older adults with physical impairment who live a sedentary life style, compared to those without impairment and active life style.[4]

Generating a physical activity profile of older adults has inspired several measurement methods including: observations reported by healthcare professionals, use of self-report physical activity questionnaires, pedometers that count numbers of footsteps, heart rate monitors for recording physiological response, accelerometers, and calorimetry for computing physiological energy expenditure.[5] In spite of significant pros and cons, pedometers have been used for screening and assessment, for outcome measurements, and as an intervention tool with ambulatory population.[5-7] Evidence suggests that using pedometers as an interventional tool is associated with improved levels of physical activity, reduced body mass index, and positive changes in blood pressure levels.[8]

A significant limitation of the above mentioned work is its emphasis on measuring walking, which therefore excludes individuals using wheelchairs or other mobility devices. Most research focused on recording wheelchair-related mobility has relied on subjective assessments using questionnaire and survey methods to capture information related to level of physical activity and participation among wheelchair users. However, research that involves actual monitoring of physical activities by the wheelchair users has not been done extensively. As a result, there is no measurement profile available, designed and developed solely for wheelchair users, that can measure and record wheelchair propulsion as a physical activity, and that can be used for making recommendations for improving levels of physical activity.

Warms and Belza reported use of Actiwatch the commercially available product for recording gross motor movements among individuals with spinal cord injury who use wheelchairs.[9] This method, although useful, only detected the motions occurring in the upper limbs, rather than providing a comprehensive measure of the extent of use of the wheelchair and the interaction between the users and their wheelchairs. A report by Wilson and colleagues demonstrated efficacy of the activPAL (a customized device) in measuring wheelchair-related mobility (distance covered, speed of travel, and time spent in wheelchair) for individuals with spinal cord injury within their natural living settings.[10] Previous work done in this area, has demonstrated effective use of a customized data logging device for measuring driving characteristics of powered wheelchairs (PWC) over the course of five days for athletes participating in the National Veterans Wheelchair Games (NVWG) and compared them to driving characteristics for PWC use at home.[11] More recently, a study reported use of data loggers for monitoring driving characteristics of MWC, comparing distance traveled, amount of continuous travel (without stopping), and hours of wheelchair use for wheelchair athletes during organized sporting events versus their community MWC use.[12] Use of wheelchair data logging devices has also been reported as a method for determining the effectiveness of pushrim-activated power-assist wheelchairs (PAPAW) in improving the mobility of individuals with SCI, in comparison with use of traditional manual wheelchairs.[13] Cooper and colleagues have also used customized data logging devices to measure wheelchair-related mobility among children using manual and power wheelchairs within the community.[14] Another instrument, the wheelchair activity monitoring instrument (WhAMI) has been developed to record wheelchair usage (indoor and outdoor) and overall occupancy time for PWC users.[15] The study proposed to use distance traveled, along with time spent in the wheelchair, and the number of bouts of acceleration, as indicators for wheelchair use.

The primary objective of this study was to quantify wheelchair-mobility characteristics for older adults during an organized sporting event, the National Veterans Wheelchair Games (NVWG), and during their community use of their wheelchairs. We also aimed to identify the relationship between an objective assessment of wheelchair use and subjective responses obtained from participants regarding level of participation in the sporting event. We hypothesized that (a) older adults will be more active as reflected by their wheelchair use during the games than their home environment use; (b) there will be differences in self-reported activity levels between manual and power wheelchair users; and (c) age, self-reported physical activities levels, and wheelchair mobility will be correlated.

5.3 METHODS

5.3.1 Study Design

The study was prospective and observational in nature and conducted at the 28th National Veterans Wheelchair Games (NVWG) in Omaha, Nebraska (July, 2008). All participants were consented prior to enrollment in the study, which was approved by the VA Pittsburgh Healthcare System Institutional Review Board (IRB).

5.3.2 Participants

All the study participants were veterans participating in the annual NVWG. A total of 42 individuals were recruited, and 39 of whom completed the study protocol. Twenty six were MWC users (n=26) and 13 were PWC users (n=13). The inclusion criteria for this study were: aged 18 years and older, and current independent wheelchair users. The exclusion criterion for the study was: pressure ulcers on their buttocks that resulted in limited sitting tolerance. We only recruited PWC users who confirmed their ability to change caster data loggers (with or without assistance). Demographic information of all the participants is presented in Table 5.1.

5.3.3 Outcomes Measurement

5.3.3.1 Instrumentation Data related to MWC mobility were collected using a customized data logging device (See Figure 5.1), which was developed at the Human Engineering Research Laboratories (HERL), part of the VA Pittsburgh Healthcare System. The data logging (DL) device is self-powered and can record wheelchair mobility data for up to three months on a flash memory chip. The DL device measures wheel rotations through use of three reed switches mounted 120° apart on a circuit board and a magnet mounted at the bottom of a pendulum sensor. Every time the wheelchair wheel rotates more than 120°, the magnet triggers one of the reed switches. As each reed switch is triggered, a date and time stamp of that event gets recorded in the device. For this study, we instrumented each participant's MWC with DL devices for a period of one month. The wheel circumference was also recorded during instrumentation, which was used during the data reduction process. The DL devices were placed between spokes of the wheels and did not interfere with routine use of wheelchairs by the participants. Use of DL devices has been reported previously for determining MWC-related mobility in community dwelling population.[13, 14, 16]

For measuring PWC use, caster DL also designed and developed at HERL, were used (See Figure 5.2). Front or back casters of PWC for each participant were replaced by customized caster DL. The caster DL records wheel rotation using magnet and switches similar to that of the manual DL described above. These devices have been successfully used to monitor PWC activities for adults and children in previous studies.[11, 14]

Figure 5.1. Manual Wheelchair Data Logging Device

Figure 5.2. Power Wheelchair Data Logging Device

5.3.3.2 Questionnaire All participants completed the Physical Activity Scale for Elderly (PASE) questionnaire. The PASE is a standardized tool for assessing subjective responses of older adults regarding their physical activity levels. The questionnaire has 10 items pertaining to the domains: leisure, household, and work-related activity. The questionnaire records responses in terms of frequency and duration of activities, which are weighted to obtain a score in each domain.[17] The overall PASE score is a summation of all domain scores. The psychometrics of PASE for recording physical activities in older adults has been reported previously (See Appendix C).[18]

5.3.4 Protocol

All participants were recruited during the 2008 NVWG. After consenting demographic information was collected, participants completed questionnaires, and we attached a data logging device to each participant's wheelchair. Participants were given written instructions to remove the data logger along with a pre-paid envelope for shipping it back to investigators two weeks after the end of the games. For PWC users, the front or back casters of wheelchairs were replaced with customized casters with built-in data loggers. Participants were given their wheelchair casters and a pre-paid envelope. They were instructed to change the casters back to their original wheels two weeks after the end of the games and to ship the data loggers to the study investigators.

5.3.5 Data Reduction

After receiving the manual and power caster DL from the participants, all data were downloaded onto a computer. The raw data were then decompressed using a customized MATLAB program. The customized program extracted the following wheelchair-related mobility variables: average distance traveled per day using the wheelchair (distance); average velocity of wheelchair propulsion (driving) per day (velocity); average maximum continuous distance traveled without a stop (endurance distance); and average number of stops taken for travelling 500 meters with wheelchair (stops/500m), and average maximum continuous time traveled without a stop (endurance time). Secondary mobility variable included sub-analysis of wheelchair velocity to determine the time spent by participants using their wheelchairs at various velocities: greater than 1 meter/second; between 0.5-1 meter/second; and less than 0.5meter/second. Detailed information (including mathematical equations) related to data reduction has been described previously by Tolerico and colleagues.[16]

5.3.6 Data Analyses

Descriptive statistics were used for demographics and wheelchair characteristics for MWC and PWC groups separately. Due to non-normal distribution, wheelchair-mobility data (distance traveled, velocity, continuous distance, continuous time, and number of stops every 500 meters) were compared within subjects (NVWG versus home) using the Wilcoxon Signed Rank test for both MWC and PWC groups. Data from the PASE questionnaire was compared between the MWC and PWC group using the Mann Whitney-U test. Comparisons were made regarding number of events participation for MWC and PWC users using the Mann Whitney-U test. To determine relationships among age, PASE score, and wheelchair mobility in home settings (distance traveled, and velocity) correlation coefficients were computed using Spearman Rho's method. All statistical analyses were performed using SPSS 16.0 software, with a significance level set *a-priori* at .05.

5.4 RESULTS

5.4.1 Participants' Demographic Characteristics

The mean age for participants in the MWC group was 63 (±6) years, compared to 67 (±7) years for PWC users. The MWC group presented with slightly higher body weight 90 (±19) kilograms as compared to 84 (±17) kilograms for PWC users. In terms of years with disability the PWC group was slightly higher 34 (±15) years compared to the MWC group 26 (±17) years. There were few female participants in the PWC group and none in the MWC group. The ethnic distribution was similar in both groups. Spinal cord injury (SCI) was the most prevalent medical condition for both groups (MWC=72%, and PWC=70%), with the MWC group having the highest number of individuals with SCI at the thoracic level (40%). The proportion of participants with SCI at the cervical level was highest for the PWC group (53%) (See Table 5.1).

Table 5.1. Subject Demographics

		Manual Wheelchair (n=26)	Power Wheelchair (n=13)
Age (Years)		62.5±5.7	66.9±7.5
Body Weight (Kg)		89.7±19.2	84.2±16.8
Disability Duration (Years)		25.3±14.8	33.5±17
Gender	Male	26	11
	Female	0	2
Ethnicity†	African American	5	3
	Caucasian	16	9
	Others	4	1
Diagnosis†	C-SCI	5	7
	T-SCI	10	1
	LS-SCI	3	1
	Other	7	4

† indicates missing data

C-SCI= Cervical level Spinal Cord Injury, T-SCI= Thoracic level Spinal Cord Injury, LS-SCI= Lumbo-Sacral Spinal Cord Injury

5.4.2 Wheelchair Characteristics

The MWC group primarily used the Quickie 2 wheelchair, while the Invacare Arrow was the most commonly used wheelchair for the PWC group (See Table 5.2). The total years of wheelchair use was slightly higher for the PWC group (27 years) as compared to the MWC group (21 years). Both groups reported high levels of satisfaction related to their wheelchair use.

Table 5.2. Wheelchair Characteristics

		Manual Wheelchair (n=26)	Power Wheelchair (n=13)
Years of Using Wheelchair		21±15.1	26.3±17.2
Most Commonly Used	Make	Quickie	Invacare
	Model	2	Action Arrow
Age of Primary Wheelchair (years)		4.9±7.4	2.5±2
Satisfaction with Wheelchair		4±.17	4±.16

5.4.3 Manual Wheelchair Usage

The results of this study indicated significantly higher MWC mobility by participants during the NVWG as compared to their home/community use. Participants were significantly more active with their wheelchairs at the NVWG in regard to: distance traveled (4466.2 m versus 1367 m, $P<.001$); wheelchair propulsion velocity (.76 m/s versus .64 m/s, $P<.001$); continuous wheelchair drive distance (328.6 m versus 183.2 m, $P=.002$); continuous wheelchair drive time

(5.2 min versus 2.5 min, *P*<.001); and number of stops/500 meters (17.4 versus 32.6, *P*<.001). The proportion of time participants were propelling their wheelchairs with velocity greater than 1 m/s was higher during the NVWG as compared to their home and community use (29.8 versus 13.9, *P*=.013) (See Table 5.3a).

Table 5.3a. Manual Wheelchair Use Comparison

	NVWG Use (n=26)	Home Use (n=26)	P-value
Distance Traveled (m)	4466.2±1192	1367.4±624.2	<.001*
Propulsion Velocity (m/s)	.76±.08	.64±.13	<.001*
Propulsion Velocity>1m/s (Proportion time)	29.8±26.1	13.9±17.8	.013*
Propulsion Velocity.5-1m/s (Proportion time)	66.4±25.5	39.2±21	.001*
Propulsion Velocity<.5m/s (Proportion time)	3.7±4.2	42±26.7	<.001*
Continuous Drive Distance (m)	328.6±111.9	183.2±190.4	.002*
Continuous Drive Time (min)	5.2±1.4	2.5±1.9	<.001*
Stops/500m (#)	17.4±3.7	32.6±10.6	<.001*

* indicates statistically significant difference between NVWG and home use

5.4.4 Power Wheelchair Usage

The results of this study indicated significantly higher PWC mobility by participants during the NVWG as compared to their home/community use. Participants were significantly more active with their wheelchairs in regard to: distance traveled (7306.2 versus 3450.5, *P*=.004); wheelchair driving velocity (.90 versus .70, *P*=.002); continuous wheelchairs travel distance (613.2 versus 344.1, *P*=.006); continuous wheelchair drive time (7.1 versus 4.2, *P*=.005); and number of stops/500 meters (18.6 versus 36.5, *P*=.002). The proportion of time participants' were driving their wheelchairs with velocity greater than 1 m/s was higher during the NVWG as compared to their home and community use (58.4 versus 29.5, *P*=.003) (See Table 5.3b).

Table 5.3b. Power Wheelchair Use Comparison

	NVWG Use (n=13)	Home Use (n=13)	P-value
Distance Traveled (m)	7306.2±2592.1	3450.5±2596	.004*
Driving Velocity (m/s)	.90±.3	.70±.3	.002*
Driving Velocity>1m/s (Proportion time)	58.4±34.5	29.5±32.3	.003*
Driving Velocity.5-1m/s (Proportion time)	30.6±31.4	42.3±20.9	.17
Driving Velocity<.5m/s (Proportion time)	11±23	27.5±19.8	.04*
Continuous Drive Distance (m)	613.2±344	344.1±324.9	.006*
Continuous Drive Time (min)	7.1±2.8	4.2±2.8	.005*
Stops/500m (#)	18.6±9.1	36.5±16.6	.002*

* indicates statistically significant difference between NVWG and home use

5.4.5 PASE Score

Participants of our study using PWC had higher PASE scores as compared to MWC users related to leisure, though this difference was not significant (108 versus 89.8, *P*=.38); and work-related activities (31.8 versus 16.5, *P*=.04). Manual wheelchair users were more active in household activities, though not significantly than PWC users (71.5 versus 51.5, *P*=.27). Overall, the total PASE score was slightly higher for the PWC cohort, the difference did not reach significance (183.2 versus 177.8, *P*=.71) (See Table 5.4).

Table 5.4. Physical Activity Scale for Elderly (PASE) scores comparison

	Manual Wheelchair (n=26)	Power Wheelchair (n=13)	P-value
PASE (Leisure Activities)	89.8±79.4	108±73.2	.38
PASE (Household Activities)	71.5±50.8	51.7±46.3	.27
PASE (Work)	16.5±23.5	31.8±21.6	.04*
PASE	177.8±112	183.2±101.3	.71

* indicates statistical significant difference between manual and power wheelchair PASE scores

5.4.6 Organized Sports Participation

No difference was observed in our MWC and PWC groups in terms of participation in number of events for all sports activities (4 versus 3.5, *P*=.12). Participation in the track and field events was highest for both groups followed by participation in other sports (nine ball, bowling etc.). Events participation using their primary wheelchair was slightly higher for the PWC group as compared to the MWC group, without a significant difference (*P*=.29).

Table 5.5. Total Events Participation at NVWG

	Manual Wheelchair (n=26)	Power Wheelchair (n=13)	P-value
Total Events	4±1.2	3.5±1.2	.12
Track and Field	1.3±1.3	1.2±1	.90
Shooting	.6±.8	.4±.7	.39
Organized Sports	.9±.7	.7±.6	.27
Others	1.2±.9	1.2±.9	.82
Events Participated Using Primary Wheelchair	2.8±1.6	3.4±1.6	.29

5.4.7 Relation Between Variables

Results for the MWC group showed a significant negative correlation between age and wheelchair propulsion velocity (r = -.40, *P*=.04). No relationship was observed between the PASE score and wheelchair mobility as described using distance (r=-.05), and velocity (r=.08). For the PWC group, a significant positive relationship was observed between age and wheelchair driving velocity (r=.68, *P*=.01). No significant relationship was observed between the PASE score to powered wheelchair mobility, distance (r=-.04), and velocity (r=-.09). (Table 5.6 and Figures 5.3 and 5.4)

Table 5.6. Relationship between Variables

	Manual wheelchair (n=26)				Power Wheelchair (n=13)			
	Age	PASE	Distance	Velocity	Age	PASE	Distance	Velocity
Age		-13 (*P*=.52)	-.005 (*P*=.98)	-.40 (*P*=.04)*		-.15 (*P*=.62)	-.03 (*P*=.91)	.68 (*P*=.01)*
PASE			-.05 (*P*=.80)	.08 (*P*=.68)			-.04 (*P*=.90)	-.09 (*P*=.76)
Distance				.52 (*P*=.007)*				.43 (*P*=.14)

* indicates a statistically significant relationship

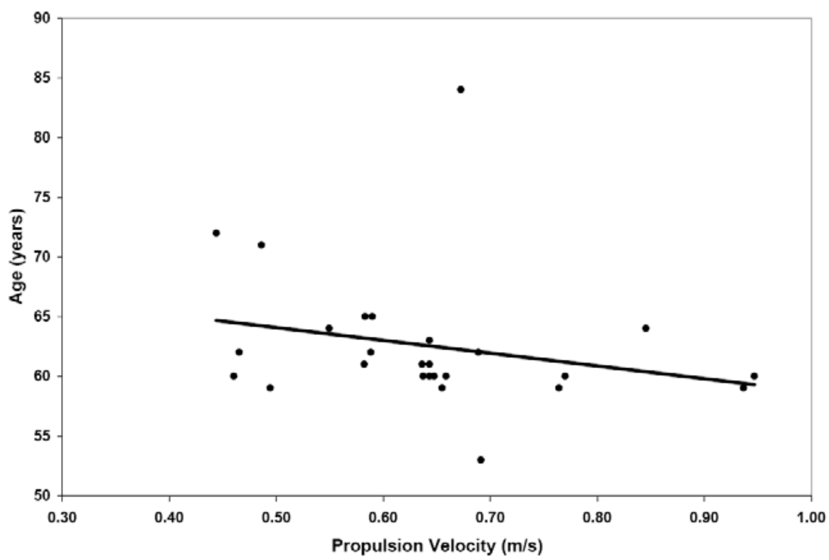

Figure 5.3. Relation between Variables for Manual Wheelchairs

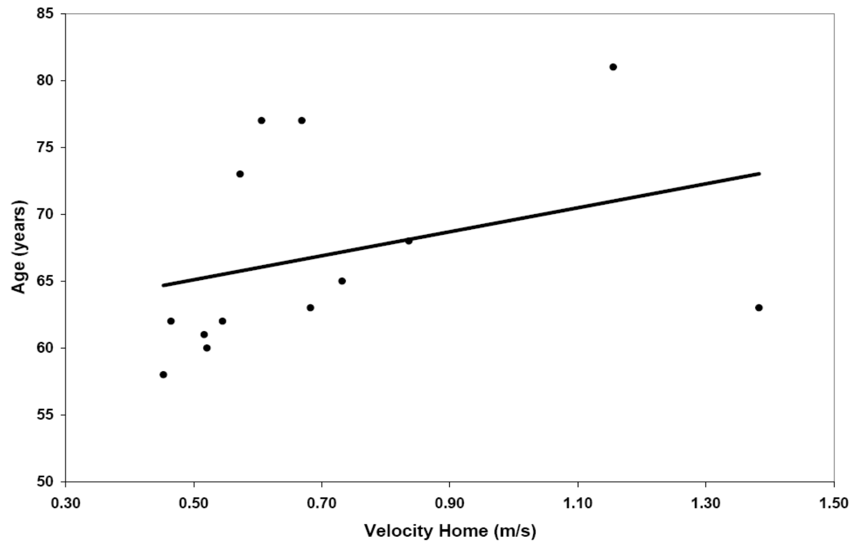

Figure 5.4. Relation between Variables for Power Wheelchairs

5.5 DISCUSSION

The utilization of prescribed wheelchairs is a critical area for understanding the benefits attained from their optimal use, and the risks associated with limited use. Wheelchair data logging devices have been successfully established as a means of objective measurement for determining use of wheelchairs within the users' natural environment.[11, 13, 14, 16] However, this method has not been utilized for community dwelling older adults to understand the extent of their use of wheelchairs for their everyday activities. Our study recruited older adults (aged 55 and above) participating in the annual NVWG, who were full-time manual or power wheelchair users and were community dwellers. We recruited two cohorts of manual and power wheelchair users. The results showed no major differences in demographic characteristics between these two groups. The only difference observed was in the level of injury; with the PWC group having higher levels of injuries compared to the MWC group. The wheelchair use was compared, separately for MWC and PWC users, between their use at the NVWG and their home use.

For the MWC group, the differences in basic wheelchair-related mobility (distance traveled and velocity of propulsion), were significantly higher during NVWG as compared to their home use. Our results resembled those reported by Tolerico and colleagues, who suggested significantly higher use of manual wheelchairs during the NVWG as compared to home use.[16] However, our cohort was less active during both the NVWG and during their use in their home environments, as compared to that represented in the Tolerico et al. paper: distance during games (4.4km versus 6.7km) and during home use (1.3km versus 2.4km). The difference was also identified in the velocity of wheelchair propulsion, with our cohort being slightly slower than those represented by the other study: during games (.76m/s versus .96m/s) and during home use (.64m/s versus .79m/s).[16] Results from the secondary analyses of data indicated a significant negative relationship between age of the wheelchair user and velocity of wheelchair propulsion. This trend has been commonly observed in ambulatory older adults, who often prefer to walk at a slower pace (velocity) compared to younger individuals. However, this study was not focused on comparison between young and old individuals using wheelchairs. The findings of the current study may help clinicians to understand the preference of speed among older adults for wheelchair propulsion.

For PWC users our study found significantly higher use in terms of distance and speed of driving during the wheelchair games as compared to in-home use (7.3km versus 3.4km). Our results are consistent with those reported by Cooper and colleagues, who also reported higher use of PWC during wheelchair games compared to in-home (community) use.[11] Our cohort was travelling faster with their PWC during games compared to their in home use, which is consistent with previous findings.[11] Our results are also consistent with those reported by Sonenblum and colleagues who found that environment significantly affected the power-wheelchair mobility patterns for individuals with disabilities.[15]

Understanding community (inside home and outside home) use is a critical determinant in matching the user with appropriate PWC technology, rather than just looking at mobility during sporting event that could misrepresent the activity patterns of the end-user. This is even more important for older adults, who constitutes one of the largest consumer groups for powered mobility devices (~50k)[19]. The evidence to support selection of the most appropriate mobility device (PWC) and how it might benefit (participation and quality of life) is very limited.[20] This could be due to the fact that the research done in this area has been based on self-report from users, without objective utilization data; which has limited strength of the evidence.[21] These factors result in a biased professional opinion that PWC use is limited in the older adult population. This in turn has affected the extent to which customizable PWC are prescribed to older adults, compared to their younger counterparts.[22]

Regarding self-reported physical activity levels, individuals using PWC were more active (overall PASE score) as compared to MWC users. The difference was significant for work-related activities, with PWC group reporting greater employment-related activity (time and intensity) as compared to the MWC users. Previously reports indicated a significant impact of wheelchairs (manual and power) in employment accessibility for individuals with spinal cord injuries.[23] A comparable study, by Tolerico and colleagues found an employment rate of 34% in their sample of MWC users.[16] There are no data available to show impact of wheelchairs on employment and to compare the rate of employment between MWC and PWC users. The rate of engagement in work-related activities for our participants was 16.5 for MWC users and 31.8 for PWC users. However, these data were obtained from the PASE questionnaire which defines ‘work’ as involvement in both paid and un-paid (volunteer) activities. Also, the PASE questionnaire is standardized for ambulatory older adults and not sensitive to older adults using wheelchairs. Therefore, the feasibility of its use in older adults using wheelchairs to assess their mobility patterns is undetermined. Use of data loggers, however, is the most objective way of assessing wheelchair-related mobility within the natural environment, though it may not be a feasible option for clinical settings that lack technical assistance for using these devices. Future attempts should be made to develop and standardize a brief self-reported survey that can be validated with the use of wheelchair data loggers and thus can measure wheelchair-related mobility with greater accuracy. Such information could aid in matching the user with the most appropriate wheeled mobility technology and helps clinicians to justify their prescriptions.

Overall, sporting event participation was higher for MWC users than PWC users, without any notable differences. It was also interesting to note that PWC users used their primary wheelchair for the majority of the sporting events; this was not the case with MWC users. Since MWC users were participating in certain organized sporting events like wheelchair basketball, and wheelchair softball; they were required to use specialized wheelchairs instead of their primary MWC. This was not the case for most of the power soccer players, who reported using their primary chair for competing. Participation in organized sporting events has been shown to have a significant impact on physical functioning, cognitive functioning, acceptance of disability, and overall improvement in quality of life.[24] These findings are also demonstrated for ambulatory older adults. Since there are no standardized measures available for assessing wheelchair mobility, no evidence is available that supports a relationship between level of wheelchair mobility and level of participation in sporting events, and to its impact on overall well being.[25]

Our study found a moderate negative relationship between age and propulsion velocity in MWC users'. From our results, we conclude that one of the preferences made by the aging population related to their wheelchair mobility is for propelling their wheelchairs at slower speeds than those preferred by their younger counterparts. This may also raise several concerns, particularly with respect to increased repetitions in propulsion patterns, which can lead to overuse injuries.[26, 27] Secondly, increased cadence is reported to be inefficient in terms of wheelchair mobility at cost of minimal energy expenditures.[26, 27] Future research using biomechanical and physiological methods to examine these issues within a controlled environment is required to evaluate this assumption. Understanding that older adults propel wheelchairs at a lower speed is also important for future research, since some of the previously conducted studies have had selected propulsion velocities that are much higher than the rates of natural propulsion patterns of older adults.[26, 28]

Our study did not find a significant relationship between self-reported levels of physical activity (PASE) and wheelchair-related mobility. One of the possible explanations is that the PASE is a standardized instrument for ambulatory older adults and our sample population was that of wheelchairs users. Self-reported questionnaires and surveys are commonly used for collection of information on physical activity levels for individuals with disabilities and older adults. However, bias, underreporting, and burden on the respondent are some of the limitations of surveys. Use of an unobtrusive method, such as a wheelchair data logger, holds promise for collecting activity level data from wheelchair users within their natural living environment.

For the PWC cohort, our results showed a significant positive correlation between age and wheelchair driving velocity. While we cannot derive any conclusions from this finding, a future line of work that may be warranted entails examining mobility patterns for older adults transitioning from manual to power wheelchair and determining their relationship to functional independence and quality of life. Likewise, for the MWC users group we did not find a relation between self-reported physical activity measures and wheelchair mobility, which again suggests the usefulness of the caster data loggers for assessing mobility patterns for power wheelchair users within their natural living environment.

Our study recruited a convenience sample of older veterans attending organized sporting events (NVWG). We realize that this cohort does not represent a typical wheelchair-using older adult living in the community or in an institutional setting (assisted living or nursing home). Therefore, generalization of the results to the civilian population, as well as to those veterans who do not participate in such events, could be limited. Wheelchair utilization data are lacking for older adults living in community, and in institutional settings. This has, in turn, limited the evidence in support of providing customized wheelchairs to this population. This limitation could be overcome by conducting studies that recruit both the community-dwelling older population as well as those living in institutional settings. Most of our participants (21 out of 26 for MWC; and 9 out of 13 for PWC) reported owning a back-up (a secondary wheelchair). We only attached a data logger onto their primary wheelchair, which could have resulted in underestimation of their overall wheelchair mobility. Future research should include attaching data loggers to secondary wheelchairs to determine the interchangeability of wheelchair use. Another limitation is pertains to the data logging devices themselves. Data regarding wheelchair-related activities could have reflected a combination of active use (participants using their wheelchairs) and passive use (someone propelling the wheelchairs for the participants). Although one of the inclusion criteria for the study was independent wheelchair use, instances may have occurred when wheelchair mobility involved both active and passive use. The DL devices were not sensitive enough to make this distinction. In the future, a data reduction program using machine learning algorithms could result in development of a model capable of distinguishing between active and passive use.

Finally, the purpose of this study was to determine wheelchair use in older veterans during a sporting event and their natural home environment. Due to our small sample size, we were not able to conclusively assess the relationship between the objective assessment (DL) and the self-reported physical activity levels (PASE score). Based on the results, we can conclude that each of these assessments measure different domains. Developing a wheelchair utilization outcomes measure could help to identify problems associated with (limited) wheelchair use and provide evidence to clinicians regarding the advisability of transitioning these individuals to alternative form of wheeled mobility devices (power-assist wheelchairs, or power wheelchairs) for improving their mobility and overall participation.

5.6 CONCLUSION

Results from our study suggest that 'context' has a big impact on the extent of use of wheelchairs among older adults. Although self-reported physical activity assessment has been successfully used with ambulatory older adults, it was not found to be sensitive as a standardized tool for assessment of wheelchairs users. In contrast the wheelchair data logging method is very effective and unbiased for objective evaluation of wheelchair use. Understanding these mobility patterns will enable clinicians to match older adults with the appropriate wheeled mobility device to meet their (mobility) needs. Participation in regular physical activity (organized sports) has several benefits for older adults with disabilities. Understanding factors that can influence participation and prescription of appropriate wheeled mobility technologies will enable maintenance of an active lifestyle for aging adults.

5.7 ACKNOWLEDGEMENT

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5.9 APPENDIX C: PASE

LEISURE TIME ACTIVITY

1. Over the past 7 days, how often did you participate in sitting activities such as reading, watching TV or doing handcrafts?

[0.] NEVER ↓ GO TO Q.#2	[1.] SELDOM (1-2 DAYS) ↓	[2.] SOMETIMES (3-4 DAYS) ↓	[3.] OFTEN (5-7 DAYS) ↓

1a. What were these activities?

____

1b. On average, how many hours per day did you engage in these sitting activities?

[1.] LESS THAN 1 HOUR [2.] 1 BUT LESS THAN 2 HOURS

[3.] 2-4 HOURS [4.] MORE THAN 4 HOURS

2. Over the past 7 days, how often did you take a walk outside your home or yard for any reason? For example, for fun or exercise, walking to work, walking the dog, etc.?

[0.] NEVER ↓ GO TO Q.#3	[1.] SELDOM (1-2 DAYS) ↓	[2.] SOMETIMES (3-4 DAYS) ↓	[3.] OFTEN (5-7 DAYS) ↓

2a. On average, how many hours per day did you spend walking?

[1.] LESS THAN 1 HOUR [2.] 1 BUT LESS THAN 2 HOURS

[3.] 2-4 HOURS [4.] MORE THAN 4 HOURS

HOUSEHOLD ACTIVITY

7. During the past 7 days, have you done any light housework, such as dusting or washing dishes?

   [1.] NO [2.] YES

8. During the past 7 days, have you done any heavy housework or chores, such as vacuuming, scrubbing floors, washing windows, or carrying wood?

   [1.] NO [2.] YES

9. During the past 7 days, did you engage in any of the following activities?

   Please answer YES or NO for each item.

		NO	YES
a.	Home repairs like painting, wallpapering, electrical work, etc.	1	2
b.	Lawn work or yard care, including snow or leaf removal, wood chopping, etc.	1	2
c.	Outdoor gardening	1	2
d.	Caring for an other person, such as children, dependent spouse, or an other adult	1	2

6.0 MANUAL WHEELCHAIR-RELATED MOBILITY CHARACTERISTICS OF OLDER ADULTS IN NURSING HOMES

AUTHORS: Amol M. Karmarkar[1-2], PhD (Candidate), MS; Diane M. Collins[1-2], PhD; Annmarie Kelleher[1-2], MS OTR/L ATP; Dan Ding[1-2], PhD; Michelle Oyster[1-2], MS; Rory A. Cooper[1-2], PhD.

AFFILIATIONS: [1]Human Engineering Research Laboratories, VA Pittsburgh Healthcare System; [2]Department of Rehabilitation Science and Technology, University of Pittsburgh

SEND CORRESPONDENCE TO:

Rory A. Cooper, PhD

VAPHS-Human Engineering Research Laboratories

7180 Highland Dr., Bldg. 4, 2nd Floor, 151R1-HD

Pittsburgh, PA 15206

Work: 412-954-5287

Fax: 412-954-5340

rcooper@pitt.edu

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6.1 ABSTRACT

Introduction: Manual wheelchairs are the most commonly prescribed form of mobility devices for older adults in nursing homes. The extent of their utilization being unknown may result in the prescription of standard wheelchairs, irrespective of the difference in characteristics of their users. The purpose of this study was to quantify manual wheelchair use by nursing home residents.

Design: Seventy-two independent wheelchair users without cognitive impairments were recruited from four nursing homes (two VA-affiliated and two private). A customized wheelchair data logger was attached to each participant's wheelchair for a period of one month. Data were reduced and compared separately for VA- affiliated and private facilities by types of propulsion pattern (arms versus legs and the combination of arms and legs) using MANOVA.

Results: Those participants who used their arms to propel their wheelchairs were more active, compared to participants who used their legs and those who used their arms and legs in combination. This finding pertain only to participants from the VA-affiliated facilities, as measured by distance (P=0.001), velocity (P=0.08), and endurance (P=0.07).

Conclusion: Older adults who live in nursing homes and use wheelchairs represent a diverse cohort. The efficacy of using an objective assessment method to measure the extent of use of wheelchairs was demonstrated in this study. This objective assessment method will help clinicians to identify needs of older adults for prescribing individualized and customizable wheelchairs, and it will thus prevent provision of standard wheelchairs irrespective of the users' needs.

Keywords: Older Adults, Nursing Homes, Wheelchair, Mobility

6.2 INTRODUCTION & BACKGROUND

Between 1.6 and 1.8 million community dwelling individuals use wheelchairs, with 58% of this population being manual wheelchair (MWC) users.[1, 2] Of these individuals, the number for older adults (age>65 years) is approximately 900,000, the majority of the latter are MWC users. In Nursing Homes (NH), the number of older adults using wheelchairs is reported to be over 50% of the total population.[2,3] Utilization of a wheelchair depends on several factors such as the person's demographics (e.g., age, gender), health factors (e.g., health status, physical impairments, functional limitations, co-morbid conditions), wheelchair characteristics (e.g., condition, type of wheelchair), environmental facilitators and barriers (i.e., accessible vs non-accessible living and community environments); and quality of service delivery (wheelchair prescription by an assistive technology specialist versus a non-specialist).[4-6] A cross-sectional study of community dwelling older Canadians aged 65 and older, found that factors including gender (men>women), level of functional limitation (greater functional limitation>lesser functional limitation), and living status (alone>living with someone) were indicators for increased wheelchair use.[7] Another cross-sectional study reported that the average use of wheelchairs by older veterans after experiencing cerebrovascular accidents was approximately 13 hours per week.[8]

Use of wheelchairs is viewed differently by professionals and by users. Although rehabilitation professionals view wheelchairs as a way to improve independence in mobility, wheelchairs are often provided to NH residents to meet their positioning needs or merely for improving transportation efficiency.[3] However, residents reported that wheelchair use improved their level of independence in functional mobility, and at the same time, increased their efficiency and safety during mobility.[9] Previous studies that focused on determining the use of wheelchairs in NH have relied exclusively on observations from investigators and healthcare professionals. This subjective method of data collection and reporting could severely compromise the accuracy of the information obtained. One report indicated that 80% of 126 NH residents who participated in a study used their wheelchair once every day. Usage was observed by the study investigators, to be maximal during meal times (lunch and dinner) and minimal between the two meals.[3]

The rate of participating in "regular physical activity" is reported to be only 22% in individuals 65 years and above, while this percentage drops to 8% for those more than 85 years of age.[10] "Regular physical activity" is defined by the US Surgeon General as engaging in moderate intensity activities for 30 minutes for at least five times a week[11]. When aging is coupled with the presence of disability, restriction in physical activity becomes a significant problem.[12] Physical inactivity is also considered a major contributing factor for increased level of disability and mortality in the older populations.[13] A high prevalence of low mobility is also often observed in older adults hospitalized or living in NH. A cycle has been identified in another study with low mobility limiting activities of daily living (ADLs) resulting in functional decline, which, in turn, results in increased use of personal assistance and greater chances of hospitalization (or admission to nursing facilities).[14]

Measuring the level of physical activity of individuals with disability and of the aging population has been a challenging task. Over 30 different methods for assessing physical activity levels have been reported in the literature, most involving ambulatory individuals. These methods include: qualitative observation reporting by healthcare staff, use of physical activity questionnaires, pedometers for counting of footsteps, heart rate monitors, use of accelerometers, and the use of calorimetery for computing physiological energy expenditure.[15] In spite of significant pros and cons, use of these methods have been expanded, for conducting population-based studies of older individuals and of those with disabilities, in the forms of screening, assessment, outcomes, or intervention tools.[15-17] For individuals using wheelchairs, similar to other types of mobility devices, levels of physical activity and participation depend on efficient use of their wheelchairs. Mobility limitations and environmental barriers within and near home are significant factors associated with restricted participation in activities outside the home environment.[18] Physical characteristics of wheelchairs is the most commonly noted factor for limiting participation by individuals with disabilities, followed by their physical impairments and the environmental barriers.[19] More recently, research has indicated that an individually prescribed wheelchair can improve independent mobility, functional reach, quality of life, and satisfaction related to devices, among residents living in NH.[20] In contrast, an inadequately prescribed wheelchair, which are bulky, and uncomfortable can negatively affect overall wheelchair use and participation in everyday functional activities.[21]

Most previous research focused on assessing wheelchair-related activities has used subjective assessments and survey methods to capture information related to physical activity and participation. A previously conducted study reports the use of a customized data logging device, for measuring driving characteristics of powered wheelchair (PWC) users, over the course of five days.[22] A recent study on MWC use compared the distance traveled, amount of continuous travel (without stopping), and hours of use of wheelchairs among wheelchair athletes, and compared these parameters during their participation in organized sporting events and during their community MWC use.[23] Wilson and colleagues demonstrated the efficacy of the activPAL (a customized device) for measuring wheelchair-related mobility (distance covered, speed of travel, and time spent in wheelchair) for individuals with spinal cord injury within their natural living settings.[24] Wheelchair data logging devices have also been used to determine the effectiveness of pushrim-activated power-assist wheelchairs (PAPAW) in improving the mobility of individuals with SCI, over traditional use of manual wheelchairs.[25] Cooper and colleagues also used customized data logging devices for measuring wheelchair-related mobility in children using manual and power wheelchairs within the community.[26]

Despite the growing literature in this area, usage of wheelchairs by older adults in NH has not been fully explored. Lack of this evidence has limited not only the individualized prescription of wheelchairs, but also the quality wheelchairs products made available to this population. The objectives of this study were to quantitatively assess wheelchair-related mobility in older adults living in NH, and to identify factors that may contribute to differences in wheelchair-related mobility characteristics.

6.3 METHODS

6.3.1 Study Design

The data for this study came from a longitudinal investigation examining the impact of wheelchairs (manual and power) on mobility, safety, and overall quality of life for older adults in NH in the southwestern Pennsylvania region. Manual wheelchair use was assessed for a period of one month for all the participants. All subjects were consented for screening and if they met the inclusion criteria, they were consented for the longitudinal study. The protocol for this study was approved by the VA Pittsburgh Healthcare System Institutional Review Board (IRB) and the Pennsylvania Department of Health. Screening consisted of assessment of the use of wheelchairs by the participants, which included observing their propulsion method (arm versus legs propulsion) and safety during propulsion. Safety assessment included three tasks: 1. forward propulsion for 25 meters, and, 2. turning 90^0 right and 3. turning 90^0 left.

6.3.2 Participants

A total of 72 MWC users completed the protocol from four NH. Two were VA-affiliated NH (VA NH), and two were private nursing homes (PNH). The inclusion criteria for this study were: age 60 years and older, and currently independent MWC user. All participants underwent a screening procedure prior to enrolling in the study, consisting of administration of Mini Mental Status Examination (MMSE).[27] The exclusion criterion for the study was: presence of a pressure ulcer on the buttocks due to sitting in the wheelchair. Demographic information from all participants is presented in Table 1.

6.3.3 Instrumentation

Data related to MWC mobility were collected using a customized data logging device (DL), which was developed at the Human Engineering Research Laboratories (HERL). The DL is self-powered and can record wheelchair mobility data for up to three months on a flash memory chip. The DL measures wheel rotations through use of three reed switches mounted 120° apart on a circuit board and a magnet mounted at the bottom of a pendulum sensor. Every time the wheelchair wheel rotates more than 120°, the magnet triggers one of the reed switches. As each reed switch is triggered, a date and time stamp of that event gets recorded in the device. For this study, we instrumented each participant's MWC with DL for a period of one month. The wheel circumference was also recorded during instrumentation, which was used during the data reduction process. The DL was placed between spokes of the wheels and did not interfere with routine use of wheelchairs by the study participants.

Figure 6.1. Manual Wheelchair Data logger

6.3.4 Data Reduction

After a period of one month, the DL was removed from participants' MWC and data were downloaded on to a computer. The raw data were then decompressed using a customized MATLAB program. The customized program provided three main wheelchair-related mobility variables: average distance per day traveled using the wheelchair (distance); average velocity of wheelchair propulsion per day (velocity); average maximum continuous distance traveled without a stop (endurance). The data were divided into three time periods to enable evaluation of interpersonal variations in wheelchair use over the study duration: baseline (day1-day7), mid (day13-day19) and end (day 25-datalogger removed). Secondary mobility variables included sub-analysis into wheelchair propulsion velocity to examine time spent by participants propelling their wheelchairs for velocities: greater than 1meters/seconds; velocity between 0.5-1meters/seconds; and for velocity less than 0.5meters/seconds. Detailed information (including mathematical equations) related to data reduction were described previously by Tolerico and colleagues.[23]

6.3.5 Data Analyses

All the continuous demographic variables (age and time spent in NH) and heath-related factors (co-morbidities and functional limitations) were analyzed and compared between VA NH and PNH facilities using Mann-Whitney U tests. Categorical demographic variables (gender and ethnic origin) were analyzed using Chi-square (Fisher Exact statistics) tests. Manual wheelchair characteristics including CMS K-codes and wheelchair propulsion methods (arm propulsion and legs/arms+ legs propulsion) were analyzed between the two types of NH facilities using Chi-square (Fisher Exact statistics) tests. Due to significant differences in demographics and health characteristics, both the primary wheelchair mobility variables and secondary variables were analyzed separately for VA NH and PNH facilities. For primary wheelchair-related mobility variables (distance, velocity, and endurance) a Multivariate Analysis of Variance (MANOVA) model was used, comparing between propulsion methods (main effect). Though wheelchair CMS codes was another variable of interest for us it was not put in the multivariate model due to small sample sizes for some of the cells (See Table 6.2). The temporal effects (baseline to mid to end) were also analyzed along with propulsion method. Univariate analysis of variance (ANOVA) statistics were used as for follow-up analysis after significant multivariate differences. Two MANOVA models were used for analyzing data for VA NH and PNH facilities. Natural log transformation for the distance, velocity, and endurance variables were computed to fulfill assumptions of univariate and multivariate normality of the dataset.

For secondary wheelchair mobility variables, four groups were created using combinations of propulsion pattern and CMS K-codes (CMS code K01 with arm propulsion; CMS code K01 with legs/combination propulsion; CMS code K04 with arm propulsion; and CMS code K04 with legs/combination propulsion). This was done to determine the interaction effects of propulsion method and types of wheelchairs used by the participants. Comparisons were made separately for VA NH and PNH facilities using Kruskal Wallis tests. All the statistical analyses were made using SPSS 16.0 software, with significance level set at 0.05 *a-priori*.

6.4 RESULTS

The results indicate that participants from the PNH facilities were significantly older than participants from the VA NH facilities (84 versus 74, $P<.001$). Also, more female participants enrolled from the PNH compared to the VA NH cohort. The proportion of Caucasian individuals was higher at both facilities compared to African Americans. Also, the proportions of individuals with cerebral vascular accidents (CVA) were highest for the VA NH cohort (49%) and second highest for the PNH cohort (38%). The PNH cohort also presented with significantly higher numbers of co-morbidities ($P=0.009$) as compared to the VA NH cohort (See Table 6.1).

Table 6. 1. Demographics and Health-Related Characteristics

		VA NH (n=48)	**PNH (n=24)**	***P<.05***
Age (Years)		73.9±8.1	83.6±5.4	<0.001*
Gender (#)	Male	43 (90%)	6 (25%)	<0.001**
	Female	5 (10%)	18 (75%)	
Ethnic Origin (#)	African-American	9 (19%)	0	0.025**
	Caucasian	39 (81%)	24 (100%)	
Diagnosis (#)	CVA	23 (49%)	9 (38%)	NA
	PD	3 (6%)	3 (13%)	
	Other	21 (44%)	12 (50%)	
Time Spent in NH (Years)		3.3±3.9	1.7±1.4	0.41
Comorbidities (#)		1.7±1.1	2.4±1.2	0.009*

* indicates statistically significant difference between two groups from Mann Whitney U test
** indicates statistically significant difference between two groups from Chi Square (Fisher Exact statistics)
CVA= cerebral vascular accident (Stroke), PD= Parkinson's Disease

The PNH cohort was using a significantly higher proportion of depot style manual wheelchairs (K01) compared to the VA NH cohort that used more lightweight wheelchairs (K04);(*P*=0.006). A significantly higher proportion of participants from the VA NH cohort propelled their wheelchairs using their arms (60%) compared to those from the PNH cohort, as more participants used their legs or a combination of arms/legs to propel their MWCs (67%) at a significant difference of *P*=0.03 (See Table 6.2).

Table 6.2. Manual Wheelchair Characteristics

		VA NH (n=48)	**PNH (n=24)**	***P<.05***
Wheelchair CMS K-codes	K01(Depot style)	5 (10%)	9 (37.5%)	0.006**
	K04(Lightweight)	43 (90%)	15 (62.5%)	
Wheelchair Propulsion Method	Arms	29 (60%)	8 (33%)	0.030**
	Legs/Combination	19 (40%)	16 (67%)	

** indicates statistically significant difference between two groups from Chi Square (Fisher Exact statistics)

6.4.1 Primary Wheelchair-Related Mobility Characteristics

For the VA NH cohort, the average distance traveled per day using wheelchairs was significantly higher for participants who used their arms to propel their MWCs compared to legs/combination propellers (*P*=0.001, partial η^2=0.22). For wheelchair propulsion velocity, a trend toward higher propulsion velocity was observed for participants using legs/combination method of propulsion as compared to arms propulsion (*P*=0.08, partial η^2=.07). A significant trend was also observed for wheelchair propulsion endurance as it was higher for participants who were arm propellers compared to participants who propelled with their legs/combination (*P*=0.07, partial η^2=0.08). For all of the primary mobility variables, no significant differences were observed among baseline to mid to end time points for the average variables across propulsion and wheelchair types (Pillai's Trace, P=0.26, partial η^2=0.18) (See Table 6.3).

Table 6.3. Wheelchair Primary Mobility Characteristics for VA NH facilities

		Arm Propulsion	Legs/Combination Propulsion	P-value (Propulsion)
Distance Traveled/Day(m)	**Baseline Distance**	1352.9±864.5	769.4±350	.001*
	Mid Distance	1463±894.7	768.5±368	
	End Distance	1394.4±828.7	793.2±364.9	
Propulsion Velocity (m/s)	**Baseline Velocity**	.48±.12	.56±.18	.08†
	Mid Velocity	.48±.15	.57±.20	
	End Velocity	.49±.15	.59±.19	
Propulsion Endurance (m)	**Baseline Endurance**	71.7±27.9	59.2±9.8	.07†
	Mid Endurance	70.5±29.2	58.6±13.1	
	End Endurance	74.6±34.7	59.3±11.8	

* indicates statistically significant difference between wheelchair propulsion type (arm propulsion versus legs/combination propulsion) † indicates a trend of difference between wheelchair propulsion type

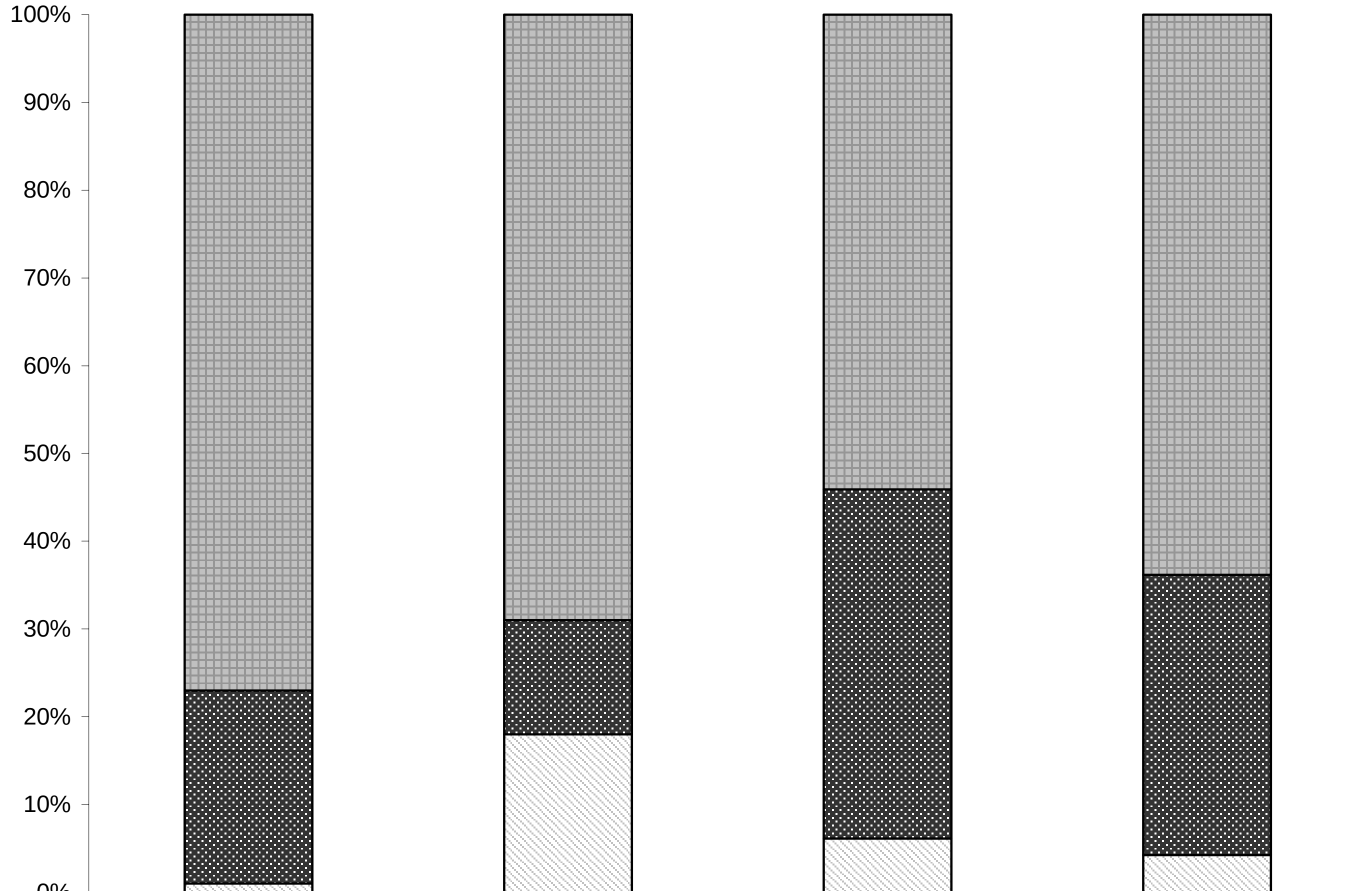
The average distance traveled per day using wheelchairs was no different for arm propellers as compared to legs/combination propellers (*P*=0.94, partial η^2=0) for the PNH cohort. For wheelchair propulsion velocity, a marginally higher propulsion velocity was observed for participants using legs/combination method of propulsion compared to arm propulsion, though not significantly different (*P*=.62, partial η^2=.01). Wheelchair propulsion endurance was marginally higher for participants who were arm propellers compared to legs/combination propellers without significant differences (*P*=0.45, partial η^2=0.03). For all the primary mobility variables, no significant differences were observed among baseline to mid to end time points when averaged across propulsion and wheelchair type used (Pillai's Trace, *P*=0.22, partial η^2=0.40).

Table 6.4. Wheelchair Primary Mobility Characteristics for PNH facilities

		Arm Propulsion	Legs/Combination Propulsion	P-value (Propulsion)
Distance Traveled/Day(m)	**Baseline Distance**	624.2±347.5	641.2±407.1	.94
	Mid Distance	671.6±445	699.9±485.9	
	End Distance	679.8±377.8	721.3±513.8	
Propulsion Velocity (m/s)	**Baseline Velocity**	.47±.13	.49±.12	.62
	Mid Velocity	.51±.16	.49±.12	
	End Velocity	.46±.10	.49±.12	
Propulsion Endurance (m)	**Baseline Endurance**	47.3±16.5	44.1±11.4	.45
	Mid Endurance	46.8±15.8	44.6±11.5	
	End Endurance	48.5±12.7	43.3±11.8	

6.4.2 Secondary Wheelchair-Related Mobility Characteristics

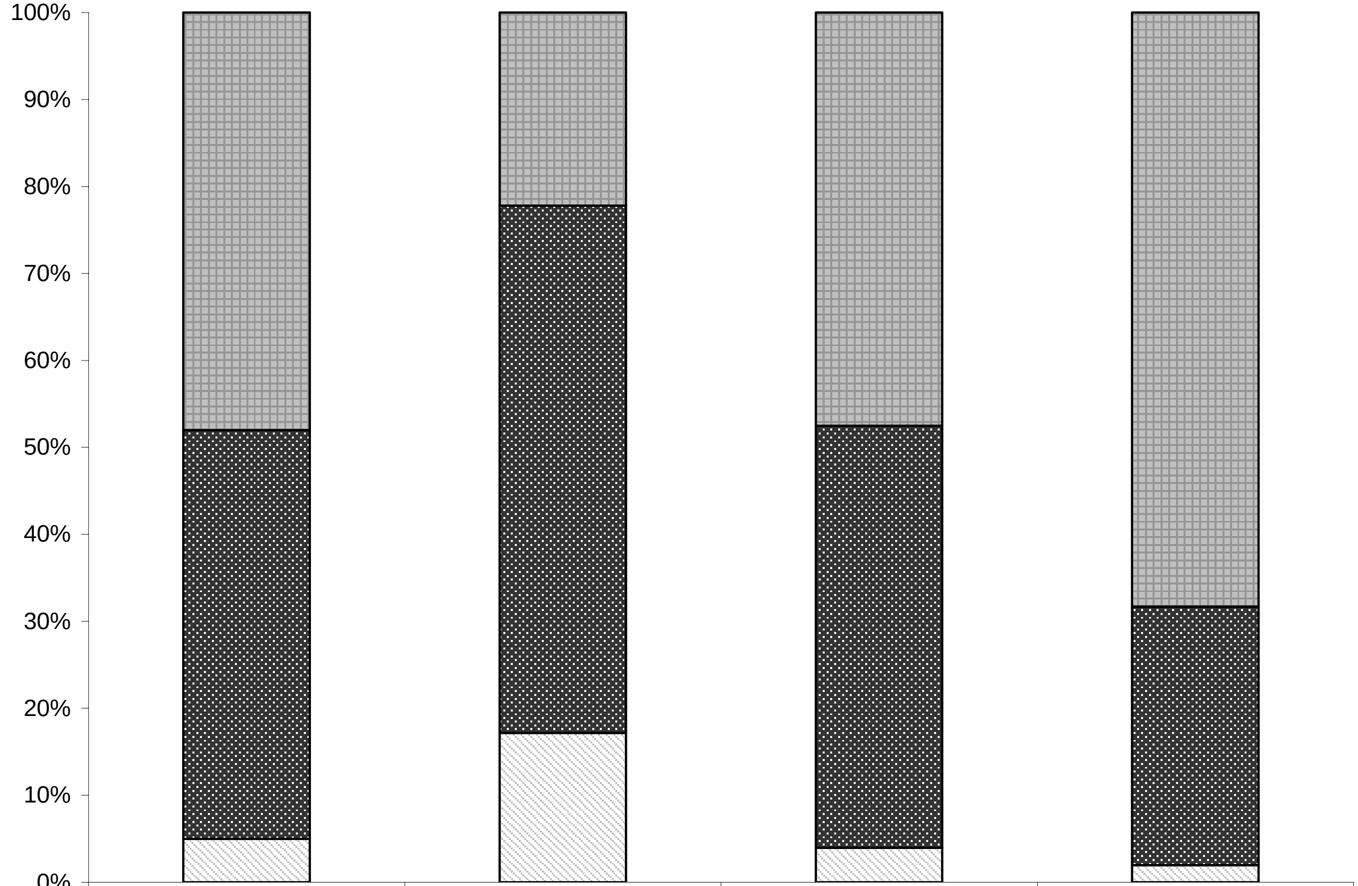
For the VANH cohort, the proportion of time for wheelchair propulsion velocity less than 0.5 meters/second was highest for participants with depot style wheelchairs who used arm propulsion (77%), and lowest for participants with lightweight wheelchairs who used arm propulsion (53%). However, the difference was not statistically significant (*P*=0.58). For propulsion velocity between 0.5-1.0 meters/second, the proportion of time was highest for participants using lightweight wheelchairs and using arm propulsion, and lowest for participants with depot style wheelchairs using legs/combination propulsion (*P*=0.25). For wheelchair propulsion greater than 1.0 meters/second, the proportion of time was highest for participants with depot style wheelchairs using legs/combination propulsion method, and lowest for participants with depot style wheelchairs and using arm propulsion method, thought not to a significant degree (*P*=0.58).



	ArmPropulsion_K01	LegsComb_K01	ArmPropulsion_K04	LegsComb_K04
Velocity<.5ms(%time)	77	69	53	60
Velocity_.5to1ms(%time)	22	13	39	30
Velocity>1ms(%time)	1	18	6	4

Figure 6.2a. Secondary Mobility Characteristics for VA NH population

For the PNH cohort, the proportion of time when wheelchair propulsion velocity was less than 0.5 meters/second was highest for participants with lightweight wheelchairs and using legs/combination propulsion (69%) and lowest for participants with depot style wheelchairs and using legs/combination propulsion (22%). However, the difference was not statistically significant (*P*=0.20). For propulsion velocity between 0.5-1.0 meters/second, the proportion of time was highest for participants using depot style wheelchairs and arm propulsion, and lowest for participants with lightweight wheelchairs using legs/combination propulsion (*P*=0.40). For wheelchair propulsion greater than 1.0 meters/second, the proportion of time was highest for participants with depot style wheelchairs using legs/combination propulsion and lowest for participants with lightweight wheelchairs and legs/combination propulsion, though not to a significant degree (*P*=0.08).



	ArmPropulsion_K01	LegsComb_K01	ArmPropulsion_K04	LegsComb_K04
Velocity<.5ms(%time)	48	22	48	69
Velocity_.5to1ms(%time)	47	60	49	30
Velocity>1ms(%time)	5	17	4	2

Figure 6.2b. Secondary Mobility Characteristics for PNH population

6.5 DISCUSSION

Due to the significant differences in the demographic (age and gender) and health-related characteristics (diagnosis, co-morbidities, and functional limitations) between the VA NH and PNH participant groups, the data were analyzed separately. The results demonstrated a significant difference in between the wheelchair types used by the participants from the VA NH versus those from the PNH. Only a marginal proportion of participants from the VA NH (10%) used depot style wheelchairs, while this rate was notably higher (37.5%) in the PNH. Provision of MWC is a part of providing long-term care in NH facilities. Despite the physical capacity and needs of residents, they often are provided with any wheelchair that is available (or most often recycled from previous users). Cost cutting by NH could be one of the several factors that impact decision-making by the occupational and physical therapists, which in turn impedes their ability to provide a wheelchair selected to meet the residents' requirements of daily mobility. Nursing home residents, therefore, are often found to be using a pre-used or a left-over wheelchair.

Research reports suggest that wheelchairs are used more as positioning devices than as mobility devices in this population.[3] Combinations of these two factors along with others, often results in limited and inefficient wheelchair mobility for older adults in NH. An interventional study by Trefler and colleagues indicated a positive impact of providing customized manual wheelchairs to NH residents, on propulsion efficiency, functional reach, and overall quality of life, for older adults in NH.[20] This work needs to be expanded to include a prospective study design with the use of more objective assessments of wheelchair mobility characteristics (data loggers), to determine whether a cause and effect relationship exists between quality of wheelchairs and mobility.

Our study also noted significant differences in the wheelchair propulsion methods used by participants within each facility. Traditionally, upper limbs (arms) have been the mode for wheelchair propulsion. However, wheelchair propulsion using legs, or a combination of arms and legs, has been noted in literature to be common in older adults using manual wheelchairs.[1] This factor needs to be considered prior to prescription of MWC for this population, for improving propulsion efficiency and reducing the rate of unintentional injuries. An interaction might exist between the type of wheelchair and the propulsion method. Given the fact that old age is often associated with lower muscle strength and types of wheelchairs that are provided to NH residents are either the depot style (weighing >36 lbs without any adjustment) or lightweight wheelchairs (weighing between 30-34lbs), the choice of propulsion pattern may be the direct result of the weight of the wheelchair provided.

For participants in the VA NH facilities, our results demonstrated a significantly higher distance covered for individuals using arm propulsion, compared to that for individuals using legs, or a combination propulsion pattern, regardless of the type of wheelchair (depot or lightweight). For individuals in PNH, no differences were noted between the distances covered, for different propulsion methods across the types of wheelchairs. Future research should look at associations between upper and lower limb strength and the wheelchair propulsion method selected, by older adults within their natural settings. Secondary analyses of the data collected for this study, such as using data classification methods including cluster analysis could help evaluate this relationship.[28] This will enable clinicians to prescribe appropriate wheelchairs based on the needs of older adults and their preferred style of wheelchair propulsion, rather than on available resources. Research has emphasized the importance of monitoring physical activity levels for ambulatory older adults in NH, for the purpose of developing assessment and intervention programs.[29] Some of the observational research to date has denounced the prescription of wheelchairs as mobility devices for this population.[3]

The velocity of wheelchair propulsion for the participants from VA NH was found to be higher for those propelling their wheelchairs using their legs or a combination pattern, as compared to those participants using arm propulsion. Previous work by Cowan and colleagues suggested that the weight of the wheelchair has a negative impact on wheelchair propulsion velocity for older adults without significant physical impairments.[30] Wheelchair weight was reported to significantly increase accumulation of biomechanical forces, which could result in the occurrence of unintentional injuries for this population.[30] Tolerico and colleagues reported average wheelchair propulsion velocity of 0.79 meters/second in their (community-dwelling) participants, as measured by data loggers.[23] Besides other differences in demographic factors, all participants except one in their study were using ultralightweight wheelchairs. Another study also reported wheelchair propulsion velocity to be 0.62 meters/second, with only two subjects reported as using lightweight wheelchairs and the rest using ultralightweight wheelchairs.[25] The trend was similar for those in PNH facilities with respect to the patterns of propulsion. However, no difference in propulsion velocity was identified between types of wheelchairs used by the participants in this group. Further classification of wheelchair propulsion velocities indicated that the participants from the PNH facilities preferred to propel their wheelchairs at speeds of less than 0.5 meters/second for the majority of the time, irrespective of the pattern of propulsion or type of wheelchair used.

Low wheelchair propulsion speeds could result in higher numbers of repetitions of upper limb motion for individuals using arm propulsion methods. This method is considered an inefficient way of propelling a MWC, that could lead to development of repeated strain injuries (RSI).[31] Adequate wheelchair propulsion and mobility training could be a possible solution for improving propulsion efficiency, and reducing occurrence of injuries.[32] However, providing wheelchair mobility training is not typically done with the NH population. Our results could be compared (to some extent) to those of Cyarto and colleagues, who found that individuals in NH had significantly lower walking speeds compared to community-dwelling older adults, when measured by pedometers.[29] Although the efficacy of wheelchair DL was tested and determined previously, it was done with the community-dwelling population, with higher level of wheelchair activities compared to the older adults population living in NH.[23]

For the participants from the VA NH facilities, wheelchair propulsion endurance was found to be higher in individuals using arms for propulsion rather than legs or a combination of arms and legs. Since there was no difference in the types of wheelchairs used by participants who were legs/combination propellers and those who were arm propellers, it can be concluded that a lack of customization results in inefficient wheelchair propulsion. Sabol and Haley have indicated an alternative form of wheelchair propulsion for older adults, and they have also suggested the need for evaluation and appropriate wheelchair adjustments according to the preferred propulsion method.[1] As previously suggested, the weight of the wheelchair and the lack of adjustability may have contributed to lower efficiency for users of depot style wheelchairs. Future research focusing on wheelchair use in older adults, incorporating a cross-over design for assessing changes in wheelchair propulsion efficiency when transitioned from the depot style to lightweight and then to the ultra-lightweight wheelchairs, will be critical to objectively determining the impact of wheelchair weight. The trends for PNH participants were similar for all types of propulsion. However, the difference between arm propulsion and legs/combination propulsions was not as large, as that observed for VA NH participants. We did not find any differences in propulsion endurance, based on the types of wheelchairs used by participants.

No significant temporal effects for primary mobility variables were observed for the participants in both the VA NH and the PNH. This suggests consistency in wheelchair use for the participants, over the period of one month. From these data, we could determine that data loggers should be attached to wheelchairs for a minimum period of two weeks to get steady wheelchair mobility measures for this population. This finding is important since the time period has not been specified and it has varied in the previously conducted protocols that used MWC data loggers.[23, 25, 26]

Due to the small numbers for wheelchair types (depot), we did not analyze this variable along with propulsion method, nor could we determine the interaction between propulsion methods and the types of wheelchairs. We believe that the choice of propulsion methods (arms versus other) is dependent on several factors, including muscle strength, medical condition, and most importantly, the type of wheelchair and its adjustability. This is ironic, given that needs assessment is the core component upon which the prescription of (customized) wheelchairs is based. The work from the current study needs to be expanded further, to include larger number of older adults using depot and ultra-lightweight wheelchairs, in order to evaluate our theory. The data obtained in the current study regarding wheelchair-related activities could have been a combination of active use (participants using their wheelchairs), and passive use (someone pushing the wheelchairs for the participants). Although, one of the inclusion criteria for the study was independent wheelchair use, instances may have occurred when the wheelchair mobility was a combination of active and passive use. The DL were not sensitive enough to make this distinction. In the future, a data reduction program, using machine learning algorithms could result in the development of a model capable of distinguishing between active and passive use. Secondary analyses of these data are critical to determining the interaction effects among several of these factors (demographics, health, and systems factors) and their relation to wheelchair-mobility characteristics. Future work should focus on conducting a cross-over interventional protocol, which can assist with providing appropriate training for the prescription of more customized MWC, as well as determining the impact of customized wheelchairs on the efficiency of use within the older adult population.

6.6 CONCLUSION

Older adults living in NH represent a wide and diverse cohort of individuals who use wheeled-mobility devices for participation in their daily functional activities. There is a paucity of evidence that can assist clinicians in the provision of customized wheelchairs for these individuals. This often leads to provision of standard wheelchairs. This, in turn may contribute to lower levels of physical activity resulting from inefficient wheelchair propulsion, as well as increased risk of repetitive strain injuries that can lead to secondary disabilities. The results of this study suggest the efficacy of a quantitative method that utilizes wheelchair data logging devices, to track wheelchair-related mobility characteristics for older adults in NH. Significant differences were identified for the extent of wheelchair use, based on the method of propulsion (arms versus legs/combination). These findings suggest that the prescription and customization of wheelchairs may be influenced by factors such as physical capacity, environmental structure, and user-technology interface. Understanding these factors, and providing appropriate training on wheelchair prescription, may lead to improved efficiency of wheelchair use and to decreased risk of unintentional injuries within the older adult population.

6.7 ACKNOWLEDGEMENT

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7.0 RISK ASSESSMENT RELATED TO MANUAL WHEELCHAIRS FOR OLDER ADULTS IN NURSING HOMES

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7.1 BACKGROUND

Wheelchairs are one of the commonly used form of Assistive Technology (AT) devices; and are also recognized to aid in the prevention of falls besides providing independent mobility in older adults.[1] There are several factors as depicted in the conceptual model (Figure 7.1) that affect outcomes related to use of wheelchairs for achieving independent mobility.

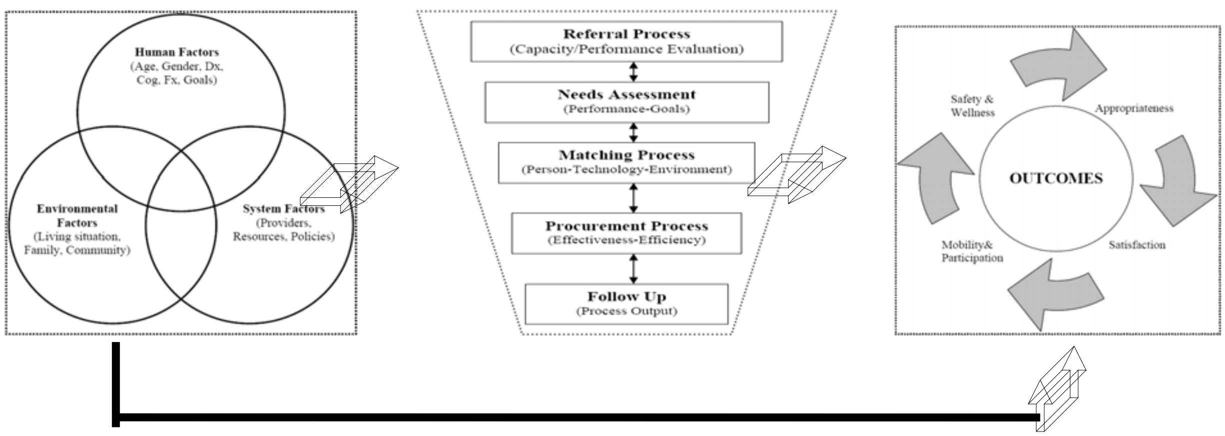


Figure 7.1: Input-Output-Outcomes Model for Wheelchairs

In spite of this fact, most of these wheelchairs that are being used, more often than not, are in a state of disrepair. This often results in occurrence of unintentional injuries and or secondary conditions, to wheelchair users. In 2003, 102,300 wheelchair-related injuries, requiring emergency medical treatment, occurred in the U.S.[2] Out of these, 69% involved individuals were aged 65 years and older, and 82% of them were in hospitals or similar institutional settings.[2] A longitudinal study also revealed the occurrence of 119 incidents related to manual wheelchair (MWC) use over a period of five years, of which 40 incidents were related to component failures in the wheelchairs.[3] Kirby and Ackroyd-Stolarz (1995) reviewed the Food and Drug Administration (FDA) database and identified a total of 368 wheelchair-related injuries documented between 1975 and 1993.[4] The study determined that out of these 368 injuries, wheelchair component failures contributed to 78% of the injuries, followed by environmental factors and errors on the part of the occupants.[4] In a case report by Kirby and Smith (2001), mismatched MWC brakes were identified as the cause of a transfer-related injury. The report calls for better design and manufacturing of brakes for the prevention of fatal injuries to users.[5] Another study focused on non-fatal wheelchair-related injuries, and described the total number of injuries to be 55,514 for the year 1992. The study identified that tipping of wheelchairs and the resultant falls are the leading cause of non-fatal injuries, followed by transfer-related injuries. [6] Similar results were also described within the Canadian population, where the investigators identified wheelchair tips and falls to be the biggest and strongest contributor resulting in both minor (86%) and serious (14%) wheelchair-related injuries.[7]

In the 1995 article, "Could Changes in the Wheelchair Delivery System Improve Safety?," researchers recommended that the Canadian government, manufacturers, third-party payers, consumers, and clinicians classify wheelchairs as medical devices so that standards and regulations could be enforced, thus reducing wheelchair-related injures.[28] One possible solution that has been proposed in the literature is the testing of wheelchairs using the American National Standards Institute/Rehabilitation Engineering and Assistive Technology Society of North America (ANSI/RESNA) Wheelchair Standards Testing. The testing approach, which mimics real world use of wheelchairs, can identify components that are prone to failure, and be of use as a comparative measure in the selection of the most appropriate and safest wheelchairs, similar to crash-test ratings for automobiles. Previous research, has indicated that better-built wheelchairs (i.e., those with higher wheelchair K-codes as defined by the Centers for Medicare/Medicaid Services) have longer useful lives compared to lower quality wheelchairs (those with lower wheelchair K-codes).[8, 9]

There is plenty of evidence that suggest inappropriate wheelchairs and improper use of wheelchairs over a long period of time leads to development of secondary and chronic injuries including:

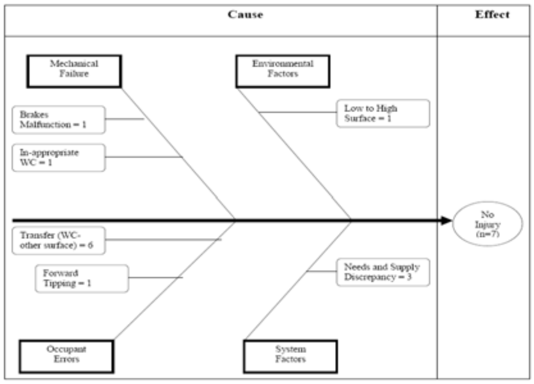
upper limb pain, soft tissue injuries, nerve entrapment, joint deformation, and pressure ulcers.[10, 11,12, 13, 14-16]

Several public health models have been proposed to describe the causes of wheelchair-related injuries, including both acute and chronic injuries. One such model determined that the interaction among: (a) users and their wheelchairs, (b) wheelchair-related activities, and (c) the environment of wheelchair use result in wheelchair-related injuries.[17] Another proposed theory has identified four classes of factors contributing to wheelchair-related accidents including: engineering (60.5%), environmental (25.4%), occupant (9.6%), and system (4.6%) factors. Engineering factors are problems associated with the design of the wheelchair itself. Environmental factors include stairways, uneven pavement, ramps, weather, and cluttered, narrow hallways in private homes or institutions. Occupant factors refer to basic human errors that may result from actions on the part of the person using the wheelchair or on part of the caregiver, and may be due to inadequate or improper training or simple negligence. System errors involve errors of the healthcare system such as prescription of an inappropriate wheelchair, improper specifications from a manufacturer, improper or lack of wheelchair repairs, and inadequate wheelchair skills training provided to the end-user. Wheelchair-related accidents and the resultant acute injuries can be due to a combination of these factors.[4]

Previous research has also revealed the negative impact of improperly maintained wheelchairs on physical health, participation, and the overall quality of life of consumers who rely on their wheelchairs for mobility.[4, 7, 18-21] Routine wheelchair assessment related to need for repairs and maintenance, can decrease the occurrence of injuries, as is evident from the findings of a randomized controlled trial.[19] This study also indicated that wheelchair-related incidents were reduced from five incidents per person per year to zero per person per year among 74 community-dwelling individuals, as a result of their wheelchairs being regularly inspected and maintained.[19] On the other hand, wheelchair-related incidents remained the same for the control group who did not receive routine wheelchair maintenance.[19]

7.1.1 Preliminary Study I: Wheelchair-related Incidents in Nursing Home: Cause-Effect Analysis

The objective of this study was to identify factors contributing to wheelchair-related incidents for older adults in nursing homes. This was the longitudinal component of the research protocol mentioned in Table 1.1. Review of the medical records (root cause analysis reports) for the study participants (study # 4, Table 1.1) with wheelchair-related injury for a time period of one month. Overall 15 wheelchair-related incidents were identified for 12 unique study participants. Wheelchair-related incidents were recorded in the form of: number, nature of incidents (transfer-related, wheelchair propulsion-related, other), factors contributing to the occurrence of an incident (mechanical failure, environmental factors, occupant errors, and system errors), and severity of injury sustained to an individual (likert scale 0-5, where 0=no injury, 5=death). Data were divided in to those incidents that resulted in any form of injury (likert scale 1-5) and those incidents that resulted in no injury (likert scale score 0). Data were analyzed using cause-effect diagrams for identifying contribution of each factor. Incidents during transfer from wheelchair to/from other surfaces were the most common cause resulting in "no injury" (See Figure 7.2). Component failures (exposed areas in wheelchairs) were the most common cause for wheelchair-related incidents resulting in some form of injury (See Figure 7.3). Wheelchair-related incidents result from an interaction of multiple factors. Understanding the role of each factor will enable design and development of effective unintentional injury prevention program for older adults using wheelchairs.



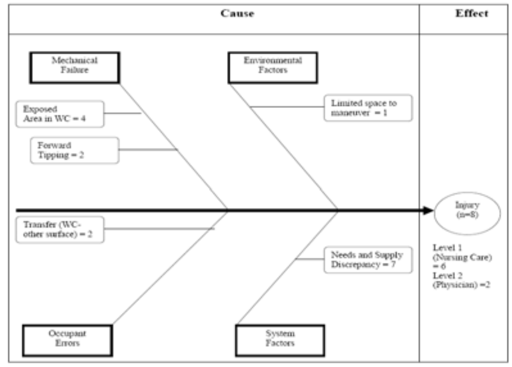


Figure 7.2 : No Injury Figure 7.3 : Injury

7.1.2 Preliminary Study II: Evaluation of Commonly Prescribed Manual Wheelchairs in Nursing Home using ANSI/RESNA Standards

Wheelchair that is being provided to residents in NH are typically of lower quality than those given to their community dwelling counterparts. The objective of this study was to identify performance of commonly prescribed manual wheelchairs in nursing homes using ANSI/RESNA Standards. Two common prescribed manual wheelchairs (Invacare 9000 XT) underwent impact and fatigue test based on American National Standard Institute (ANSI) and Rehabilitation Engineering Society of North America (RESNA) wheelchair testing and performance assessment standards (Section number 8). We selected a set of impact and fatigue tests from the Section 8 of the ANSI/RESNA standards. The impact tests were: armrests impact, footrest impact, backrest, handrims impact, and caster impact test. The fatigue tests were: brakes fatigue test, double drum test, and curb drop test. Both the wheelchair passed all the impact tests (armrest, footrest, backrest, handrims, and casters impact test). Also, the wheelchairs passed the wheel brakes fatigue test (60,000 cycles). However, both wheelchair failed the double drum test (wheelchair 1: 13,453 cycles, and wheelchair 2: 51,402 cycles) (See Figure 7.4). Wheelchairs, like other durable medical equipment (DME), are prone to component failures with repeated use. Although ANSI/RESNA standards application has limited feasibility in a clinical setting, development of a screening procedure is valuable in identifying problems related to component failure. Such a tool could be useful as a risk assessment for prevention of wheelchair-related injuries in the clinical environment.

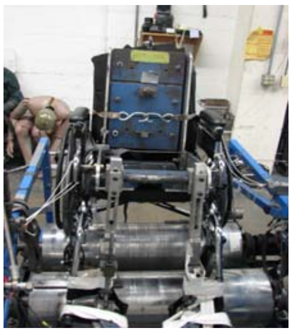


Figure 7.4a Double Drum

Figure 7.4b. Class III failure

Figure 7.4c. Class III Failure (2)

The proposed study was conducted in two phases: Phase I – development and standardization of a wheelchair assessment checklist (WAC); Phase II – utilization of the developed checklist for the assessment of quality (conditions) of wheelchairs in nursing homes and to identify the impact of wheelchair condition on the mobility, satisfaction, and safety related to wheelchair use.

7.2 SPECIFIC AIMS AND HYPOTHESES: PHASE I

7.2.1 Specific Aim 1

To develop and standardized the Wheelchair Assessment Checklist.

Hypothesis 1.1: The Wheelchair Assessment Checklist will demonstrate high internal consistency.

Hypothesis 1.2: The Wheelchair Assessment Checklist will demonstrate high inter-rater reliability.

Hypothesis 1.3: The Wheelchair Assessment Checklist will demonstrate high intra-rater reliability.

7.3 METHODS: PHASE 1

7.3.1 Study Design

The study was cross-sectional in nature for development and standardization of the Wheelchair Assessment Checklist (WAC).

7.3.2 Participants

A total of 12 raters completed the protocol of wheelchair assessment using the WAC. Raters included clinicians (physicians, physical and occupational therapists) and rehabilitation engineers with experience in wheeled mobility technology. Detailed information for raters is given in Table 7.1.

Table 7.1. Description of Raters

Rater	Professional Qualifications	Assistive Technology Specialization
1	Occupational Therapist	Assistive Technology Practitioner
2	Physiatrist	
3	Physical Therapist	Assistive Technology Practitioner
4	Occupational Therapist	
5	Rehabilitation Engineer	Rehabilitation Engineer Technologist
6	Rehabilitation Engineer	
7	Physical Therapist	
8	Rehabilitation Engineer	
9	Physical Therapist	
10	Rehabilitation Engineer	Rehabilitation Engineer Technologist
11	Physical Therapist	
12	Physiatrist	

7.3.3 Protocol

The protocol was conducted at the Human Engineering Research Laboratories (HERL). A checklist was created and sent to raters to be used for assessing wheelchairs. Two manual wheelchairs with different physical and workable conditions were provided to raters for assessment. All raters used the Wheelchair Assessment Checklist (WAC) for objectively assessing repairs and maintenance issues with the wheelchairs.

7.3.4 Data Analyses

Standardization of the WAC was established in the form of validity (face validity and internal consistency) and reliability (interrater reliability and intrarater reliability). For face validity, subjective assessments were obtained from the raters asking about the effectiveness of the WAC in determining repairs and maintenance issues with a MWC. The reliability analysis was performed separately for two wheelchairs. To evaluate internal consistency Cronbach's α was computed. Interrater reliability was determined by computing the Intraclass Correlation Coefficient (ICC) using ICC (model 3). Intrarater reliability was also determined by computing the Intraclass Correlation Coefficient (ICC). All statistical analyses were computed using SPSS 15.0 software.

7.4 RESULTS: PHASE I

The developed WAC (version 1) comprises of total of 26 items representing five domains, namely: wheelchair frame and attachments (11 items); wheels and casters (4 items); postural seating and support (6 items); propulsion interface (3 items); wheel locks (2 items). The raters used a Likert scale from 1-3, with 3 as a maximum score and 1 as a minimum score for each item. There was also an option to indicate not applicable for each of the items (See Appendix D).

The internal consistency for the first wheelchair was Cronbach's α=.94, which is considered very high. For the second wheelchair Cronbach's α=.96. Interrater reliability for the first wheelchair was slightly lower (ICC=.58) than for the second wheelchair (ICC=.66). The correlation matrix for the first wheelchair showed low (r=.24) to very high (r=.92) correlation among raters for all items of the checklist. The lowest correlation was found to be between rater 10 and rater 11, and the highest correlation was found to be between rater 6 and rater 9 (See Table 7.2a). The correlation matrix for the second wheelchair showed a moderate (r=.43) to very high (r=.96) correlation coefficient among raters for all items of the checklist. A moderate correlation was found to be between rater 1 and rater 11, and the highest correlation was found to be between rater 5 and rater 7 (See Table 7.2b). The intrarater reliability was (ICC=.95) indicting very high reliability.

Several comments and feedback were received on the first version of the WAC from the clinicians and engineers who used it (Specific Aim 1). As a result, a second version of the checklist was developed. For the second version, the checklist was divided in the six domains: wheelchair frame and attachments (nine items), wheels and casters (four items), postural seating and support (three items), propulsion interface (one item), wheel locks (one item), and user wheelchair interface (nine items) (Appendix D). Scoring weight (1-6) was assigned to each domain. The weight system was decided based on findings of previous studies, which have reported failures in different components of wheelchairs.[4,7,8,10-12,23,24] Based on their findings, wheel locks are therefore given highest weight, followed by user wheelchair interface, propulsion interface, postural seating and support, wheels and casters, and wheelchair frames and attachments. The composite score for each domain was obtained by adding the raw scores and dividing the sum by the number of valid items, then multiplying that value by the weight assigned to each domain. The composite scores for all domains were summed to generate a total score.

Table 7.2a Correlation Matrix for Wheelchair 1

	Rater1	Rater2	Rater3	Rater4	Rater5	Rater6	Rater7	Rater8	Rater9	Rater10	Rater11	Rater12
Rater1		.751	.558	.644	.840	.527	.590	.714	.608	.647	.694	.755
Rater2			.690	.719	.679	.735	.572	.677	.734	.435	.829	.791
Rater3				.681	.470	.605	.373	.428	.653	.374	.565	.715
Rater4					.555	.698	.584	.747	.622	.499	.719	.793
Rater5						.494	.501	.541	.610	.776	.536	.628
Rater6							.720	.532	**.919**	.415	.642	.696
Rater7								.507	.766	.437	.545	.653
Rater8									.484	.377	.663	.619
Rater9										.469	.655	.691
Rater10											**.238**	.597
Rater11												.619
Rater12												

Table 7.2b Correlation Matrix for Wheelchair 2

	Rater1	Rater2	Rater3	Rater4	Rater5	Rater6	Rater7	Rater8	Rater9	Rater10	Rater11	Rater12
Rater1		.688	.682	.742	.814	.688	.813	.618	.573	.601	**.434**	.705
Rater2			.801	.696	.700	.794	.775	.700	.659	.606	.457	.550
Rater3				.877	.765	.714	.734	.728	.734	.730	.442	.572
Rater4					.849	.724	.810	.719	.693	.675	.511	.528
Rater5						.697	**.957**	.711	.616	.833	.528	.566
Rater6							.705	.690	.584	.527	.443	.527
Rater7								.675	.640	.757	.604	.610
Rater8									.630	.807	.578	.548
Rater9										.612	.750	.857
Rater10											.498	.551
Rater11												.640
Rater12												

7.5 SPECIFIC AIMS AND HYPOTHESES: PHASE II

7.5.1 Specific Aim 2

To determine prevalence of wheelchair defects requiring repair or replacement by using a standardized wheelchair assessment checklist.

Hypothesis 2.1: At the time of the initial assessment, more than 50% of wheelchairs inspected will be presented in a state of disrepair (score less than 50^{th} percentile on the wheelchair assessment).

Hypothesis 2.2: Wheelchairs with a lower k-code will have a lower wheelchair assessment score.

7.5.2 Specific Aim 3

To determine the impact of wheelchair conditions as established by the Wheelchair Assessment Checklist scores on wheelchair use of older adults in NH.

Hypothesis 3.1: There will be a positive relationship between Wheelchair Assessment Checklist score and wheelchair-related mobility (distance, speed of propulsion, and propulsion endurance), as measured by wheelchair data logging devices.

Hypothesis 3.2: There will be a positive relationship between Wheelchair Assessment Checklist score and satisfaction related to wheelchairs, as measured by the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST).

Hypothesis 3.3: There will be a positive relationship between Wheelchair Assessment Checklist score and wheelchair skills, as measured by the Wheelchair Skills Test (WST).

7.5.3 Specific Aim 4

To determine the impact of wheelchair conditions on wheelchair-related incidents.

Hypothesis 4.1: Users of wheelchairs with lower Wheelchair Assessment Checklist scores will have higher wheelchair-related incidents, as determined from the medical charts review.

7.6 METHODS: PHASE II

7.6.1 Study Design

The study had a cross-sectional and a longitudinal component. The cross-sectional component included assessment of wheelchairs at one point in time. The longitudinal component included assessment of wheelchair-related mobility and wheelchair-related incidents over a period of two weeks and three months, respectively. Study procedures were reviewed and approved by the VA and the University of Pittsburgh Institutional Review Boards (IRB) and the Pennsylvania State Department of Health.

7.6.2 Participants

A total of 43 (n=43) older adults consented to participate in the study, of whom 41 completed the protocol. One subject was hospitalized and another withdrew. The inclusion criteria for the study were: residents of one of the four NH namely Southwestern Veterans Center (SWVC), Hollidaysburg Veterans Center (HVC), Presbyterian Senior Care Southmont Campus (SM), and Presbyterian Senior Care Willows Campus (WO). Also included were veterans or family members eligible to reside at either of NH, age of 18 years or older; and independent users of manual wheelchairs. Participants unable to provide informed consent form were excluded from study participation. To date all 41 residents who completed the study were from the SWVC facility.

7.6.3 Protocol

All consented participants completed a demographic questionnaire. Manual wheelchairs were assessed by the study investigator. Satisfaction related to manual wheelchairs and service delivery was determined using the Quebec User Evaluation of Satisfaction with Assistive Technology Version 2.0 (QUEST 2.0). The QUEST 2.0 assesses satisfaction of individuals who use AT by allowing them to rate their device (wheelchair) and also the service delivery of the device (wheelchair) on a five-point Likert scale (1 to 5). A score of 1 indicates "Not satisfied at All" and a score of 5 indicates being "Very satisfied." The QUEST 2.0 is designed to measure satisfaction with a broad range of AT devices in a structured manner. The QUEST consists of 12 items, 8 of which are related to device characteristics and 4 are related to service delivery. Previous research studies has established the validity and reliability of the QUEST, and also indicated its sensitivity in determining satisfaction levels with use of various assistive technology devices including wheelchairs in various populations.[22-24]

Participants' manual wheelchair skills level was determined using the Wheelchair Skills Test (WST) assessment. The WST is a standardized performance-based assessment for measuring the skill level of manual wheelchair users. Components of the test range from a simple task (application of wheelchair brakes) to a complex task (descending stairs). To enable consistency evaluation of all participant, we selected the first 10 items on the test that range from application of brakes to ability to maneuver sideways. The test rates skills of users on two aspects, namely, skills (pass or fail) and safety (pass or fail).[25-27]

A wheelchair data logging device was attached to each participant's wheelchairs for a period of two weeks to objectively measure wheelchair-related mobility (distance, velocity of propulsion, and propulsion endurance). The data logging device features a real-time clock, eight megabytes of flash memory, and a lithium battery capable of collecting data for a month or more. A pendulum sensor is used to trigger event recording. Each time a chair wheel rotates more than 120 degrees, the time of the motion event is recorded with one tenth second accuracy. This method has been successfully implemented in previously conducted studies for measuring wheelchair-related mobility in a variety of populations.[28-30] Finally, we collected wheelchair-related incidents data for each participant for a period of three months. These data were collected from the incident reports generated by the Quality Control/Patient Safety Department at the nursing home (SWVC). (See Appendix D)

7.6.4 Data Reduction

7.6.4.1 Wheelchair Assessment Checklist Score The data obtained from the assessment of wheelchairs for 41 participants were divided into four categories for comparison and evaluation of relationships.

a. Wheelchairs with minor problems: Score at the 75th percentile or higher on the assessment using the WAC

b. Wheelchairs with moderate problems: Score between the 50 and the 75th percentile

c. Wheelchairs with extensive problems: Score between the 25 and the 50th percentile

d. Wheelchairs that need immediate action: Score below the 25th percentile

7.6.4.2 Wheelchair-Related Mobility After two weeks wheelchair data loggers were removed from participants' wheelchairs. All data were downloaded onto a computer. The raw data were then decompressed using a customized MATLAB program. The customized program provided wheelchair-related mobility variables: average distance traveled using the wheelchair (distance) per day; average velocity of wheelchair propulsion (velocity) per day; average maximum continuous distance traveled without a stop (endurance distance); and number of stops taken for travelling 100 meters of distance with the wheelchairs (stops/100m). Detailed information (including mathematical equations) related to data reduction was described previously by Tolerico and colleagues.[30]

7.6.5 Data Analyses

Hypothesis 2.1: Prevalence was calculated to determine the percentage of wheelchairs presented with a score below the 50th percentile on the Wheelchair Assessment Checklist

$$\text{Prevalence} = \frac{\text{Number of Wheelchairs with Score} < 50^{th} \text{ percentile on the Wheelchair Assessment Checklist}}{\text{Total Number of Wheelchairs Assessed in a nursing home}}$$

Hypothesis 2.2: A correlation coefficient was computed (Spearman rho) to determine the relationship between wheelchair k-codes and the Wheelchair Assessment Score.

Hypothesis 3.1: Correlation coefficients (Spearman rho) were computed to determine the relationship between wheelchair-related mobility and the Wheelchair Assessment Checklist score (after controlling for wheelchair propulsion methods).

Hypothesis 3.2: Correlation coefficients (Spearman rho) were computed to determine the relationship between satisfaction related to wheelchair use and the Wheelchair Assessment Checklist score.

Hypothesis 3.3: The associations between wheelchair skills and safety, and the Wheelchair Assessment Checklist scores were computed using Cochran-Mantel-Haenszel (CMH) tests. This test was chosen to determine association between Wheelchair Assessment Checklist score and wheelchair skills, controlling for confounding effect of wheelchair propulsion method (arms versus legs/combination propulsion). Since, seven out of the 10 wheelchair skills assessed involved wheelchair propulsion, controlling for the propulsion method was necessary. Prior to this analysis, the Wheelchair Assessment Checklist score was recoded to two categories (0=score<50th percentile, 1=score greater than 50th percentile), as was the association identified for wheelchair skills performance (0=fail, 1=pass) and safety of wheelchair skills performance (0=fail, 1=pass), controlling for wheelchair propulsion method (0=arms, 1=legs/combination propulsion).

Hypothesis 4.1: Prior to this analysis, the wheelchair assessment score was recoded to two categories (0=score<50th percentile, 1=score greater than 50th percentile). Frequency analyses were done to identify occurrence of wheelchair-related incidents in the above mentioned two categories. Association between wheelchair assessment score and factors related to occurrence of incidents (component, environmental, system, and occupant) were determined using Chi-Square (Fisher exact) statistics.

7.7 RESULTS: PHASE II

Forty-one consented participants completed the study protocol. The mean age of the participants was 77.3 years (±9.3), and the mean time for residence in the NH was 3.3 years (±3.8). The proportion of males (n=38, 93%) in our sample was higher than females (n=3, 7%), which is typical for the veterans population. Neurological conditions were the most common form of diagnosis (n=21, 51%), followed by orthopedic conditions (n=9, 22%). Details regarding demographics and health-related characteristics are provided in Table 7.3.

Table 7.3. Demographics and Health-related Characteristics

Variables		N=41
Age (years)		77.3±9.3
Gender	Male	38 (93%)
	Female	3 (7%)
Ethnicity	Caucasian	38 (93%)
	African-American	3 (7%)
Time in Nursing Home (years)		3.3±3.8
Diagnosis	Neurological Conditions	21 (51%)
	Orthopedic Conditions	9 (22%)
	Spinal Cord Conditions	2 (5%)
	Cardio-Vascular Pulmonary Conditions	5 (12%)
	Other	4 (10%)
Self-Reported Limitations (#)		4.8±2.2
Education (years)		11.6±2.8
Marital Status	Married	8 (19%)
	Single (or Widowed)	33 (81%)

The prevalence of wheelchairs with a score of less than 50th percentile was 51.21%. The number of wheelchairs evaluated classified in each of the percentile categories were: <25th percentile (n=10), 25-50th percentile (n=11), 50-75th percentile (n=10), and >75th percentile (n=10). Detailed scoring for each domain is provided below (See Table 7.4).

Table 7.4. Wheelchair Assessment Checklist scores

Categories	Domains	Mean	SD	Min	Max
<25th Percentile	1	2.3	.34	1.9	2.9
	2	4.3	.75	3.5	6
	3	6.3	.67	5	7
	4	6	2.1	4	8
	5	9.6	4.2	6	18
	6	9	2	6.7	13.3
	Total	37.6	4	29.9	42.7
25th-50th Percentile	1	2.5	.50	2	3.8
	2	4.6	.59	3.5	5.5
	3	6.7	1.3	5	9
	4	8	3.1	4	12
	5	13.1	4.5	6	18
	6	10.9	2	7.9	14.2
	Total	45.8	2.2	42.8	48.8
50th-75th Percentile	1	2.5	.24	2.3	3
	2	4.9	.39	4.5	5.5
	3	7.4	1.2	6	9
	4	9.6	2.1	8	12
	5	15	3.2	12	18
	6	11.5	1.8	8.3	14.3
	Total	51	.82	49.4	52.2
>75th Percentile	1	2.5	.22	2.3	2.9
	2	5.2	.80	3.5	6
	3	7.9	1.5	5	9
	4	11.2	1.7	8	12
	5	17.4	1.9	12	18
	6	15	5.4	10.8	30
	Total	59.3	3.9	52.8	63.3

Majority of participants were using standard wheelchairs without customization (n=28, 68%). For this category of wheelchairs, Invacare 9000 XT was the most commonly used wheelchair (n=23, 82%). The proportions of moderately adjustable, lightweight wheelchairs (n=7. 17%) as well as highly customizable ultralightweight wheelchairs (n=6, 15%) were low. For the second category, Sunrise Breezy was the most common type of wheelchair used (n=3, 43%). Quickie 2 was the most commonly used wheelchair (n=4, 67%). The relationship between CMS k-codes to the Wheelchair Assessment Checklist score was moderately positive (r=.43, *P*=.005).

Wheelchair-mobility data collected using the data loggers suggested that all participants were using their wheelchairs on average, for 949 (±577.3) meters per day. The average wheelchair propulsion speed was .46 (±.14) meter/second. After controlling for wheelchair propulsion method (arms propulsion versus combination), a moderate positive relationship was observed between the wheelchair assessment checklist score and wheelchair propulsion endurance (continuous distance of wheelchair propulsion without a stop) (r=.60, *P*=.06). However, for the arms/legs combination propulsion group, a moderate negative relationship was observed between the Wheelchair Assessment Checklist score and the average distance of wheelchair propulsion (r=-.44, *P*=.02). Details are given in Table 7.4.

Table 7.5. Relationship between Wheelchair-related Mobility and Wheelchair Assessment Score

	Arms Propulsion	**Arms/Legs Propulsion**
	Wheelchair Assessment Score	**Wheelchair Assessment Score**
Distance (m)	r=.27 (*P*=.42)	r=-.44 (*P*=.02)*
Propulsion Velocity (m/s)	r=.04 (*P*=.91)	r=-.02 (*P*=.92)
Propulsion Endurance (m)	r=.60 (*P*=.06)†	r=-.20 (*P*=.31)
Stops/100 meters (#)	r=-.33 (*P*=.31)	r=-.09 (*P*=.64)

* indicates significant association, † indicates trend

Participants reported being ‘quite satisfied’ related to wheelchair use (3.9±1.1), wheelchair service delivery (4.1±1), and overall (3.9±1.1). Low positive relationships were identified between the wheelchair assessment score and satisfaction related to their wheelchairs (r=.30, *P*=.07), satisfaction related to overall wheelchair service delivery (r=.20, *P*=.30), and overall satisfaction (r=.31, *P*=.06). Details are given in Table 7.5.

Table 7.6. Relationship between Wheelchair Assessment Score and Satisfaction

Satisfaction Variables	Wheelchair Assessment Checklist Score
Device Combined	r=.30 (*P*=.07)†
Services Combined	r=.20 (*P*=.30)
QUEST Total	r=.31 (*P*=.06)†

† indicates a trend

Results related to association between wheelchair assessment scores and wheelchair skills indicated a significant association between performance safety related to application of brakes to wheelchair assessment score ($\chi^2_{(1)}$=4.2, *P*=.04). The logit Relative Risk (RR) indicates four times (CI: .74-21.9) more likelihood for participants with higher wheelchair assessment score to ‘pass’ the application of brakes task. A significant association was also noted between the wheelchair assessment score to performance skills ($\chi^2_{(1)}$=4.5, *P*=.03) and performance safety ($\chi^2_{(1)}$=4.5, *P*=.03) during the task of turning wheelchair 90 degrees while propelling forward. For both performance skills and performance safety the RR value was 1.2 (CI: 1-1.5). Details are provided in table 7.6.

Table 7.7. Association between Wheelchair Skills and Wheelchair Assessment Score

	Performance Skills			Performance Safety		
	χ^2	***P***	**Logit RR**	χ^2	***P***	**Logit RR**
Brakes	1.1	.28	2.1	4.2	.04*	4.03
Footrest	2.5	.11	.6	2.5	.11	.6
Armrest	.30	.58	1.1	.30	.58	1.1
Forward 10m	-	-	-	-	-	-
Forward 10m/30Sec	1.7	.18	2.9	1.7	1.8	2.9
Backward 5m	-	-	-	-	-	-
Forward 90°	4.5	.03*	1.2	4.5	.03*	1.2
Backward 90°	2	.16	.45	2	.16	.45
Turn 180°	.21	.64	.72	.21	.64	.72
Sideways	.37	.54	.76	.37	.54	.76

RR=Relative Risk, * significant association between wheelchair assessment score and performance skills or performance safety controlling for propulsion method; - values were not generated as all participants passed these tasks

To evaluate the association between the Wheelchair Assessment Checklist score and wheelchair-related incidents, we used only two categories for the wheelchair assessment score (<50th percentile, and >50th percentile). Overall, there were 27 wheelchair-related incidents for 41 participants in the time period of three months. Nineteen out of the 27 incidents (70%) occurred for the cohort with scores less than 50th percentile on the assessment. Whereas, only eight incidents were identified for the cohort with score above 50th percentile (>50th percentile). For the first group 42% of the total incidents (n=19) occurred during transfer to and from wheelchairs (n=8), 50% occurred while sitting in wheelchairs (n=9), and only 8% occurred during wheelchair propulsion (n=2). For the second group (>50th percentile), 63% of the total incidents occurred during transfer (n=5), and 37% occurred during sitting in wheelchairs (n=3). The association between the wheelchair assessment score and component failures was not significant (χ^2=.14, *P*=.71). So were those between wheelchair assessment score and environmental factors (χ^2=.34, *P*=.66), system factors (χ^2=.14, *P*=.71), and users' errors (χ^2=1.4, *P*=.53).

Table 7.8 Association between Wheelchair Assessment Score and Wheelchair-Related Incidents

Factors	Response	**Wheelchair Assessment Score**			
		<50th Percentile	**>50th Percentile**	χ^2	*P*
Component Failures	No	8 (42%)	4 (50%)	.14	.71
	Yes	11 (58%)	4 (50%)		
Environmental Factors	No	14 (74%)	5 (63%)	.34	.66
	Yes	5 (26%)	3 (37%)		
System Factors	No	8 (42%)	4 (50%)	.14	.71
	Yes	11 (58%)	4 (50%)		
Users' Errors	No	16 (84%)	8 (100%)	1.4	.53
	Yes	3 (16%)	0		

7.8 DISCUSSION

Inadequate and inappropriate use of wheelchairs often results from: the cumulative effects of physical or cognitive abilities, type of wheelchair prescribed, the condition of the wheelchair; and the training received regarding use. This often results in low wheelchair-related mobility, which compromises functional independence and overall participation. A wheelchair, which on one hand can provide safety and a great sense of security to older adults, may also be a causative factor for falls and other injuries when mechanical failures occur. Patient safety is a high priority and a critical component of healthcare service provision within hospitals, nursing homes, and home health settings. This has prompted health-care providers to utilize a standardized procedure prior to, during, and after provision of services. One such example is the successful implementation of the Surgical Safety Checklist, developed under the Patient Safety Program by the World Health Organization (WHO). The utilization of the Surgical Safety Checklist has significantly reduced mortality and complications for patients undergoing non-cardiac surgical procedures in hospital settings.[31] The practice of screening and failure detection of medical equipment (including wheelchairs), using a standardized procedure, has also been suggested to be useful in NH for prevention of injuries to residents.[32] Some of the suggested risk management practices, within the NH setting, for ensuring safety related to medical equipments include: development of a visual checklist for periodic safety inspection, development of a preventive maintenance schedule, staff training, and reporting (documentation) of incidents.[32]

For wheelchairs in particular, this practice must include risk and safety assessment that involves detection of disrepair and identification of non-functional or missing parts .[32, 33] Identification of risk (provision of an inappropriate wheelchair or detection of component failures) could be divided in several involving: identification and rectification of problems in the current models by their respective manufacturers; post-market analysis of products for ensuring their safety and reliability; detection of problems by clinicians who prescribe wheelchairs; collection of outcomes data from end-users regarding negative and positive impact; and root cause analysis of injuries to users (as a result of technological, human, system, environmental factors) (See Figure 7.5).

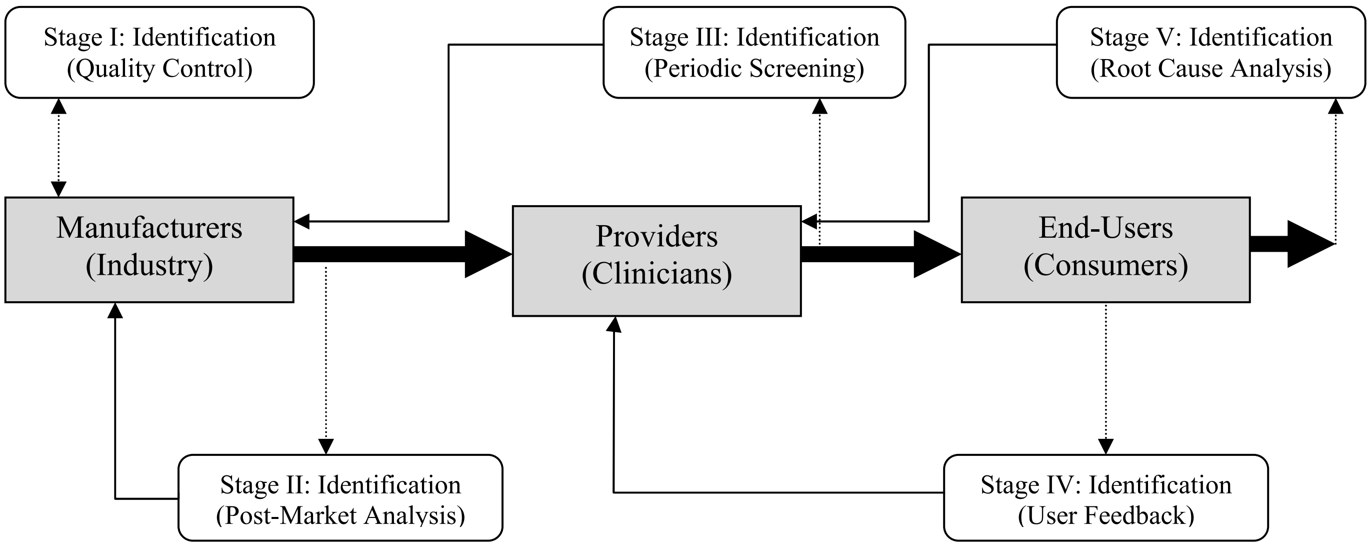


Figure 7.5 Risk Assessment and Problems Identification Stages

Several studies have focused on identifying defects in wheelchairs at the manufacturing level and post-market levels. Very limited work has been done to assess professionals/clinicians issuing/prescribing wheelchairs, with respect to the measures they can take for identification of problems in devices and provision of interventions for controlling rate of injuries.[19] At present, there is no objective tool available for clinicians to use to assess the condition of wheelchairs. The label 'durable medical equipment' does not guarantee lifetime durability of the wheelchair, especially when used extensively. This often results in the use of unsafe wheelchairs by patients/residents and significant risk of sustaining wheelchair-related injuries.[2] Yet research has demonstrated that routine wheelchair inspection and scheduled maintenance can control the rate of wheelchair-related injuries and accidents.[19] The results from this study suggest the potential benefit of developing and utilizing a wheelchair assessment tool that is clinician friendly (less time consuming and standardized) and can aid in decision making by clinicians. This tool should be such that it can be repeatedly administered and produce consistent results. Currently available tools are either self-reports collected from users, or subjective assessments conducted by occupational or physical therapists, neither of which has established standardized parameters.[18, 19]

The present study was conducted in two phases: Phase I – development and standardization of a wheelchair assessment checklist (WAC); Phase II – utilization of the developed checklist for the assessment of quality (conditions) of wheelchairs in nursing homes and to identify the impact of wheelchair condition on the mobility, satisfaction, and safety related to wheelchair use.

There are several steps involved in the development and standardization of an evaluation tool. The psychometric/clinimetric properties of an instrument typically require the establishment of properties including, but not limited to: content validity (face validity and content validity), internal validity (internal consistency), external validity (concurrent validity), reliability (test retest, and inter-rater reliability), generalizability (applicability of the instrument for use in clinical practice), and predictive validity (ability of an instrument to predict a course).[34] For our study, we focused on establishment of the first four aspects of psychometric/clinimetric properties. The generalization of this checklist may enable clinicians in various settings to evaluate wheelchairs using the checklist, and prove to be useful for identifying the translational aspect of this work, from the research to the clinical environment. In general, participants from Phase I of this study indicated their interest in further development and standardization of such a tool. Preliminary analyses suggest high internal consistency for items in the tool, suggestive of measurement of a single domain, namely, wheelchair condition. For both wheelchairs, ICC values for interrater reliability ranged from .58 to .66, indicating moderate agreement among raters. The correlation matrixes further suggested a significant variation in the agreement levels between raters, which could be a causes of lower ICC values.[34] Some of the subjective responses obtained on the checklists suggested a need for improvement in clarity of items, which could reduce variations in their interpretation. Intrarater reliability was very high, indicating good test-retest reliability of the developed checklist. Overall, the results point to the importance of using a standardized wheelchair assessment tool for screening and detection of problems in the use of wheelchairs, which could prevent occurrence of wheelchair-related accidents.

The results from Phase II of the study indicated that over 50% of the manual wheelchairs assessed by the investigators scored below the 50th percentile on the WAC. In a comparable study by Hansen and colleagues, this rate was reported to be 99%.[19] Another study reported that 26% of their sample performed wheelchair maintenance over six months. The problem with both of these studies pertain to measurement: the former used a subjective method for looking at repairs and maintenance issues with wheelchairs, while the latter relied on participants' self-report of wheelchair conditions. In contrast, our study used a systematically developed checklist and scoring system for categorizing wheelchairs, based on their physical and working conditions. Another reason could be our study recruited a small and (relatively) homogenous sample from only one NH. The expansion of this protocol to three additional NH will provide results in a more heterogeneous sample, for better determination of the prevalence of wheelchairs scoring less than 50th percentile on the checklist.

Sixty-eight percent of our participants were using standard manual wheelchairs, while only 15% were using fully customized wheelchairs. Previous studies have reported results of wheelchair testing using ANSI/RESNA standards indicating a high correlation between low quality of wheelchairs and their failure rates.[8, 9, 35] Relationships between mechanical and component failures to occurrence of wheelchair-related incidents have also been reported. [4, 5] However, none of these studies have examined at the association between quality of wheelchairs and their evaluation based on a standardized clinical assessment tool. Indeed, one of the probable reasons for a moderate relationship in our study was the homogeneity of our sample drawn from a single NH.

Findings for the relationship between wheelchair assessment score and wheelchair-related mobility were not conclusive in this study. We found a moderate positive relationship between wheelchair assessment score and wheelchair propulsion endurance (maximum continuous distance without a stop) only for individuals using their arms (primarily) for wheelchair propulsion. For those using their arms and legs for propulsion, we found a moderate negative relationship between the wheelchair assessment score and the average distance traveled using the wheelchair. Our results, however, contradict those reported by Fitzgerald and colleagues who found no relationship between wheelchair maintenance and repairs status and wheelchair-related mobility.[18] One possible explanation for this difference is the fact that our study utilized wheelchair data loggers for assessing the mobility aspect, whereas the other study collected these data through participants' self-reports.

We found a low correlation between wheelchair assessment scores and overall satisfaction related to wheelchairs and service delivery. User satisfaction could be one of the critical outcome parameters for detection of problems associated with devices (wheelchairs) and those related to service delivery. Our results resemble those of Fitzgerald and colleagues, who reported a negative relationship between number of wheelchair repairs and maintenance episodes and satisfaction related to wheelchairs.[18] Also, increased satisfaction levels have also reported with provision of better quality and customized wheelchairs to older adults in NH, instead of mere standard wheelchairs.[36]

The results from wheelchair skills tests revealed an association between the Wheelchair Assessment Checklist score and performance safety related to application (and release) of wheelchair brakes (wheel locks). The score was also found to be associated with performance skills and safety related to performing a 90 degrees turn while propelling the wheelchair forward. There was a lack of sensitivity related to the use of the WST in our sample, since seven out of 10 selected tasks were assessing propulsion rather than the interface between users and their wheelchairs. None of the studies that have used the WST as an outcomes measure has reported a direct relationship between type of wheelchair and performance on the WST.[26, 37, 38] Our objective in presenting individuals wheelchair skills separately was to distinguish between interface versus propulsion skills. However, in the future, it would be more appropriate to look at the overall performance skills score and overall safety score rather than assessing performance of individual skills.[27] Such an approach will allow us to examine the relationships among the wheelchair assessment score, wheelchair-related mobility, and wheelchair skills performance.

Wheelchair-related incidents were higher in the group with wheelchair assessment score below the 50th percentile than those above the 50th percentile. However, further analyses revealed no association between wheelchair assessment score and component failures. On the contrary, the association between wheelchair assessment score and users' errors was strongest. Results from our study, do not fully support those reported in earlier studies that have shown a significant association between engineering problems related to wheelchairs and the occurrence of incidents.[7] Our results need to be interpreted with great caution due to the small number of wheelchair-related incidents. Nevertheless, active wheelchair inspection (screening and assessments) in prevention of injuries to the occupant is crucial.[19] Our analytical method offers an important perspective to enable understanding of wheelchair-related incidents (falls and other injuries), which are often multi-factorial in nature.[39-41] Unlike previous studies, which pointed to these factors individually, our study has presented findings that could suggest a possibility of interaction among several factors. These interactions are often missed or unintentionally ignored by investigators while looking at falls (incidents) data. At the same time our interpretations may have overestimated those factors that are relevant to the outcomes of the study and underestimated other factors. For our study, we looked at all incident reports for our participants, selected only those incidents involving users' wheelchairs, and extracted the data. This method is much more accurate than collection of numbers alone (incidents), and deriving a conclusion based on that. However, our study did not look at the association among subject demographics (age, gender, diagnosis, cognitive abilities), and that of use of medication (antihypertensives, antipsychotic drugs), to wheelchair-related incidents. Future work should take these factors into consideration along with cognitive 'masking', which is common for NH residents to better estimate the relationship between wheelchair conditions and incidents.

This study has several limitations. There are no comparable assessment tools (method) available, therefore concurrent validity of the checklist could not be established. The length of the checklist and the number of items in the present form of the checklist may limit its usability by clinicians. Looking at item reduction using factor analyses and similar procedures, may ensure applicability and usability within clinical environments. The weighting system that was developed was based on studies and research looking at wheelchair component failures and from results of our first preliminary study. Future work should incorporate findings from the first preliminary study was from phase II to re-develop the weighting system. We did not utilize the Item-Response Theory (IRT) procedure for analyzing accurateness of response of each item of the checklist. This limitation must be address in future by assessing wheelchairs from more nursing homes and looking at contribution of each item in classification of wheelchairs with minor, moderate or extensive problems. Finally, we used percentile scores (25^{th}, 50^{th} and 75^{th}) as a cutoff for classifying wheelchairs. Some of the standardized procedure such as "Bookmark Standard Setting Procedure", to develop cutoff scores [42] needs to be employed with more and diverse data points.

Limitations also exist in our selection of some of the outcomes assessments. We were hoping that the WST can relate the differences in performance of wheelchair skills to wheelchair conditions. However, the test was not sensitive to our population for distinguishing between failures due to personal limitations as opposed to problems in wheelchairs. Since the rating was subjective in nature (pass/fail), we anticipated some degree of rater bias in the scoring. In the future, this assessment needs to be conducted by an independent investigator who is not involved in the assessment of wheelchairs. Finally, although data related to wheelchair incidents were extracted directly from participants' incident report, we did not control for demographics, and health-related factors that could confound association between wheelchair conditions and incidents. Future work collecting this information retrospectively through use of the

Minimum Data Set (MDS) or a large number of incident reports will be useful to support or refute this proposition. It is worth noting that even though we targeted older adults living in nursing homes, utility of the checklist is beyond this population. However, further modification and restructuring of the checklist is required before generalizing its use to other wheelchair user groups.

7.9 CONCLUSION

Our study suggests potential for further development of the Wheelchair Assessment Checklist, with a primary focus on: reduction of number of items and further standardization. Although we found that the checklist can differentiate quality of wheelchairs, the decision making guidelines regarding repair or replacement of the existing wheelchair cannot be achieved based on these data. Larger and more heterogeneous group of wheelchair users is required for achieving that objective. We found a significant trend in the relationship between condition of wheelchairs to wheelchair-related mobility, skills performance, safety, and satisfaction. Safety and prevention has become an extremely important component of every aspect of healthcare. Use of a screening tool that would ensure identification of risks associated with using wheelchairs that are in poor working condition could prevent (reduce) associated injuries to users.

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7.11 Appendix D

7.11.1 Wheelchair Assessment Checklist_v1

Subject ID: ____________	Date of Inspection: ____/____/____	Investigator Initials: ______
Done	**Review the following**	**Checklist**
	Manual Wheelchairs (MWC)	
	Wheelchair frame and attachments	
☐	Wheelchair is the one prescribed for the resident (serial number/name plate match chart)	Yes No
☐	Frame tubes and weld points	3= No cracks, fractures and distortion 2= Cracks but no fractures or distortions 1= Fractures and distortions
☐	WC rolling	3= Straight without drag and no audible grinding sounds or clatter 2= Deviation with drag no audible grinding sounds or clatter 1= Deviation with drag audible grinding sounds or clatter
☐	WC is free of encrusted debris	3= Free of encrusted debris 2= Encrusted debris to moderate extent 1= Encrusted debris to severe extent
☐	Footrests	3= Move up/down smoothly and maintain position 2= Move with moderate efforts and cannot maintain position 1= Move with great difficulty and cannot maintain position
☐	Leg	3= Swing away and latch easily; no visible bends 2= Swing away and latch with some difficulty; no visible bends 1= Swing away and latch with great difficulty; with visible bends
☐	Leg rests are the appropriate length and position	3= Appropriate length and position 2= Moderately short/long in length and moderately close to/away from WC 1= Significantly short/long in length and significantly close to/away from WC
☐	Armrests latch, remove, and reposition easily	3= Remove and reposition easily 2= Remove and reposition with some difficulty 1= Remove and reposition with great difficulty

☐	Armrest upholstery	3= Intact 2= Minor damage 1= Significant damage
☐	Anti-tippers are present and evenly placed	3= Present and evenly placed 2= Present but not evenly placed 1= Missing
☐	Inspect for missing fasteners and tighten any loose fasteners	3= No missing or lose fasteners 2= Moderate amount of missing or lose fasteners (< 3) 1= Significant amount of missing or lose fasteners (> 3)
	Wheels and casters	
☐	Wheels have working quick release axles (manual chairs)	Yes No
☐	Caster forks	3= Swivel freely stems are perpendicular to the floor 2= Swivel freely stems are not perpendicular to the floor 1= Does not swivel freely stems are not perpendicular to the floor
☐	Caster hubs	3= Free of cracks tires have tread and are inflated 2= Free of cracks tires do not have tread and are not inflated 1= Have cracks tires do not have tread and are not inflated
☐	Drive wheel tires	3= Free of cuts or sidewall damage and are properly inflated 2= Free of cuts or sidewall damage but are not properly inflated 1= Cuts and sidewall damage with inappropriate inflation
	Postural seating and support	
☐	The frame tubes	3= Do not impinge upon the body 1= Impinge upon the body
☐	Seatback	3= Intact and if removable has working release fittings 2= Intact and if removable does not has working release fittings 1= Not intact and if removable does not has working release fittings
☐	WC cushion	3= Correctly inflated (if applicable) and positioned appropriately 2= Correctly inflated (if applicable) but not positioned appropriately 1= Incorrectly inflated (if applicable) and not positioned appropriately

□	Seat base	3= Firm no sling upholstery and is appropriate length and width for resident 2= Sling upholstery but is appropriate length and width for resident 1= Sling upholstery and inappropriate in length and width for resident
□	Headrest, if present	3= Aligned, tight and has intact upholstery 2= Aligned, tight but does not has intact upholstery 1= Not aligned, lose and does not has intact upholstery ______ NA
□	Lateral supports	3= Aligned, and intact 2= Intact but not aligned 1= Not intact and not aligned ___ NA
	Propulsion Interface	
	Hand rims are present and attached properly	3= Present and attached properly 1 =Present but are not attached properly ___ NA
	Hand rims are smooth and do not pose any danger of acute injuries	3= Smooth and do not pose any danger of acute injuries 1= Not smooth and pose any danger of acute injuries ___ NA
	Seat to floor height is appropriate for feet propulsion	3= Appropriate 2= Low resulting in excessive knee flexion 1= High resulting in sliding out of chair ___ NA
	Wheels Locks	
	Wheel locks	3= Aligned and engage the wheel firmly (Bilaterally) 2= Aligned and engage the wheel firmly (Unilaterally) 1= Not aligned and does not engage the wheel firmly
	Reaching to Wheel Locks	3= Can reach and use his wheel locks independently and without any difficulty 2= Can reach and use his wheel locks independently with moderate difficulty 1= Cannot reach and use his wheel

		locks independently
	Total Maintenance Score	

Wheelchair Inspection Check List Page 2
Residents WC complaints/concerns: 1. ____________________ 2. ____________________ 3. ____________________ 4. ____________________ 5. ____________________

7.11.2 Wheelchair Assessment Checklist v2

Mark Items Not Applicable	I: Wheelchair Frame and Attachments (Weight 1)	Right Side	Left Side
☐	Frame tubes and weld points **Comments:**	3= No cracks, fractures and distortion 2= Cracks but no fractures or distortions 1= Fractures and distortions	3= No cracks, fractures and distortion 2= Cracks but no fractures or distortions 1= Fractures and distortions
☐	Encrusted debris **Comments:**	3= Free of encrusted debris 2= Encrusted debris to moderate extent 1= Encrusted debris to severe extent	3= Free of encrusted debris 2= Encrusted debris to moderate extent 1= Encrusted debris to severe extent
☐	Footrests **Comments:**	3= Move up/down smoothly and maintain position 2= Move with difficulty 1= Move with difficulty and cannot maintain position	3= Move up/down smoothly and maintain position 2= Move with difficulty 1= Move with difficulty and cannot maintain position
☐	Legrests **Comments:**	3= Swing away and latch easily; no visible bends 2= Swing away and latch with difficulty, no visible bends 1= Swing away and latch with difficulty, with visible bends	3= Swing away and latch easily; no visible bends 2= Swing away and latch with difficulty, no visible bends 1= Swing away and latch with difficulty, with visible bends
☐	Armrests position and adjustment **Comments:**	3= Remove and reposition easily 2= Remove and reposition with some difficulty 1= Remove and reposition with great difficulty	3= Remove and reposition easily 2= Remove and reposition with some difficulty 1= Remove and reposition with great difficulty
☐	Armrest upholstery **Comments:**	3= Intact 2= Minor damage 1= Significant damage	3= Intact 2= Minor damage 1= Significant damage

☐	Anti-tippers **Comments:**	3= Present and evenly placed 2= Present but not evenly placed 1= Present in inappropriate working conditions	3= Present and evenly placed 2= Present but not evenly placed 1= Present in inappropriate working conditions
☐	Fasteners **Comments:**	3= No missing or lose fasteners 2= Moderate amount of missing or lose fasteners (< 3) 1= Significant amount of missing or lose fasteners (> 3)	3= No missing or lose fasteners 2= Moderate amount of missing or lose fasteners (< 3) 1= Significant amount of missing or lose fasteners (> 3)
☐	Push Handles **Comments:**	3= Intact no damage 2= Minor damage 1= Significant damage	3= Intact no damage 2= Minor damage 1= Significant damage
Composite Score=(Total Score/Valid Items)*Weight			
Mark Items Not Applicable	**II: Wheels and casters (Weight 2)**	**Right Side**	**Left Side**
☐	Axle **Comments:**	3= Quick release fully adjustable 2=Quick release moderate adjustment (Vertical/horizontal) 1=No adjustment	3= Quick release fully adjustable 2=Quick release moderate adjustment (Vertical/horizontal) 1=No adjustment
☐	Caster forks **Comments:**	3= Swivel freely stems are perpendicular to the floor 2= Swivel freely stems are not perpendicular to the floor 1= Does not swivel freely stems are not perpendicular to the floor	3= Swivel freely stems are perpendicular to the floor 2= Swivel freely stems are not perpendicular to the floor 1= Does not swivel freely stems are not perpendicular to the floor
☐	Caster hubs **Comments:**	3= Free of cracks tires have tread and are inflated 2= Free of cracks tires do not have tread and are not inflated 1= Have cracks tires do not have tread and are not inflated	3= Free of cracks tires have tread and are inflated 2= Free of cracks tires do not have tread and are not inflated 1= Have cracks tires do not have tread and are not inflated

☐	Drive wheel tires **Comments:**	3= Free of cuts or sidewall damage and are properly inflated 2= Free of cuts or sidewall damage but are not properly inflated 1= Cuts and sidewall damage with inappropriate inflation	3= Free of cuts or sidewall damage and are properly inflated 2= Free of cuts or sidewall damage but are not properly inflated 1= Cuts and sidewall damage with inappropriate inflation
Composite Score=(Total Score/Valid Items)*Weight			
Mark Items Not Applicable	**III. Postural Seating and Support (Weight 3)**	**Right Side**	**Left Side**
☐	The frame tubes **Comments:**	3= Do not impinge upon the body 2= Impinge upon the body 1=Significantly impinge on body affecting seating posture	3= Do not impinge upon the body 2= Impinge upon the body 1=Significantly impinge on body affecting seating posture
☐	Seatback **Comments:**	3= Intact and if removable has working release fittings 2= Intact and if removable does not has working release fittings 1= Not intact and if removable does not has working release fittings	3= Intact and if removable has working release fittings 2= Intact and if removable does not has working release fittings 1= Not intact and if removable does not has working release fittings
☐	WC cushion **Comments:**	3= Correctly inflated (if applicable) and positioned appropriately 2= Correctly inflated (if applicable) but not positioned appropriately 1= Incorrectly inflated (if applicable) and not positioned appropriately	3= Correctly inflated (if applicable) and positioned appropriately 2= Correctly inflated (if applicable) but not positioned appropriately 1= Incorrectly inflated (if applicable) and not positioned appropriately
Composite Score=(Total Score/Valid Items)*Weight			

Mark Items Not Applicable	IV: Propulsion Interface (Weight 4)	Right Side	Left Side
☐	Hand rims conditions **Comments:**	3= Smooth and do not pose any danger of acute injuries 2= Rough but do not pose any danger of acute injuries 1= Pose any danger of acute injuries	3= Smooth and do not pose any danger of acute injuries 2= Rough but do not pose any danger of acute injuries 1= Pose any danger of acute injuries
Composite Score=(Total Score/Valid Items)*Weight			
Mark Items Not Applicable	**V: Wheels Locks (Weight 6)**	**Right Side**	**Left Side**
☐	Wheel locks position **Comments:**	3= Aligned and engage the wheel firmly (no movement) 2= Aligned and engage the wheel with back forth movement 1= Not aligned and does not engage the wheel firmly (back/forth; rotation)	3= Aligned and engage the wheel firmly (no movement) 2= Aligned and engage the wheel with back forth movement 1= Not aligned and does not engage the wheel firmly (back/forth; rotation)
Composite Score=(Total Score/Valid Items)*Weight			
Mark Items Not Applicable	**VI: User Wheelchair Interface (Weight 5)**	**Right Side**	**Left Side**
☐	WC propulsion **Comments:**	3= Straight without drag and no audible grinding sounds or clatter 2= Deviation with drag no audible grinding sounds or clatter 1= Deviation with drag audible grinding sounds or clatter	3= Straight without drag and no audible grinding sounds or clatter 2= Deviation with drag no audible grinding sounds or clatter 1= Deviation with drag audible grinding sounds or clatter

□	Legrests length and position **Comments:**	3= Appropriate length and position 2= Moderately short/long in length and moderately close to/away from WC 1= Significantly short/long in length and significantly close to/away from WC	3= Appropriate length and position 2= Moderately short/long in length and moderately close to/away from WC 1= Significantly short/long in length and significantly close to/away from WC
□	WC Cushion Placement **Comments:**	3= Appropriately placed on wheelchair 2= Inappropriately oriented 1= Cushion tuck in back or sliding in front	3= Appropriately placed on wheelchair 2= Inappropriately oriented 1= Cushion tuck in back or sliding in front
□	Seat base **Comments:**	3= Firm no sling upholstery and is appropriate length and width for resident 2= Sling upholstery but is appropriate length and width for resident 1= Sling upholstery and inappropriate in length and width for resident	3= Firm no sling upholstery and is appropriate length and width for resident 2= Sling upholstery but is appropriate length and width for resident 1= Sling upholstery and inappropriate in length and width for resident
□	Headrest **Comments:**	3= Aligned, tight and has intact upholstery 2= Aligned, tight but does not has intact upholstery 1= Not aligned, lose and does not has intact upholstery	3= Aligned, tight and has intact upholstery 2= Aligned, tight but does not has intact upholstery 1= Not aligned, lose and does not has intact upholstery
□	Lateral supports **Comments:**	3= Aligned, and intact 2= Intact but not aligned 1= Not intact and not aligned	3= Aligned, and intact 2= Intact but not aligned 1= Not intact and not aligned
□	Hand rims position **Comments:**	3= Present and attached properly (no excessive upper limb flexion/extension) 2 =Present with minor problems 1=Present with improper attachment (excessive upper limb flexion/extension)	3= Present and attached properly (no excessive upper limb flexion/extension) 2 =Present with minor problems 1=Present with improper attachment (excessive upper limb flexion/extension)

□	Seat to floor height (feet propulsion) **Comments:**	3= Appropriate 2= Low resulting in excessive knee flexion 1= High resulting in sliding out of chair	3= Appropriate 2= Low resulting in excessive knee flexion 1= High resulting in sliding out of chair
□	Wheel locks applications **Comments:**	3= Can reach and use wheel locks independently and without any difficulty 2= Can reach and use his wheel locks independently with moderate difficulty 1= Cannot reach and use his wheel locks independently	3= Can reach and use wheel locks independently and without any difficulty 2= Can reach and use his wheel locks independently with moderate difficulty 1= Cannot reach and use his wheel locks independently
Composite Score=(Total Score/Valid Items)*Weight			
Sum All Composite Scores			

7.11.3 Wheelchair Skills Test

Participant #

Wheelchair Skills Test 4.1
Manual Wheelchair - Wheelchair User

Name: ______________________________

Date: _______________ Time start: __________

Tester: _______________ Time finish: __________

❑ Caregiver ☑ WST-1
☑ Wheelchair User ❑ WST-2

Scoring Guide
✓ = pass ✗ = fail
NT = not tested (easier skill has been failed)
No Part = wheelchair has no such part

	Individual Skills	Skill ✓	Skill ✗	Safety ✓	Safety ✗	Safety NT	Comments
1.	Applies and releases brakes						No Part ❑
2.	Clears and replaces footrests						No Part ❑
3.	Removes and replaces armrests						No Part ❑
4.	Rolls forward 10m						
5.	Rolls forward 10m in 30s						
6.	Rolls backward 5m						
7.	Turns 90° while moving forward L&R						
8.	Turns 90° while moving backward L&R						
9.	Turns 180°in place L&R						
10.	Maneuvers sideways L&R						
11.	Gets through hinged door in both directions						
12.	Reaches 1.5m high object						
13.	Picks object from floor						
14.	Relieves weight from buttocks						
15.	Transfers from WC to bench and back						
16.	Folds and unfolds wheelchair						No Part ❑
17.	Rolls 100m						
18.	Avoids moving obstacles L&R						
19.	Ascends 5° incline						
20.	Descends 5° incline						
21.	Ascends 10° incline						
22.	Descends 10° incline						
23.	Rolls 2m across 5° side-slope L&R						
24.	Rolls 2m on soft surface						
25.	Gets over 15cm pot-hole						
26.	Gets over 2cm threshold						
27.	Ascends 5cm level change						
28.	Descends 5cm level change						
29.	Ascends 15cm curb						
30.	Descends 15cm curb						
31.	Performs 30s stationary wheelie						
32.	Turns 180° in place in wheelie position L&R						
33.	Gets from ground into wheelchair						
34.	Ascends stairs						
35.	Descends stairs						

Additional comments: ____

7.11.4 Wheelchair Incidents Report

Research Questionnaire **Subject ID: __________**

WHEELCHAIR INCIDENT SUMMARY REPORT

Month of Incident: __________ Time of Day if Known:__________________

Chief Dx: ____

What Happened: ____

____

____

Environmental Factors: ____

Others Involved: ____
(If residents, just use initials)

Activity Related: ☐ Transfer ☐ Sitting ☐ Walking Behind ☐ Tripped over legrests ☐ Propelling
☐ Uneven surfaces ☐ Stairwell ☐ Loading/unloading onto van ☐ Collision
☐ Mechanical Failure: ____
☐ Other: ____

____

Description of Wheelchair:
Manufacturer:

Model: ☐ Manual ☐ Power ☐ Scooter

Legrests: ☐ Detachable ☐ Fixed ☐ Folding ☐ Only one used ☐ Missing ☐ In disrepair ☐ None Used
Armrests: ☐ Detachable ☐ Unstable ☐ Fixed ☐ Missing ☐ In disrepair ☐ Other: ____________________
Backrest: ☐ Sling ☐ Solid ☐ In disrepair ☐ Other: ____________________________________
Seat: ☐ Sling ☐ Solid ☐ In disrepair ☐ Other: ____________________________________

Was an injury sustained: ☐ (0) NO ☐ (1) Yes If yes, describe injury: _________________________

____

____

Rate the injury: _____

0	No injury noted
1	Minor abrasions/cuts treated at facility
2	Injuries required care of a facility physician
3	Injuries required emergency room visit only
4	Injuries required hospitalization.
5	Injuries resulted in a fatality.

(Complete a Summary Report for each incident that has occurred since last assessment period.)

8.0 CONCLUSIONS

The primary objectives of this dissertation were: to determine the appropriateness of wheelchairs used (prescribed) to older adults living in community settings (home environments), and institutional settings (nursing homes, assisted living centers). The purpose was also to examine the outcomes resulting from use of wheelchairs in home and institutional environments. Finally, the objective of the last chapter of the dissertation was to develop a risk and safety assessment tool for evaluating the conditions of wheelchairs used by older adults in nursing homes and determine their impact on mobility, and safety of the older adults using them.

For the second chapter, data from a cohort of 723 older adults using wheeled mobility devices were analyzed. These cohorts represented older adults living in, both, community settings as well as institutional settings. It was found that the factors including age, gender, diagnosis, and living settings were associated with the differences in use of manual versus powered mobility devices. Differences were also noted with respect to the use of sub-types of manual (depot, standard, and customized) and those of powered (scooter, standard, and customized) mobility devices. The prescription of wheelchairs should follow the guidelines from conceptual models that suggested consideration of human factors (demographic and health-related), environmental factors (physical and social living environment), goals of the end-user, availability of resources, and the interaction of all these factors; for improving the quality and appropriateness of wheelchairs for older adults.

The objectives of chapter three of this dissertation were to identify the factors that impact prescription of wheeled mobility devices for older adults, and to determine the effects that living settings have on the types of devices that older adults receive. Data were gathered from medical charts on 337 older individuals from the Center for Assistive Technology (CAT). These individuals were aged >60 years, and each of them received a new wheeled mobility device from the Center for Assistive

Technology during the years 2007 and 2008. Data were analyzed in three tiers: tier 1 (manual versus powered mobility devices); tier 2 (motorized scooters versus power wheelchairs); and tier 3 (customized versus standard power wheelchairs).

For tier 1, the factor that was found to be associated with higher odds for receiving manual wheelchairs as opposed to a powered mobility device was cognitive limitations. For tier 2, the diagnosis of cardio-vascular and pulmonary conditions was found to be associated with prescription of motorized scooters. For tier 3, neurological conditions, male gender, institutional living, and lower age, were all found to be associated with higher chances of receiving customized power wheelchairs. This study objectively describes the clinical decision making process used for prescription of wheeled mobility for older adults. This information can aid in the development of guidelines and improving standards of practice for the process of prescription of wheelchairs for older adults.

The objective of the fourth chapter was to analyze the satisfaction data collected from three cohorts of older individuals living at nursing homes (VA and Private) and in the community settings. One hundred thirty two older adults completed the standardized Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST). Ninety of these participants were residents of either the VA or private nursing homes, and 42 were community dwelling participants. All the participants enrolled were independent users of either manual or power wheelchairs, and did not have any cognitive impairment. The manual wheelchairs used by the community dwelling participants were found to be of higher quality compared to those used by the participants living in nursing homes. The community dwelling group reported significantly higher levels of satisfaction with their wheelchairs and of overall satisfaction ratings, as compared to those by the nursing home participants. Similarly, community dwelling participants who used power wheelchairs were more satisfied with the service delivery they received. The level of satisfaction should be incorporated as a quality indicator for evaluating wheelchair prescriptions and service delivery programs for older Americans. This study also supports the establishment of a reevaluation process of wheelchair fit, to aide in provision of the best quality wheelchairs and service delivery programs for the recipients within nursing homes and for those living in the community.

The purpose of the fifth chapter was to determine wheelchair mobility patterns for community dwelling older adults, and to identify whether age has any impact on wheelchair use, or levels of self-reported physical activities. Manual and power wheelchair-related mobility activities were monitored objectively for older adults participating in the National Veterans Wheelchair Games (NVWG, 2008). The participants using manual wheelchairs were significantly more physically active during the games as compared to when they used their wheelchairs at their homes; in terms of the distance traveled and of the averaged speed of propulsion. The trend was the same for power wheelchair users, with a difference in the extent of use during games and that of use at home; with respect to distance, and to averaged speed. The users of power wheelchair reported to be engaged in higher levels of work-related activities that compared to those reported by the users of manual wheelchairs. The difference in the level of participation, in the sporting event, for the manual and power wheelchair users, was not significant. An objective evaluation is important, for understanding the factors associated with wheelchair use, and for the development of strategies for improving wheelchair mobility, and thus enhancing the overall participation on part of the wheelchair users.

The purpose of the sixth chapter was to quantify manual wheelchair use by nursing home residents. A total of 72 independent wheelchair users without cognitive impairments were recruited from four different nursing homes (two VA-affiliated and two private). A customized wheelchair data logger was attached to each participant's wheelchair for a period of one month. Data were reduced and compared separately for VA- affiliated and private facilities by types of propulsion pattern (arms versus legs, and the combination). Those participants who used their arms to propel their wheelchairs were more active, when compared to the participants who used their legs, as well as to those who used their arms and legs in combination. This finding was applicable only for the participants from the VA-affiliated facilities, as measured by distance, velocity, and endurance. Older adults living in nursing homes and who use wheelchairs, represent a diverse cohort. The efficacy of using an objective assessment method for measuring the extent of use of wheelchairs was demonstrated by this study. This objective assessment method will help clinicians in identifying the needs of older adults for prescribing individualized and customizable wheelchairs, and thus preventing the provision of standard wheelchairs that do not meet the users' needs.

The objectives of the seventh chapter were achieved in two phases. Phase I of the study involved the development and standardization of a wheelchair assessment checklist (WAC). Phase II of the study focused on utilization of the developed checklist for the assessment of quality (condition) of wheelchairs in nursing homes, and to identify the impact of wheelchair condition on the mobility, satisfaction, and safety, related to wheelchair use. The developed WAC comprises of six domains and twenty seven items. The six domains assessed related to the wheelchair conditions include: wheelchair frame and attachments (nine items), wheels and casters (four items), postural seating and support (three items), propulsion interface (one item), wheel locks (one item), and user wheelchair interface (nine items). These domains are assessed using a likert scale with '1' being the mimimum score, and '3' being the maximum score for each item. The results from phase II of the study indicated the impact of wheelchair conditions on wheelchair-related mobility, wheelchair skills perfromance, and satisfaction related to use of wheelchairs. The particpants who were using wheelchairs that were in better conditions had a fewer number of wheelchair-related incidents. The incidents that occurred were found to be resultant from the complex interaction between several factors, including wheelchair component failures, environmental factors, system factors, and the occupants' errors.

This work should be viewed as a series of research ptotocol for identification of critical problems associated with use of wheelchairs (wheeled mboility devices) by older adults. Due to the pilot nature of all of these studies, focusing on small and homogenous samples, a genralization of the findings to the entire aging population may be limited. However, this work highlights the need for the development of more rigorous (longitudinal and randomized) protocol for deteremining the true causality, between wheelchair use and its impact on the lives of older adults. This, in turn, will be helpul in the development of interventional protocol for older adults, for improving the appropriateness of wheelchair prescription, efficiency of their use, and prevention of unintentional injuries.

9.0 BIBLIOGRAPHY

See the references at the end of each chapter.