INVESTIGATION OF THE MOBILITY CHARACTERISTICS AND ACTIVITY LEVELS OF MANUAL WHEELCHAIR USERS IN TWO REAL WORLD ENVIRONMENTS

by

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INVESTIGATION OF THE MOBILITY CHARACTERISTICS AND ACTIVITY LEVELS OF MANUAL WHEELCHAIR USERS IN TWO REAL WORLD ENVIRONMENTS

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The primary objective of this study was to collect descriptive data on the mobility characteristics and activity levels of manual wheelchair users in two different environments: at the National Veterans Wheelchair Games (NVWG) and in the subjects' residential setting. This was accomplished using a custom data logging device. A secondary objective was to identify demographic factors that might influence the mobility characteristics and activity levels of the wheelchair users in their home environment. Thirty nine subjects were recruited to participate in this study over a two year period. A data logging device was instrumented on each subject's wheelchair for a total of six days at the NVWG and an additional one or two weeks in the home environment, depending on year of enrollment. The participants were also asked to complete a brief demographic survey. It was found that subjects traveled significantly (P=0.000) further and were active for significantly (P=0.000) more hours during an average day at the NVWG compared to their residential setting. The subjects traveled on average 6566.84 ± 3203.90 meters and were active for an average 12.00 ± 3.56 hours per day at the NVWG. In their home environment, subjects traveled an average distance of 1994.09 ± 1851.20 meters and were active for 7.13 ± 4.85 hours per day. When comparing the speed traveled in the two environments, no significant differences were found. It was found that the activity levels of the subjects at the NVWG were significantly greater when compared to their home environment. Analysis of demographic factors revealed that subjects who used a wheelchair for more years were found to travel significantly further and accumulate more minutes of movement per day. Also, employment was found to be a demographic factor that influenced wheelchair usage in the home environment. The findings of this study provide a more objective measure of wheelchair usage patterns in two real world environments: one that facilitates participation in activities and one that contains barriers that the subjects need to overcome. The results also indicate that there are demographic factors that influence wheelchair usage patterns in the residential setting.

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1. INTRODUCTION

The physical and mental health benefits achieved from engaging in an active lifestyle have been well documented for unimpaired populations (1-3). The current guidelines set forth by the Centers for Disease Control and Prevention and the American College of Sports Medicine recommend that people should participate in a minimum of 30 minutes of moderate intensity activity on a daily basis (1). Unlike previous physical activity recommendations which focused on vigorous structured leisure time activity, the current approach emphasizes incorporating activity into the daily lifestyle. Activities such as gardening, walking, dancing, mowing the lawn, and household chores are considered moderate activity if executed at a level similar to a fast paced walk (1). Participating in such activities has been found to reduce the risk of cardiovascular disease, non-insulin-dependent diabetes mellitus, osteoporosis, osteoarthritis, and several cancers (2,4-7). Physical activity has also been associated with decreasing the effects of depression and anxiety as well as enhancing the psychological well being of individuals (3,8). Overall, participating in daily physical activity can greatly impact the quality of life of individuals.

Although research clearly suggests that incorporating physical activity into ones' daily lifestyle has numerous quality of life benefits, a majority of Americans live a sedentary lifestyle. It has been found through population based surveys (e.g. the National Health Interview Survey (NHIS) and the Behavioral Risk Factor Surveillance System (BRFSS)) that as little as 15-21% of Americans achieve the recommended level of physical activity (9). Results from these reports also indicate that physical inactivity is more prevalent among individuals with disabilities than individuals without disabilities. For this group of people, attaining some level of physical activity is especially important because it can reduce the risk of secondary disabilities that would further limit their functional independence. While the fact that physical inactivity is more prevalent among individuals with disabilities may be true, the extent to which this group of people is inactive has been difficult to quantify because the assessment tools used lack the necessary sensitivity to provide an accurate measurement. These assessment tools are commonly self-report methods such as diaries, logs, and recall surveys. Tudor-Locke and Myers (9) suggest that the current self-report tools used are unable to accurately detect the activity patterns of these individuals because their activities are at the lower end of the continuum of physical activity. In addition, most of the surveys do not include questions regarding involvement in activities of daily living (ADL) and instrumental activities of daily living (IADL), which are important in determining the activity patterns of individuals with disabilities because for some these tasks require a large amount of effort and energy (10). Another limitation of these self-report tools is that they are not specific enough to account for the numerous physical and mental differences that exist among the population of individuals with disabilities (9,10). Rimmer et al. (11) describes the need to develop reliable field based tools for measuring activity levels of different subgroups of individuals with disabilities, such as those with mobility impairments requiring the use of a wheelchair.

With an increased interest in providing a more objective measure of the physical activity patterns of several subgroups of individuals with disabilities, researchers have begun investigating the use of electronic sensor technology as a more direct and objective method of data collection. Using such technology eliminates the possibility of recall bias and misinterpretation of survey questions, which are commonly associated with self- report measures (9,12). Motion sensors have been used in several studies to provide a more precise measure of the activity levels of wheelchair users. A study by Dearwater et al. (13) used an electronic movement counter to compare the activity levels of individuals with spinal cord injuries. This study evaluated the activity levels of 28 male individuals with paraplegia and quadriplegia in a rehabilitation facility over a two day period. Results revealed that the individuals with paraplegia were significantly more active than those with quadriplegia in terms of the number of counts recorded on the electronic counter. Another study conducted by Washburn and Copay (14) validated the feasibility of using a commercially available portable accelerometer, which outputs a measure of total number of counts per minute, to measure the physical activity levels of individuals who use a wheelchair. Subjects were asked to propel their manual wheelchair over an indoor course at three different speeds while two accelerometers were attached to each wrist. When comparing the accelerometer readings and oxygen consumption for the three speeds, significant relationships were found; therefore suggesting that this type of technology would be effective in measuring wheelchair propulsion.

In a study by Warms and Belza (15), the ability of an actigraphic monitor that measures acceleration to accurately assess the activity levels of individuals with spinal cord injuries in a real world setting was explored. Through the use of the actigraphic monitor worn on the wrist and a self-reporting method, the study was able to positively correlate the readings obtained from two assessment tools while subjects conducted daily activities in a free-living environment. In another validation study, Postma et al. (16) successfully showed that an activity monitor, which was attached to a number of locations on the skin, was a valid instrument to determine wheelchair propulsion in individuals with a spinal cord injuries. A comparison between acceleration data collected by the activity monitor and video recordings was used to determine the validity of using the device to accurately detect wheelchair propulsion when the wheelchair users completed a number of tasks that were representative of typical daily activities.

Although these studies found that electronic activity monitors were effective in measuring the activity levels of manual wheelchair users, a number of them were conducted in a laboratory setting. Since there are a number of uncontrollable factors experienced in real world settings, additional testing is needed to determine their effectiveness in monitoring activity levels in free living environments. Also, the size, location, and complexity of the monitoring devices could be considered obtrusive and cumbersome to the subject; therefore, limiting the length of the study period and ability of the monitor to get a true account of the wheelchair users typical daily activities in a free living environment.

It is clear that the development of an activity monitor that is unobtrusive to the propulsion patterns and daily functioning of manual wheelchair users is necessary to provide a more objective and detailed account of the typical activity levels in a community based setting. Only a few studies have used such a device to directly monitor the mobility characteristics (e.g. distance and speed) of wheelchair users. Over a four month period, Sawazky et al. (17) used bicycle odometers to track the distance traveled by thirteen children with spina bifida who use a manual wheelchair to determine the effectiveness of a Web based exercise program in motivating children to engage in physical activity. The distance traveled was measured to assess the progress being made by the children and to provide a distinct goal for the children to attain. Results revealed that over the four months the children traveled an average of 476 kilometers. In addition, trends towards increased strength and decreased energy expenditure were found after the completion of the exercise program. Cooper et al. (18) utilized a TFX-11 single board computer with a customized enclosure to successfully log the activities of two groups of power wheelchair users over a five day period. Results indicated that the group of individuals who attended the NVWG was more active in terms of distance and speed traveled compared to a group of subjects monitored in their home environment (Pittsburgh, Pennsylvania). Analyses revealed that the subjects who attended the NVWG traveled an average of 17164 ± 8708 meters during the five day study period, while the group in their home environment traveled an average of 8335 ± 7074 meters. It was also found that the subjects actively used their wheelchairs for a majority of the day, except during the time period of 1:00 A.M. to 5:00 A.M.

Kaminski (19) used two different types of data logging devices to investigate how far and fast children with wheelchairs typically travel. The TFX-11 data logger was used to monitor the children who used power wheelchairs, while the data logging device employed in the current study was used to measure the activities of the children who used a manual wheelchair. It was found that the usage patterns of children who use manual wheelchairs was similar to those who use power wheelchairs. The manual wheelchair users traveled an average daily distance of 1583.6 ± 880.2 meters at a speed of 0.67 ± 0.16 meters/second and the power wheelchair users traveled 1524.5 ± 1057.0 meters at a speed of 0.63 ± 0.16 meters/second. A comparison of the wheelchair usage patterns based on gender was also completed and found that on average the male wheelchair users traveled further and faster than the female wheelchair users. The average distance and speed traveled by the males were 1910.1 ± 1160.0 meters at 0.66 ± 0.14 meters/second, respectively. The average distance and speed traveled by the females were

1118.9 ± 247.9 meters at 0.60 ± 0.19 meters/second, respectively. The distance and speed traveled were also compared to the driving characteristics of adults and were found to be similar. Fitzgerald et al. (20) also used a similar device to track the activities of community dwelling manual wheelchair users while using a pushrim activated power assisted wheelchair (PAPAW) and their own personal wheelchair. When comparing the distance and speed traveled using the PAPAW verses a personal wheelchair, no significant differences were found. However, the mobility data were then combined to successfully quantify the mobility characteristics of manual wheelchair users over a total of four weeks. Over this time period, subjects covered an average distance of 1671.4 ± 314.8 meters per day at a speed of 0.44 ± 0.09 meters/second.

To get a true understanding of the amount of physical activity manual wheelchair users engage in, monitoring should be completed in real world environments. The settings investigated in this study enabled an investigation of mobility characteristics and activity levels in one environment that promoted an active lifestyle while the other setting was a location where the wheelchair users spent a majority of their time. The National Veterans Wheelchair Games (NVWG) facilitated participation in a number of activities by providing ample accessible transportation to a number of venues, planned social events, and competitive wheelchair sporting events. It was an intention that the data from the NVWG would provide a measure of activity that the wheelchair users were capable of achieving, while the home setting of the wheelchair users, which is typically not as accommodating, would provide a realistic measure of the mobility and activity levels achieved during a typical day.

1.1 Specific Aims

The primary objective of this study was to collect descriptive data on the mobility characteristics and activity levels of manual wheelchairs in two different environments: at the National Veterans Wheelchair Games (NVWG) and in the subjects' residential setting. The data were obtained through the use of a data logging device, which was mounted onto one wheel of each subjects' wheelchair, to enable direct monitoring of wheelchair usage. Collecting quantitative data to characterize manual wheelchair driving in two real world environments provides practical information on typical manual wheelchair mobility patterns and activity levels. A secondary objective of the study was to identify demographic factors that might influence the mobility characteristics and activity levels of the manual wheelchair users in their home environment.

The specific aims of this study include:

1. Determine the mobility characteristics of manual wheelchair users in natural environments by collecting data on the average distance (total, forward and backward), average speed, and average number of active hours per day during and post the NVWG.

2. Investigate activity levels of manual wheelchair users by measuring the average maximum continuous movement (i.e. distance and time interval between consecutive stops), average number of start/stops per thousand meters, and average daily accumulated movement time during and post the NVWG.

3. Determine if there was a difference in the mobility patterns of manual wheelchair users during the first and second week after returning home from the NVWG to verify that the protocol modification made to extend the length of the study was necessary.

4. Examine if the demographic factors of age, years of using a wheelchair, body weight, type of residential setting, satisfaction with primary wheelchair, perceived influence of community accessibility on daily activities and employment status are related to the mobility characteristics and activity levels of manual wheelchair users in their home environment.

2. METHODS

2.1 Demographic Characteristics of Subjects

Forty three subjects were recruited to partake in this study. The inclusion criteria included 1) using a manual wheelchair as a primary source of mobility, 2) being 18 years of age or older, and 3) available to meet with study personnel to have the data logging device attached to their wheelchair and other times as necessary. One subject did not return the data logging device at the end of the study and the data from three subjects was incomplete due to problems with the instrumentation; therefore, the data for a total of 39 subjects were used for analysis in this study.

A majority (92.3%) of the subjects who participated in this study were male. The participants ranged in age from 19 to 73 years old with a mean of 45.62 ± 12.26 years old. The amount of time participants have used a wheelchair ranged from 2 to 56 years with a mean of 13.17 ± 10.87 years. Thirty (76.9%) of the 39 subjects used a manual wheelchair due to a spinal cord injury. Information was not obtained on the type of injury (i.e. complete or incomplete). The other nine subjects reported disabilities of muscular dystrophy (n=1), multiple sclerosis (n=3), post polio syndrome (n=1), traumatic brain injury (n=1), Guillain-Barre syndrome (n=1), and an amputation (n=2). Additional demographic information can be found in Table 1.

Table 1 Summary of subjects' demographic information

Variables		Number of subjects (n)	Percentage (%)
Ethnic origin		(n=38)*	
	African American	7	18.4
	Asian American	1	2.6
	Caucasian	25	65.8
	Hispanic	3	7.9
	Native American	2	5.3
Gender		(n=39)	
	Male	36	92.3
	Female	3	7.7
Veteran		(n=38)*	
	Yes	37	2.6
	No	1	97.4
Disability/Injury		(n=39)	
	Spinal Cord Injury	30	76.9
	Cervical level	4	10.3
	Thoracic level	20	51.3
	Lumbar level	6	15.4
	Other Disability	9	23.1

* Demographic data from one subject was missing

2.2 Recruitment Procedures

Subjects were recruited during the 24th annual NVWG held in St. Louis, Missouri during June 2004 and the following year at the 25th NVWG in Minneapolis, Minnesota. Subject recruitment was carried out by study personnel at the NVWG sponsored exposition, which took place each year during the opening day of the games. Individuals who expressed interest in this research completed the study during that time or set up an appointment to meet later at a more convenient time.

2.3 Description of Protocol

The VA Pittsburgh Healthcare System Institutional Review Board approved the study's protocol before its initiation. The nature of the study was explained and written informed consent was obtained from all subjects before the start of data collection. A data logging device was instrumented on each subject's wheelchair. In addition, the participants were asked to complete a brief demographic survey. At this time, subjects also received a packet that contained materials (i.e. a hex key, box with prepaid postage, packing wrap, and removal instructions for the instrumentation) to remove the data logging device at the end of the study period and send it back to the Human Engineering Research Laboratories (HERL). The data logging device was placed in a location that did not obstruct the propulsion of the wheelchair or interfere with the subjects' functioning. The data logging device required little to no attention during the study period, so individuals were able to conduct daily activities as normal. For all subjects, the data logging device monitored their wheelchair activities for six days during the NVWG. Participants who enrolled in the study during the 24th NVWG were then monitored for an additional week in their home environment, while participants who attended the 25th NVWG had the data logging device attached for an additional two weeks after returning home from the games. The protocol modification, which added an additional week of monitoring during the second year of testing, was implemented to accommodate for different modes of travel from the NVWG, length of stay at the NVWG, and recovery time from the games. It was of interest to determine if the week after the NVWG was representative of a typical week in the home environment. After the second or third week of the study, depending on year of enrollment, subjects were instructed to remove the data logging device from their wheelchair using the materials provided to them at the initial appointment. Reminder notices were also mailed to the subjects. If the subjects did not return the data logging device within two weeks of the removal date, subjects were called as an additional reminder.

2.4 Demographic Survey

The surveys used in this study were developed to collect data on demographic factors of the wheelchair users. During the first year of the study, the survey used inquired about age, type of injury/disability, ethnic origin, and gender. Questions about the subjects' wheelchair were also asked to get a better understanding of the types of wheelchairs used in this study. These questions included the make and model of their primary wheelchair, age of their primary wheelchair, and number of years using a wheelchair. This survey has been successfully used in previous studies to collect demographic data on wheelchair users (18,19). During the second year of data collection, additional questions were added to the survey to enable a more in-depth characterization of the study sample. Additional information on the subjects' primary residential setting, body weight, employment status, type and frequency of use of back-up wheelchair, satisfaction with primary wheelchair, perceived influence community accessibility has on daily activities, and ability to use transportation independently were included on the survey. A copy of the surveys used during the first and second years of testing can be found in Appendix A and B, respectively.

2.5 Details of Custom Data Logging Device

The data logging device used in this study was developed by researchers at HERL to provide a more reliable method of monitoring the activities of manual wheelchair users in real world environments. The data logging device is approximately 5 centimeters in diameter and 3.8 centimeters in depth. It is self contained, lightweight and powered by a 1/6D lithium wafer cell battery, which enabled the data logging device to collect and store data for over three months. The data logging device easily attaches to the spokes of a manual wheelchair using a small aluminum strap and screws (Figure 1); therefore, requiring no modifications to the wheelchair.

Figure 1 Mounting method for data logging device

Since the data logging device is used in a number of different settings, it was designed to withstand most types of weather conditions. This activity monitor measures the rotation of the wheelchair wheel through the use of three reed switches mounted 120 degrees apart on the back of the printed circuit board (Figure 2) and a magnet mounted at the bottom of a pendulum (Figure 3). The pendulum/magnet combination maintains its position due to gravity. Therefore, whenever the wheelchair wheel exceeds 120 degrees of rotation, one of the reed switches is triggered, which in turn, activates a low power microcontroller as it swipes past the magnet.

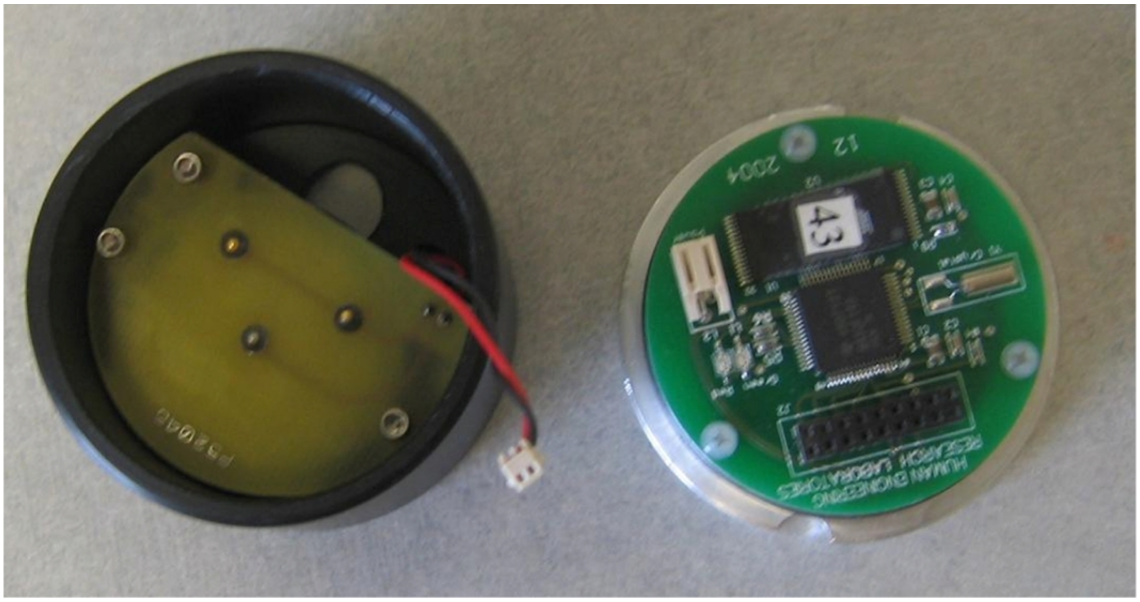

Figure 2 Inside of data logging device

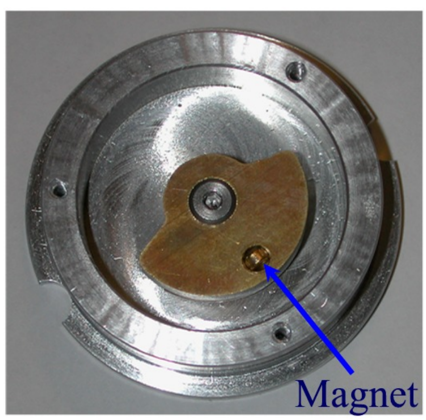

Figure 3 Pendulum and magnet located in base of data logging device

As each reed switch is triggered, a date and time stamp of the event to the nearest tenth of a second is recorded (21). The time stamp data enabled the calculation of distance, speed, and time of movement. It was assumed that three sensor hits in sequence was equal to the circumference of the wheel. The design of using three reed switches as compared to one in a previous design (22) also enabled the determination of forward and backward movement of the wheelchair.

Figure 4 Data logging device mounted on manual wheelchair

2.6 Reduction of Data Logging Device Data

Raw data stored on the flash memory chip of the data logging device were transferred to a personal computer. The raw data files were then decompressed and analyzed using a custom designed MATLAB[a] program. The custom code computed the mobility characteristic variables of daily distance traveled (total, forward, and backward), average daily speed and active hours. The daily distance (D_{day}) was calculated using:

$$D_{day} = \frac{(\# of\ time\ stamps * C_{wheel})}{3}$$

where C_{wheel} is the circumference of the wheelchair wheel on which the data logging device was mounted. Daily distance was measured in meters. To find the average speed (S_{day}) at which the wheelchair users traveled during a single day, the total daily distance (D_{day}) during the 24 hour period was divided by the total amount of time the wheelchair user was moving in their wheelchair during that day. The total length of time the wheelchair user was moving is defined below as the total accumulated movement time. S_{day} was measured as meters/second. When calculating the average number of hours the wheelchair users were active per day, an hour was considered to be active if the wheelchair users traveled greater than 50 meters within a 60 minute time period.

The activity level variables of total accumulated movement time, number of starts/stops per thousand meters, maximum period of continuous activity between consecutive stops, and maximum distance traveled between consecutive stops were also calculated using MATLAB[a] code. The total accumulated movement time was calculated by summing the length of time between time stamps when the users were considered to be active (i.e. not in an idle state). Wheelchair users were considered to be idle or stopped if the amount of time between the current time stamp $t\ (i)$ and the next time stamp $t\ (i+1)$ exceeded seven seconds. The number of starts/stops per thousand meters ($N_{stop/1000m}$) was calculated using:

$$N_{stop/1000m} = \frac{N_{stop/day}}{D_{day}} * 1000$$

where $N_{stop/day}$ is the total number of stops recorded during a single day. Averaging the number of start/stops per thousand meters was done to accommodate for differences in mobility levels among the subject population. To find the maximum period of continuous activity (T_{max}), the maximum length of time between two consecutive stops was found using the equation

$$T_{\max} = \max_i (T_{stop}^{i+1} - T_{stop}^{i})$$

where T_{stop}^{i+1} and T_{stop}^{i} represent the $(i+1)^{th}$ and i^{th} stop, respectively. Similarly, the maximum distance (D_{max}) traveled during continuous movement was calculated by finding the maximum distance traveled each day between two consecutive stops. All data obtained after processing it through the MATLAB[a] code were entered into a Microsoft[b] Excel for management purposes.

2.7 Data Analysis

Descriptive statistics were used to analyze the demographic factors associated with the subjects. The demographic factors included gender, age, number of years utilizing a wheelchair, type of injury/disability, ethnic origin, and veteran status. Descriptive statistics were also computed to determine mobility characteristics over the entire study period (i.e. NVWG and home settings combined) as well as the mobility and activity level characteristics of each of the two settings. Table 2 provides information on the time periods in which analyses were completed for the NVWG and the home setting.

Table 2 Characteristics of the study period

Year of testing	Setting	Date	Days of week
First (2004)	24th NVWG	June 14th-19th	Monday-Saturday
	Home	June 20th-26th	Sunday-Saturday
Second (2005)	25th NVWG	June 27th- July 2nd	Monday-Saturday
	Home (week 1)	July 3rd- 9th	Sunday-Saturday
	Home (week 2)	July 10th- 16th	Sunday-Saturday

To determine if the protocol modification made during the second year of testing was necessary, repeated measures analysis of variance (ANOVA) tests were used. It was of interest to determine if differences existed in the mobility characteristics and activity level data collected during the NVWG, week 1 in the home environment and week 2 in the home environment. Since the statistical tests indicated there were no significant differences found between the data obtained for week 1 and week 2 in the home for all variables, the data from the two weeks were averaged and used in the subsequent analyses to characterize the mobility characteristics and activity levels of the subjects in their home environment.

Comparisons were made between the two settings (i.e. the NVWG and the home environment) to determine if differences existed in the driving behaviors of manual wheelchair users when traveling in the two different environments. The mobility and activity level variables, which were all continuous, were analyzed to determine the distribution of data. Paired t-tests were used to determine differences in the two settings for the variables of average daily speed, active hours and total accumulated movement time. Since the other variables (i.e. daily distance, number of starts/stops, maximum period of continuous movement, maximum distance between stops) were not normally distributed, Wilcoxon Signed Ranks Tests were used to determine if differences existed. Repeated measures analysis of variance (ANOVA) tests were used to determine if there were differences in the mobility characteristics and activity levels of subjects across the days of the week. Mann-Whitney U tests were computed to determine if differences existed in the mobility characteristics and activity levels when comparing weekdays (Monday-Friday) to weekends (Saturday and Sunday) in the home environment. To determine if there was a relationship between age and the mobility characteristics (average daily distance, velocity, and active hours) and activity level measures (average accumulated minutes and maximum continuous distance) in the two settings, Spearman's Rho correlation tests were completed. Similar comparisons were also made between years of wheelchair use and the mobility characteristics and activity level measures.

Additional analyses of the demographic factors that may influence the mobility characteristics and activity levels of subjects in their home environment were computed. Data from the 26 subjects who enrolled in the study during the second year of testing was used in these analyses because supplementary demographic questions were added to the survey at this time. Spearman's Rho correlation tests were computed to determine if body weight was correlated to the mobility characteristics and activity levels of subjects. To determine whether the mobility characteristics (average daily distance, velocity, and active hours) and activity level variables (average accumulated minutes and maximum continuous distance) differed with respect to employment status (yes/no), Mann-Whitney U tests were used. Kruskal-Wallis H analysis of variance tests were used to investigate whether residential setting (rural, suburban, and urban), satisfaction with primary wheelchair and perceived influence of community accessibility on daily activities (helps a lot, helps some, has no effect, limits some and limits a lot) help explain the differences in the mobility characteristics and activity level measures in the home enivironment. All statistical analyses were completed using SPSS v13.0[c] software. Statistical significance was set at $P < 0.05$.

3. RESULTS

Data from thirty nine subjects collected over a two to three week period were used to describe the mobility patterns and activity levels of community based manual wheelchair users. Of the subjects (n= 37) who reported the current manufacturer and model of their personal wheelchair on the survey, 97.3% (n=36) used an ultralight manual wheelchair (classified as being less than 30 lbs) as their primary means of mobility and the other 2.7% (n=1) used a lightweight chair (classified as being less than 34 lbs). The age of the subjects' wheelchairs ranged from brand new (less than one month old) to 20 years old with a mean of 2.69 ± 3.73 years old. The characteristics of the manual wheelchairs used in this study are presented in Table 3.

Table 3 Characteristics of wheelchairs used in study

Type of wheelchair	Manufacturer and Model (n)
Ultralight (classified as < 30 lbs)	Sunrise Medical Quickie[d] (23) XTR (1) 2 (5) 2HP (2) R2 (1) Ti (8) Revolution (1) GPV (4) GT (1)
	Invacare[e] (9) TopEnd (4) A4 (3) Super Pro T (1) MPV (1)
	TiLite[f] (3) X (2) TRC (1)
	Everest and Jenning[g] (1) Vision/Record (1)
Lightweight (classified as <34 lbs)	Invacare[e] (1) 9000XT (1)

To describe the sports activities the subjects participated in at the NVWG, the survey requested participants to list the events they were registered to compete. The events available for participants to compete in ranged from high intensity activities such as wheelchair rugby, basketball, and the slalom to less demanding activities such as air guns and archery. Of the 39 subjects who completed the study, 19 (48.7%) participated in a total of five events (the maximum number allowed), 11 (29.7%) participated in four events, and 7 participated (18.9%) in three or less. Figure 3 provides a breakdown of the number of participants who competed in each event. If a subject competed in more than one event in the same category (i.e. field events for track, races for track and swimming), the subject was only included once toward the total event count. Also, two subjects did not participate in any events at the NVWG. This is because one subject was a spectator and the other was involved with helping run the annual event.

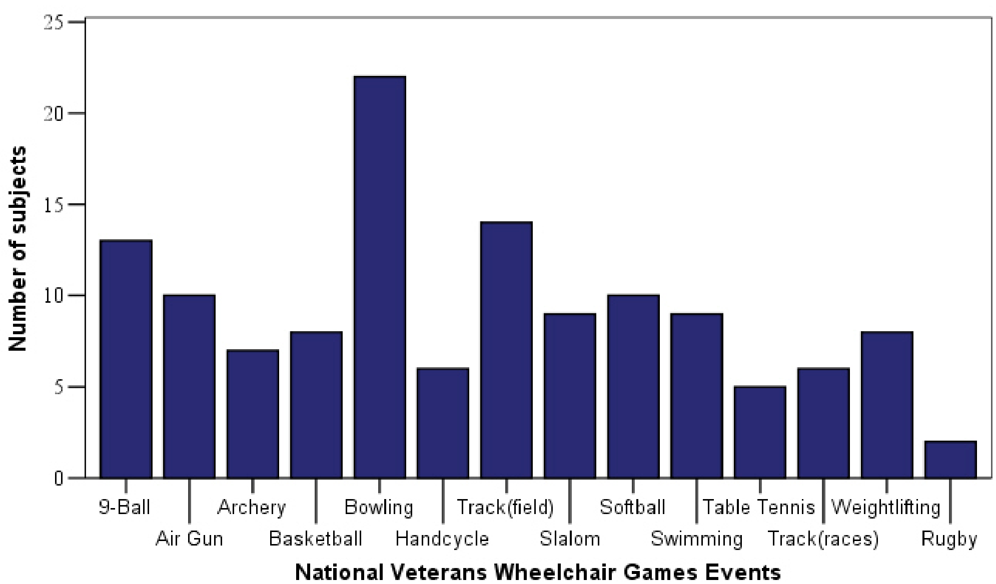

Figure 5 Number of subjects participating in each event at the NVWG

Table 4 summarizes the average daily distance (i.e. total, forward, and backward), daily speed, number of active hours and total accumulated minutes traveled over the entire study period (i.e. NVWG and home settings combined). Overall, data from the data logging device revealed that the 39 subjects traveled an average of 3547.10 ± 3230.21 meters per day at a speed of 0.89 ± 0.32 meters/second. The maximum total distance traveled by a subject was 19437.93 meters, which occurred during a day at the NVWG. Further analysis of the distance data revealed that the subjects traveled on average 88.8% of the time in the forward direction. The subjects were also found to be active (traveled >50 meters per hour) for an average of 8.78 ± 5.02 hours per day during the entire monitoring period. The number of hours the subjects were active in both settings ranged from 0 hours to 19 hours.

Table 4 Summary of mobility patterns over entire study period

Variables	Mean ± Standard Deviation
Total Distance (m)	3547.10 ± 3230.21
Forward (m)	3149.07 ± 2998.01
Backward (m)	398.03 ± 484.00
Speed (m/s)	0.89 ± 0.32
Active hours (hrs)	8.78 ± 5.02
Accumulated movement time (min)	66.16 ± 54.02

In the home setting, there were days in which the instrumentation did not record any data. Therefore, explaining why the minimum number of active hours recorded was zero. All of these inactive days occurred during the second year of testing. Overall, there were 38 (8.4% of all days in the home setting) inactive days recorded among 14 subjects. One reason for the inactive days could be that the subjects were utilizing their back-up wheelchair. Results from the survey indicate that a majority (87.5%) of the subjects who enrolled in the study during the second year own and use a back up wheelchair. Of the 14 subjects who recorded inactive days, five indicated using their back-up wheelchair at least once a week, two reported using it several times a month, four several times a year, and three did not use or own a back-up wheelchair. The days when no activity was recorded were still used in the analyses since it represents actual real world wheelchair usage patterns.

The data obtained from the data logging device used by subjects who enrolled in the study during the 25th NVWG (2nd year) were analyzed to determine if significant changes in mobility patterns occurred during week 1 and week 2 in the home environment. Table 5 provides a summary of the results. No significant differences were found in the mobility characteristics and activity levels between the two weeks in the home environment. Differences in the data between the two weeks were all found to be minimal, with the subjects being slightly more active during the first week compared to the second for most variables.

Table 5 Comparison of mobility and activity level variables for data collected in the home environment during the 2nd of testing

Variables	Week 1	Week 2	P-value
Distance (m)	2406.72 ± 2030.15	2255.11 ± 1860.79	0.428
Speed (m/s)	0.90 ± 0.34	0.89 ± 0.41	0.811
Active Hours (hrs)	8.73 ± 4.25	8.76 ± 4.35	0.941
Number of Starts/Stops (per thousand meters)	138.28 ± 94.18	137.70 ± 85.61	0.950
Accumulated movement time (min)	47.08 ± 36.20	45.33 ± 34.15	0.591
Maximum period of continuous movement (min)	2.73 ± 2.61	2.64 ± 3.25	0.740
Maximum distance of continuous movement (m)	199.51 ± 226.81	195.43 ± 284.16	0.873

A comparison of the mobility characteristics between the NVWG and home can be found in Table 6. The subjects traveled significantly (P=0.000) further during an average day at the NVWG than in their residential setting. On a typical day at the NVWG, subjects traveled 6566.84 ± 3203.90 meters and in the home environment subjects traveled a daily average of 1994.09 ± 1851.20 meters. When comparing the speed traveled in the two environments, no significant differences (P=0.058) were found. Subjects traveled at an average speed of 0.924 ± 0.170 meters/second at the NVWG and 0.877 ± 0.386 meters/ second in the home environment. The subjects were found to be active for a total 12.00 ± 3.56 hours per day at the NVWG and a total of 7.13 ± 4.85 hours in their home environment; a difference which was also significant.

Table 6 Comparison of mobility variables between the NVWG and home

Mobility variables	NVWG	Home	P-value
Distance (m)	6566.84 ± 3203.90	1994.09 ± 1851.20	0.000
Forward (m)	6022.69 ± 2918.49	1671.22 ± 1674.61	0.000
Backward (m)	544.15 ± 636.37	322.88 ± 361.24	0.000
Speed (m/s)	0.924 ± 0.170	0.877 ± 0.386	0.058
Active hours (hrs)	12.00 ± 3.56	7.13 ± 4.85	0.000

The activity levels of the individuals were also significantly different between the two environments. At the NVWG, subjects traveled an average of 116.23 ± 50.30 accumulated minutes per day over the six day period compared to 42.60 ± 34.13 minutes in their home environment. The range of average daily accumulated minutes traveled at the NVWG was 0.22 to 321.34 minutes, while the range in the home environment was 0.00 to 169.07 minutes. As previously mentioned, the data logging device recorded no data on some days, explaining the minimum value. The subjects were also found to travel significantly further and for longer periods of time between consecutive stops, which indicates an increased level of activity at the NVWG. Table 7 summarizes the results found when comparing the activity levels in both environments.

Table 7 Comparison of activity variables between the NVWG and home

Activity Level Variables	NVWG	Home	P-value
Accumulated movement time (min)	116.23 ± 50.30	42.60 ± 34.13	0.004
Maximum period of continuous movement (min)	5.94 ± 2.17	2.43 ± 2.73	0.000
Maximum distance of continuous movement (m)	448.81 ± 190.36	175.39 ± 241.30	0.000
Number of starts/stops (per thousand meters)	71.26 ±44.78	131.69 ± 98.36	0.000

Analyses were conducted to determine if there were differences in the mobility characteristics and activity levels of subjects among each day of the week. Figure 6 shows the average distance traveled in the two settings across the days of the week. The average distance traveled by subjects on Monday and Saturday at the NVWG were significantly less (P=0.000) than the other days of the week. No significant differences (P=0.564) were found in the average distance traveled among the days of the week in the home environment. However, there was a slight decrease in average distance traveled during the days of Friday, Saturday, and Sunday. Figure 7 shows the average accumulated movement time in the two settings for each day of the week. No significant differences were found in accumulated minutes at the NVWG (P=0.324) and the home environment (P=0.674) across days of the week. When investigating the other mobility characteristics and activity levels variables, no significant differences existed across the days of the week.

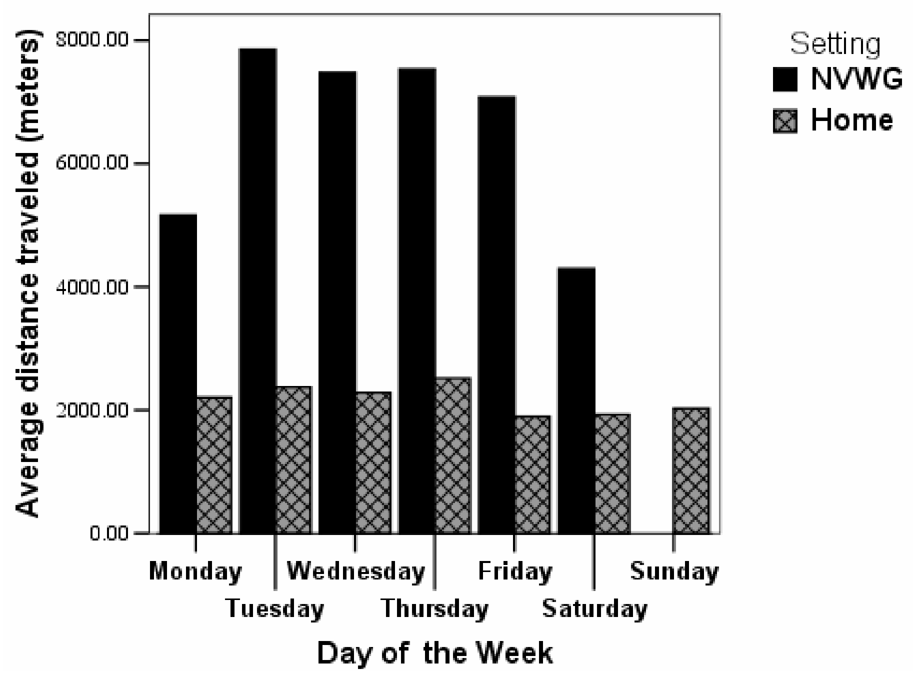

Figure 6 Average distance traveled across the days of the study period

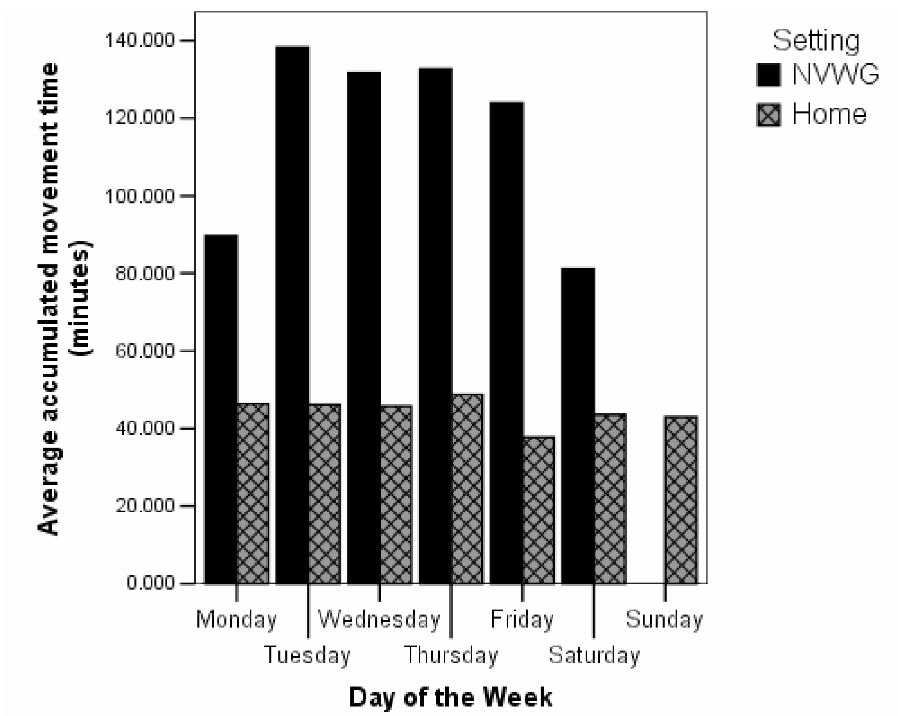

Figure 7 Average accumulated movement time across days of the week

Table 8 summarizes the mobility characteristics and activity levels found when the days of the week were grouped into two variables, weekday (Monday-Friday) and weekend (Saturday and Sunday). A significant difference (P=0.008) in the number of stops per thousand meters was found in the home environment with the subjects making more stops on the weekends compared to the weekdays. No significant differences were found among the other mobility characteristics and activity level variables when comparing weekdays to weekends.

Table 8 Summary of mobility characteristics and activity levels during the weekdays and weekends

Variables	Weekday (Monday- Friday)	Weekend (Saturday and Sunday)	P-Value
Distance (m)	2251.65 ± 1867.47	1976.64 ± 1714.09	0.141
Speed (m/s)	0.87 ± 0.33	0.87 ± 0.50	0.059
Active hours (hrs)	8.35 ± 4.23	7.74 ± 4.44	0.220
Accumulated movement time (min)	44.86 ± 33.54	43.22 ± 32.51	0.728
Maximum period of continuous movement (min)	2.67 ± 2.89	2.66 ± 2.36	0.799
Maximum distance of continuous movement (m)	199.56 ± 265.64	171.62 ± 184.65	0.076
Number of starts/stops (per thousand meters)	139.15 ± 91.31	162.07 ± 96.43	0.008

Analyses of demographic data collected revealed that age was not significantly correlated with the mobility characteristics and activity level variables. The number of years of utilizing a wheelchair was found to be significantly positively correlated with the average daily distance (r=0.323, P=0.045) and average daily accumulated minutes of movement (r=0.373, P=0.019) in the home environment. No significant correlations were found between the other mobility characteristics and activity level variables.

Table 9 summarizes the results found from the additional demographic survey information obtained from the 26 subjects who enrolled in the study during the second year of testing. The self-reported body weight of the subjects ranged from 125 to 312 pounds with a mean of 202.23 ± 44.34 pounds. A majority (57.7%) of the subjects reported living in a suburban residential setting. Forty eight percent (n=12) of the subjects reported being very satisfied with their wheelchair. The only subject who reported being very dissatisfied with their wheelchair was the one subject in the study who used a lightweight wheelchair. Sixty seven percent (n=16) of the subjects reported that they were currently unemployed. When subjects were asked how they felt their community's accessibility influenced their daily activities, 56% (n=14) reported that it helps a lot. Three subjects felt that their community's accessibility limits their participation in some way. Type of residential setting was not found to be related to perceived influence since these three subjects reported living in three different types of residential settings (i.e. rural, suburban, and urban).

When investigating the additional survey data to determine if there were relationships between the various demographic factors and the mobility characteristics and activity levels of subjects, employment status was found to be significantly related to the mobility characteristics of average daily distance (P=0.024) and average number of active hours per day (P=0.017) and the activity level variable of maximum daily distance traveled between consecutive stops (P=0.024), with those who were employed traveling more and being more active throughout the day. Although the subjects who were employed also traveled on average faster and accumulated more minutes per day, the differences were not significant. The demographic factor of body weight was found to be negatively correlated with the mobility characteristics and activity levels of manual wheelchair users; however, the relationships were not significant. Also, no significant differences existed between residential setting, satisfaction with primary wheelchair, and perceived influence of community on activities when compared to the mobility characteristics and activity level variables.

Table 9 Additional demographic survey information collected during the 2nd year of testing

Variables		Number of subjects (n)	Percent (%)
Residential Setting		(n=26)	
	Rural	5	19.2
	Urban	6	23.1
	Suburban	15	57.7
Satisfaction with primary wheelchair		(n=25)*	
	Very satisfied	12	48.0
	Satisfied	9	36.0
	Neither dissatisfied, nor satisfied	2	8.0
	Dissatisfied	1	4.0
	Very dissatisfied	1	4.0
Employment status		(n=24)**	
	No	16	66.7
	Yes	8	33.3
Perceived influence of community accessibility on activities		(n=25)*	
	Helps a lot	14	56.0
	Helps some	4	16.0
	Has no effect	4	16.0
	Limits some	2	8.0
	Limits a lot	1	4.0

* Demographic data from one subject was missing

** Demographic data from two subjects were missing

4. DISCUSSION

This study monitored the mobility characteristics and activity levels of manual wheelchair users in two different environments using a data logging device. It was found that over the entire study period subjects traveled an average of 3547.10 ± 3230.21 meters per day at a speed of 0.892 ± 0.323 meters/second. After the completion of the first year of testing, it was thought that the week of testing in the home environment following the NVWG might not, in fact, be representative of a typical week in the home environment due to a number of circumstances such as being tired from traveling long distances, fatigued from altering their to normal daily routines, and soreness from the strenuous activities at the NVWG. Therefore, an extension was made to the length of the study. However, it was found that there were no significant differences in the two weeks following the NVWG; suggesting that participating in the NVWG did not have a negative effect on the subjects when returning home and that the mobility characteristics and activity levels attained at the games could be a goal for individuals in their home environment.

When comparing data obtained from the two environments, the mobility characteristics of the individuals were significantly greater at the NVWG than in their residential environment for all aspects under investigation except average speed. While attending the NVWG, subjects traveled an average daily distance of 6566.84 ± 3203.90 meters at a speed of 0.924 ± 0.170 meters/second. In the home environment, subjects were found to travel an average of 1994.09 ± 1851.20 meters while moving at a speed of 0.877 ± 0.386 meters/second. The subjects were also active for significantly more hours at the NVWG compared to their home environment. Although no other study has investigated the mobility characteristics and activity levels of a single group of wheelchair users in two different environments, particularly the NVWG and their residential setting; a few studies have investigated the differences in mobility patterns between different groups of wheelchair users in these environments. A study by Cooper et al. (18) compared the driving characteristics of a group of power wheelchair users who attended the NVWG to a group of power wheelchair users that resided in Pittsburgh, Pennsylvania. Similar to the results of this study, Cooper et al. (18) found that the individuals who participated at the 20th NVWG traveled significantly further than those in their home environment. The average distance traveled by the power wheelchair groups were 3432.8 ± 1741.6 meters per day at the NVWG and 1667.0 ± 1414.8 meters per day in the home environment. A study by Hoover et al. (23) compared the usage characteristics of 54 adult manual and power wheelchair users who were recruited from both the NVWG and Pittsburgh, Pennsylvania, to determine if there were differences in the driving behaviors of the two types of wheelchair users and found no significant differences existed. It was calculated that the power wheelchair users traveled an average of 3792.22 meters per day while the manual wheelchair users 3544.46 meters. The average daily distance traveled by manual wheelchair users was very similar to the results obtained in this study when averaging over the entire study period, which is not surprising since Hoover et al. (23) collected data from both NVWG participants and those in their home environment. The speed at which the power and manual wheelchair users traveled was 0.711 and 0.530 meters/second, respectively. Fitzgerald et al. (20) examined the mobility patterns of individuals when using a PAPAW and their own personal wheelchair over the course of four weeks. Although there were no significant differences found in the mobility patterns when comparing the two types of wheelchairs, this study measured the average daily distance traveled by manual wheelchair users to be 1671.4 ± 314.8 meters, which is similar to the results found in this study.

Overall, the results of the mobility characteristics found in this study are supported by those previously reported for adult wheelchair users monitored in real world environments.

The results obtained from investigating the activity levels of manual wheelchair users provide a more objective measure of the actual amount of physical activity attained on a daily basis. It has been suggested that the recommended level of physical activity for wheelchair users can be achieved by self propelling a wheelchair for a total of 30-40 minutes per day or by participating in more intensive activities such as wheelchair basketball or rugby for a period of 20 minutes (24). It was found that while attending the NVWG subjects accumulated an average of 116.23 ± 50.30 minutes of movement per day and stopped an average of 71.26 ± 44.78 times per thousand meters. In addition, the average maximum period of continuous movement was 5.94 ± 2.17 minutes. The length of time of continuous movement provides a measure of activity intensity. Since propelling a wheelchair, requires strength, stamina and flexibility, the longer the length of time of continuous movement the greater the intensity of activity. From the activity level data obtained from the data logging device and the fact that nearly half of the subjects participated in the maximum number of events allowed at the NVWG, it can be concluded that on average the subjects attained the recommended level of physical activity per day while participating in the NVWG. To provide further evidence of this conclusion, it should be noted that when participating in events such as basketball, rugby, and racing, most of the subjects used an alternative sports wheelchair and therefore, this activity was not included in the data obtained from the data logging device. Due to the various circumstances involved with participating in the NVWG such as the excitement of traveling to new places, the opportunity to see old friends and create new ones, and the flow of adrenaline associated with competitive sports, it is not surprising that that the mobility characteristics and activity levels of the subjects were significantly increased at the NVWG compared to their home environment. However, this information obtained could provide an objective measure of the levels of activities that the subjects are capable of achieving.

In the residential environment, the subjects were significantly less active compared to the NVWG. The average accumulated minutes of movement per day was found to be 42.60 ± 34.13 minutes while stopping an average of 131.69 ± 98.36 times per thousand meters. It was also found that the average maximum time of continuous movement was 2.43 ± 2.73 minutes. Although the average accumulated time is greater than the recommended 30 minutes of activity per day, the results of the other activity variables suggest that the intensity of the activity was greatly decreased. The significant decrease in the maximum continuous movement time and distance as well as the increase in the number of stops per thousand meters provide evidence that there may be factors in the home environment that limit manual wheelchair users participation in activities. Also, the fact that there were several days in the home environment in which no activity was recorded also suggests there are factors influencing the activity levels of wheelchair users in the home environment. As suggested before, this may only be due to the fact that the wheelchair users were using a back up wheelchair for their mobility needs. However, when looking at the demographic information collected on the subjects that recorded no activity during days of the study, it was found that only about half of the group indicated using their back-up wheelchair at least once a month. Therefore, suggesting there are other explanations for the days of inactivity. When investigating the types of injuries/disabilities reported by the 14 subjects to possibly explain the inactivity, no conclusion could be drawn due to the wide range of injuries/disabilities reported by these subjects.

Several studies have investigated the perceived barriers that limit the participation of wheelchair users in their residential environment. Levins et al. (25) explored barriers to participation in physical activity among a group of individuals with SCI and found subjects felt that there were individual and societal influences that limited their participation. Individual influences were described as coming to terms with being disabled and the struggle to establish a new identity. Among the societal influences included both environmental and attitudinal barriers. The fact that the negative societal attitudes are virtually eliminated when participating at the NVWG because all of the participants have the common factor of having a disability might also explain the higher level of activity at the NVWG and the lower levels in the home environment. In another study by Rimmer et al. (26), environmental barriers including insufficient number of curb cuts, inaccessible access routes, and lack of elevators have been reported as factors limiting participation among people with disabilities. Additional factors such as lack of education about the importance of living an active lifestyle, limited access to accessible transportation, cost, inaccessible exercise facilities, lack of instruction and organization of events (11,25,27,28) have also been noted as barriers to participation for individuals who use a wheelchair. A longitudinal study by Meyers et al. (29) which followed participants for 28 days found that there were barriers in the environment that wheelchair users commonly encountered. Some of these barriers were overcome such as lack of ramps, the steepness of the ramp, other peoples' rudeness, and the location of door handles/weight of the door, while others were not (e.g. personal illness, limited strength, and bad weather). The results from these studies further strengthen the notion that there are barriers that inhibit participation in activity in the home environment.

When investigating the mobility characteristics and activity levels of manual wheelchair users across the days of the week, it was found that the subjects traveled significantly less during the first and last days of the NVWG. Since Monday and Saturday were the days that participants typically arrived and departed from the games, it was not surprising that there was a difference in the mobility patterns when compared to the other days of the week when there were numerous planned activities. The fact that the mobility characteristics and activity levels were not significantly different among days of the week in the home environment could be a result of the fact that a majority of the subjects were not employed. Therefore, their routines might not change between the days of the week. The finding that the subjects stopped significantly more times on the weekends compared to weekdays and the slight reduction in some mobility characteristics and activity level variables might simply be a result of subjects relaxing during the weekends. Since there was only limited data collected for weekend days, additional data and information on the activities subjects participated in the home environment is necessary to further explain these results.

A secondary investigation of the results from the survey and the data obtained from the data logging devices was completed to further characterize the mobility patterns of manual wheelchair users in their home environment. It was found that age was not related to the mobility characteristics and activity levels of the manual wheelchair users. A study by Cooper et al. (30) found the opposite to be true among a group of manual wheelchair users with a similar average age as the current study. The conflicting results suggest that there are additional factors influencing the mobility characteristics and activity levels of individuals who use a manual wheelchair. It was found that the number of years of utilizing a wheelchair was related to the average daily distance traveled and total accumulated minutes per day, with those who have been using a wheelchair for a longer period of time traveling further and accumulating more movement per day. This may be due to the fact that propelling a wheelchair requires strength, and therefore, those who are newly injuries have not yet developed the necessary muscle mass. Employment was found to be a demographic factor that influences the mobility and activity levels of wheelchair users. It was found that the eight (out of 24) individuals who were currently employed on average traveled further, were active for more hours, and traveled on average further between consecutive stops per day than those who were unemployed. This finding emphasizes the importance of integrating wheelchair users into the workplace. However, even though those individuals who were employed traveled further than those who were unemployed, the employed subjects were still more active at the NVWG when compared to their home environment. Since the other survey variables of body weight, residential setting, satisfaction with primary wheelchair, and the perception of community influence on daily activities were found not to influence the mobility characteristics and activity levels of manual wheelchair users, further investigation is needed to further explain factors that are related to the mobility characteristics and activity level patterns of manual wheelchair users in their home environment.

4.1 Limitations

There are a few limitations to this study that need to be addressed. The fact that the sample was primarily made up of male veterans who use ultralight manual wheelchairs limits the generalizability of the study. Obtaining a greater distribution of females and individuals from all age groups as well as those who use different types of manual wheelchairs would provide a more comprehensive characterization of typical mobility patterns and activity levels of all manual wheelchair users. The study sample primarily consists of individuals with spinal cord injuries. Recruiting subjects with other disabilities would enable a comparison of the data to determine if differences existed in mobility characteristics and activity levels among different groups of individuals with similar disabilities. This study collected data only during the summer months, which due to the weather conditions, is when individuals typically use their wheelchair the most. Collecting data during other times of the year would provide a more accurate estimation of mobility characteristics and activity levels of wheelchair users. Also, since a number of the subjects used a back-up wheelchair or sports wheelchair during the study period, the mobility characteristics and activity levels were not a complete measure for all subjects. The secondary analysis of demographic factors influencing mobility and activity level characteristics only included 26 subjects due to the modifications made to the survey. Collecting data on additional subjects might provide a better explanation of demographic factors that influence the mobility and activity level characteristics in the home environment.

4.2 Recommendations for future studies

A number of recommendations can be made for future studies. One recommendation would be for future studies to focus on collecting the usage patterns of females who use manual wheelchairs to determine if their mobility characteristics and activity levels are similar to males. In addition, collecting data on different populations of individuals who use manual wheelchairs such as minorities and individuals with a disability other than a spinal cord injury would provide information on whether differences exist in the mobility characteristics and activity levels between specific populations. Collecting additional data on individuals with spinal cord injuries would also provide valuable information on the differences in the mobility characteristics and activity levels among individuals with paraplegia compared to those with tetraplegia. Another recommendation would be to attach a data logging device to each subject's sports wheelchair or back-up wheelchair as well as their primary wheelchair to enable a more complete measure of the mobility characteristics and activity levels achieved during the study period. Determining if the subjects are involved in sports activities or other regular activities in their home environment would be beneficial in explaining the activity levels of manual wheelchair users in their home environment. Since research has shown that a majority of manual wheelchair users experience shoulder pain, it would be beneficial to investigate if there is a relationship between shoulder pain and the mobility characteristics and activity levels of manual wheelchair users. Shoulder pain could possibly be a factor that influences the usage patterns in the home environment. Also, since the data logging device only uses time stamp data to obtain the mobility and activity level characteristics, it is unclear when subjects are traveling over uneven terrain (e.g. hills and ramps). Creating a more advance monitoring device that includes sensor technology to collect this data would provide a more detailed account of the mobility and activity levels of the wheelchair users. Another recommendation would be to collect data before the NVWG in the home environment to determine if there is a change in mobility characteristics and activity levels before and after the NVWG.

5. CONCLUSION

Using a data logging device that was attached to the wheels of manual wheelchair users' over a period of two to three weeks, this study was able to provide a more objective measure of the mobility characteristics and activity levels of manual wheelchair users in two real world environment: at the NVWG and their residential environment. The ability to measure this information enables a better understanding of the typical activity levels achieved for a group of individuals for which this information is currently unknown or misrepresented. It was found that the mobility characteristics and activity levels of the wheelchair users were significantly different between the two environments. The high level of activity measured at the NVWG may be explained because the environment facilitates physical activity for wheelchair users by eliminating a number of the barriers commonly experienced in everyday life. The levels of activity achieved at the NVWG can serve as a target for the individuals to attain in their home environment. The fact that employment was found to be a factor that is related to the mobility and activity levels of wheelchair users provides evidence of the importance of importance of integrating manual wheelchair users into the workplace. Future research is needed to further investigate the mobility characteristics and activity levels of wheelchair users as well as the factors that influence these patterns.

APPENDIX A

Survey used during first year of testing

PARTICIPANT SURVEY

DATE: _________ TIME:_________

Name ____ Age: ________

Address: ______________________________________ Gender: ________

____

Phone Number: ________________________________

Disability or Injury Level: ________________________

Date of Disability Onset or Injury: __________________________

Veteran **(circle)**: YES / NO

Ethnic Origin: ____African American _____Caucasian _____ Native American
____Asian American _____ Hispanic _____ Other

Information Regarding Your Wheelchair

Type of Wheelchair: _____ Manual _____ Power

Wheelchair Make: ____________________________ Model: __________________

If Power Wheelchair:
Average Amount of Time Before You Charge Your Battery? _________

Age of Current Wheelchair: ____________ **Wheel Diameter: _______**

Number of Years Since You Starting Utilizing a Wheelchair: ___________

Additional Comments

____

____

____

DATALOGGER # _______________

APPENDIX B

Survey used during second year of testing

Participant Contact Information (Taken after Consent)

Date: _________ Time: _________

Name ______________________________________ Age: ________

Address: ____________________________________ Gender: ________

____

Phone Number: _____________________ Email address: ____________________

Disability or Injury Level: _______________________

Date of Disability Onset or Injury: _________________________

Veteran: ______ Yes _____ No

Ethnic Origin: ____African American _____Caucasian _____ Native American
____Asian American _____ Hispanic _____ Other

Body weight: ____________

Events participating in the NVWG: 1. _____________ 2. ____________3. ___________
4. ____________ 5. ____________

Will you be using your primary wheelchair to participate in these events?
______ Yes ______ No

Primary Residence Setting: _____ Rural _____ Urban ______ Suburban

Information Regarding Your Wheelchair(s)

Type of **Primary** Wheelchair: _____ Manual _____ Power

Wheelchair Make: ___________________________ Model: __________________

If Power Wheelchair:
Average Amount of Time Before You Charge Your Battery? _________

What kind of power base do you have?
___ Front wheel drive ___ Mid-wheel drive ___ Rear wheel drive

What kind of seating system does your power wheelchair have? ***(check all that apply)***
___ Power recline ___ Power leg elevator
___ Power tilt ___ No features
___ Power seat elevator ___ Other

Age of Current Primary Wheelchair: ____________

Number of Years Since You Started Utilizing a Wheelchair: ___________

Type of **back-up** wheelchair:
_____ Manual _____ Power _____ Do not use or own a back-up wheelchair

On average, how often do you use your **back-up** wheelchair?
_____ At least once a week
_____ Several times a month
_____ Several times a year
_____ Do not use or own a back-up wheelchair

Overall, how satisfied are you with your **primary** wheelchair?
______ Very satisfied
______ Satisfied
______ Neither dissatisfied, nor satisfied
______ Dissatisfied
______ Very dissatisfied

Are you currently employed (full or part time)? _____ Yes _____ No

How does the accessibility of your community environment influence your daily activities?
_____ Helps a lot
_____ Helps some
_____ Has no effect
_____ Limits some
_____ Limits a lot

Can you use transportation independently? ______ Yes _____ No

Additional Comments:

____

____

____

Wheel Diameter: ______________ DATALOGGER # __________

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List of Suppliers

a. The MathWorks Inc., 3 Apple Hill Drive, Natick, MA 01760.

b. Microsoft Corporation, One Microsoft Way, Redmond, WA 98052.

c. SPSS Inc, 233 S Wacker Drive, 11th Floor, Chicago, IL 60606.

d. Sunrise Medical, 2382 Faraday Avenue Suite 200, Carlsbad, CA 92008.

e. Invacare Corporation, One Invacare Way, Elyria, OH 44035.

f. TiLite, 1426 East Third Ave., Kennewick, WA 99337

g. Everest and Jennings, 4203 Earth City Expressway, St. Louis, MO 63045.