APPLICATION OF A COMMERCIAL DATALOGGER TO ELECTRIC POWERED AND MANUAL WHEELCHAIRS OF CHILDREN

by

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BSE BME, Case Western Reserve University, 2002

Submitted to the Graduate Faculty of

Rehabilitation Science and Technology in partial fulfillment

of the requirements for the degree of

Masters in Rehabilitation Science and Technology

University of Pittsburgh

2004

UNIVERSITY OF PITTSBURGH

FACULTY OF REHABILITATION SCIENCE AND TECHNOLOGY

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APPLICATION OF A COMMERCIAL DATALOGGER TO ELECTRIC POWERED AND MANUAL WHEELCHAIRS OF CHILDREN

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Objective: This study was conducted to investigate the usage characteristics of children wheelchair users. This was accomplished by utilizing dataloggers to quantify how far and how fast children drive or propel their wheelchairs, as well as observing the movement time data. The relationships between usage per type of wheelchair, gender, and day of the week were evaluated.

Methods: 20 subjects between the ages of 6-17 years old who use a manual (n=10) or power (n=10) wheelchair for their primary source of community-based mobility were studied. The children in this study reported the disabilities of cerebral palsy (n=6), spina bifida (n=11), Duchenne muscular dystrophy (n=2), and spinal cord injury (n=1). Overall, nine females and 11 males participated in the study. All subjects, or their parents, provided demographic information and characteristics of their wheelchair. Each child's wheelchair was then instrumented with a datalogger. The datalogger was attached to wheelchair for five to seven days. During this time, the participants were instructed to go about their daily activities as usual.

Results: On an average day, the manual wheelchair users traveled 1583.6 ± 880.2 meters at an average speed of 0.67 ± 0.16 meters/sec, while the power wheelchair users traveled 1524.5 ± 1057.0 meters at 0.63 ± 0.16 meters/sec. Overall, the children traveled average daily distances in the range of 8.5 meters to 3929.1 meters and at speeds between 0.39 to 1.42 meters/sec. The males in the study, on average, traveled 1910.1 ± 1160.0 meters per day at 0.66 ± 0.14 meters/sec while the females traveled 1118.9 ± 247.9 meters at 0.60 ± 0.19 meters/sec. The children were active for an average of 15 hours per day on the weekdays and 12.5 hours on the weekend days. The children traveled an average of 1738.7 ± 1173.5 meters per day at 0.63 ± 0.14 meters/sec on the weekdays and 1088.9 ± 902.8 meters per day on the weekends. Data from nine manual wheelchair shows the subjects drove in the forward direction 93.2% of the time and backwards 6.8% of the time.

Conclusions: No differences were found between the distance and speeds traveled for children manual and power wheelchair users. In comparison, the children wheelchair users show similar driving characteristics in speed and distance traveled to adult wheelchair users. The findings suggest that the male children traveled longer distances per day ($P = 0.046$) and at higher speeds. The children appear to be more active on weekdays as compared to the weekends. The weekday distance is significantly higher than weekend distance ($P = 0.035$).

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ACKNOWLEDGEMENTS

I would like to thank my Master's studies advisor, Dr. Cooper, and the other members of my committee, Rosi Cooper and Dan Ding. Also, I would like to thank the other faculty, staff, and students at the Human Engineering Research Labs, especially the machine shop crew. I would like to give a special thanks to Michelle Tolerico, who assisted me with this study and the dataloggers. I also need to thank all of those who helped me recruit subjects: Jim Albring, the Spina Bifida Coordinators Dorinne Kinnunen and Georgia Wiltsie, Lisa McGinnis, Steve Balt, Kathy Elms, the Children's Institute therapists and Rosi Cooper. Finally, I would like to thank my parents and family for their continual support.

1. INTRODUCTION

From Census 2000, the US Census Bureau indicates that there are approximately 2.6 million children (5.8%) between the ages of 5-15 with disabilities, including sensory, physical, mental, and self-care. Some common childhood disabilities that often manifest mobility difficulties include cerebral palsy, muscular dystrophy, and spina bifida. From the 1988 National Health Interview Survey, Boyle et al (1994) reports that 23 of every 10,000 children 17 years of age or younger had cerebral palsy. The National Center on Birth Defects and Developmental Disabilities reports that Duchenne/Beckers muscular dystrophy affects one out of every 3,500 to 5,000 boys in the United States. The Spina Bifida Association of America reports that spina bifida affects one out of every 1,000 live births in the United States and estimates that more than 70,000 people in the United States are living with this birth defect. A study by Lewis et al (2004) followed 87 children born with spina bifida and evaluated their ambulation status over 10 years. The study found that 18% of the children used wheelchairs at age two and 46% used wheelchairs at age 10.

For many children with disabilities, the first goal of therapists and parents is for the child to gain (or regain) the ability to walk. However, numerous studies have shown that ambulation for these children is inefficient and very energy consuming, thus leaving the child with little energy for other activities. In a study by Duffy et al (1996), the energy consumption while walking of children with spina bifida and cerebral palsy was investigated. Children in both groups tend to walk with energy-expensive gait patterns with hip and knee flexion and other abnormalities. These children tended to walk at lower speeds than normal and with higher oxygen consumption per meter walked. Rose et al (1990) showed that the mean energy expenditure for a group of children with cerebral palsy was three times higher than for normal children and it occurred at lower walking speeds. Bernardi et al (1995) studied the efficiency of walking for several paraplegic subjects using reciprocating gait orthosis (RGO). Paraplegic RGO walkers attained velocities that were much lower than normal subjects using the RGO. The paraplegic subjects experienced high oxygen uptake, large metabolic energy expenditures, and a great demand for mechanical energy during locomotion with an orthosis. Bottos and Gericke (2003) examined the long-term maintenance of ambulation capacity in children with cerebral palsy. Typically, children with cerebral palsy fall into two groups - those who lose independent walking at an early age and those who lose it later in life. Despite the age, loss of independent walking is influenced by intensity of therapy, joint deterioration, physiological and psychological problems, fatigue, and too much or too little surgery. Even with the child and therapist's time, effort, and expense, the reported failure rates of walking as adults are 70 to 100 percent (Stillwell 1983). Reports indicate (Bleck 1975) that the use of a wheelchair as a preventative measure might reduce joint deterioration and fatigue, preserve the capacity for walking, and increase functional independence after the loss of walking.

When considering the use of wheelchairs for young children, parents and rehabilitation professionals often feel that walking will help further motor development and maintain a more favorable overall health outcome for the child. Several studies show that the outcomes are actually fairly similar. Liptak et al (1992) studied two groups of children with spina bifida, one group used a wheelchair for mobility from an early age and the other group used a parapodium (upright bracing unit of both legs for ambulation). It was found that there was no difference in the occurrence of reflux, hydronephrosis, urinary-tract infections, skin breakdown, hip-flexion contractures, urinary continence, extracurricular activities, independent skills, or utilization of health services. Users of the parapodium were more likely to have hip dislocations, fractures, and obesity. Wheelchair users were more likely to have knee-flexion contractures. From the use of the parapodium, 59% of the children had switched to using HKAFO's and/or a wheelchair by the average age of 10 years old. Mazur et al (1989) conducted a similar study with a group of children who used wheelchairs from a young age and another group who participated in a walking program from a young age. They found no differences in the occurrence of obesity, ADL scores, and manual hand function. Walkers were less likely to have fractures and pressure ulcers but spent more days in the hospital. By the average age of ten, 47% of the young walking children were using wheelchairs. Nilsson and Nyberg (2003) suggest that through learning to drive a power wheelchair, young children may increase wakefulness and alertness, improve limited upper extremity function, promote understanding of cause-and-effect relationships, and development of initiative and exploratory behaviors.

When it comes to philosophical perspectives on management paths for children with physical disabilities, Wiart and Darrah (2002) suggest that the views have changed significantly over the past decade, especially in consideration of wheeled mobility. Traditionally, children with physical disabilities were challenged to reach independent movement without the use of assistive devices. In the hierarchical view of motor skills, walking and normal movement patterns were regarded as the desired goals, especially from the point of view of rehabilitation professionals. Modification of external factors, such as adding wheeled mobility (especially power wheelchairs), was considered only as a last resort. The management plan was also usually expert-driven, with little input from the family. Recently, pediatric rehabilitation has tended to shift towards a new family-centered philosophy that includes the family in decision-making roles regarding their child's rehabilitation program. Also, the Dynamic Systems Theory (DST) model of motor behavior has become more widely adopted by rehabilitation therapists. This model accepts that normal movement patterns may not be the most efficient or functional patterns for a child and that the families may choose a mobility solution appropriate for their environment, including assistive technology. Thus, independent movement and self-initiated exploration of the environment is highly encouraged and thought to be importation in the development of the child. The growth of the disability movement, the incorporation of functioning into the classification of disabilities, and the increase in availability of assistive technology are also thought to contribute to changing philosophies. However, many parents may still want to avoid their child's use of a wheelchair. Reasons for this may include difficulty accepting their child's disability and loss of "normality," perceiving it as giving up on their child's ability to walk, and fear of the social attitudes of others. Bottos et al (2001) conducted a study in which power wheelchairs were introduced to 29 young children with mobility impairments. At the initial interview of the parents, the majority (21 of 25) were opposed to their child using a power wheelchair. However, after their child had experimented with and used the power wheelchair, 23 of 25 of the parents expressed positive feelings. The parents noted an increase in activity, improvements in the child's behavior ('happier'), and an increase in their child's level of independence.

Evaluation tools do exist that can assist clinicians in determining the appropriateness of powered mobility for children. Tefft and colleges have investigated the cognitive factors that influence the ability for children to successfully master powered mobility. Tefft (1999) studied 26 children between the ages of 20 and 36 months that had disabilities with little or no cognitive impairment and were able to drive with a conventional joystick. The children were given Piagetian-based cognitive development tests to assess the child's performance in the areas of object permanence, cause-effect, problem solving, spatial relations, and symbolic play. The children were also given six one-hour sessions on power wheelchair driving (per performance in dynamic wheelchair driving tasks). After the training, 11 of the 26 children were successful at driving a power wheelchair. It was found that achieving above a certain developmental score in the spatial relations and problem-solving tests was predictive of the ability to learn to drive a power wheelchair. The spatial relations and problem-solving tests were combined to form the Pediatric Powered Wheelchair Screening Test (PPWST). The PPWST was further studied by Furumasu (2004). Furumasu studied 50 children between the ages of 21 months and 6 years 11 months with various disabilities and methods of access for driving. The children were administered the PPWST, along with an assessment of symbolic representation and coping skills. For children with orthopedic/neuromuscular disabilities (without cognitive deficits), the symbolic representation and coping tests did not add predictive power for successful driving over using only the PPWST. For children with cerebral palsy (including cognitive deficits), adding the symbolic representation to the PPWST increased the predictive power. Among children using switches, only problem-solving scores were significant for predicting successful driving, thus the PPWST is not an adequate predictive tool. Several other studies have looked at young children and powered wheelchairs and found that many children are able to competently drive a powered wheelchair (Bottos et al 2001, Butler et al 1983, 1984, Jones et al 2003). This process, though, may require many practice sessions and much teacher patience. Bottos et al (2001) found that successful driving was not statistically related to the IQ or motor impairment of the child, but rather it was correlated to the time spent in the power wheelchair.

Several studies have explored factors that influence children with disabilities who use manual wheelchairs for mobility. Jarvis and Rolfe (1982) conducted a study to look at the effects of wheelchair positioning for children with disabilities who use a manual wheelchair.

Using a wheelchair with six positions for the axel (three wide by two high), they found that the axel in the "center high" position (about midway through the seat depth with the handrim 15 cm above the seat level) provided the children with disabilities with the most dynamic output. For children in manual wheelchairs, studies have shown that an exercise routine that includes upper extremity muscular strengthening can significantly impact wheelchair propulsion. Studies by O'Connell et at (1992, 1995) had children with Cerebral Palsy and Spina Bifida complete an 8-9 week circuit-training program. Afterwards, the children had increased muscle endurance when propelling, decrease time for a 50-m dash, and increased distance traveled in a 12 minute propulsion test. A study by Bednarczyk and Danderson (1994) investigated the differences in propulsion techniques in adults and children with spinal cord injuries. They used 3-dimensional video analysis to determine the movement of upper body angles during propulsion. The study found that overall, there was little difference in the propulsion patterns between the adults and children. Both populations spend approximately 25% of their propulsion cycle actively pushing. Also, the upper extremity body angles were similar between the groups. Thus, research and clinical practices for the adult wheelchair users may be applicable to the pediatric population.

As far as actual wheelchair usage is concerned, there are no studies to date that quantify usage characteristics of children wheelchair users. Butler et al (1983, 1984) studied the ability of very young children to learn to drive power wheelchairs with little instructioning. The parents of the children in this study were asked to keep a daily log of their children's activity. They also were to record the readings of an engine-hour-meter, representing the amount of time the wheelchair was in motion. However, this does not give any information on the distances or speeds traveled by the children in the wheelchairs. To gain a true understanding of wheelchairs usage patterns, users should be observed in their every day environment during their daily routine through a quantifiable method.

1.1. Specific Aims and Research Questions

The objective of this descriptive study is to investigate the usage characteristics of children wheelchair users. This is accomplished by utilizing dataloggers to quantify how far and how fast children drive or propel their wheelchairs, as well as observing the movement time data. Including usage data from children with data previously collected from adults will create a well-rounded sample of wheelchair usage information that covers the life span. The information collected could then direct improvements in wheelchair designs, including batteries, motors, frames, and drive components, and lead to changes in the process of recommending wheelchairs for persons with disabilities. The research questions for this study include:

Question 1: Do children power wheelchair or manual wheelchair users travel longer average daily distances and at faster average speeds?

Question 2: Is there a difference in the average distance or speed traveled between male and female children wheelchair users?

Question 3: Will children wheelchair users, on average, travel further during weekdays than they travel on weekend days?

2. METHODS

The methodology used in this study was taken from the protocol approved by the University of Pittsburgh Institutional Review Board (IRB) protocol #0301129.

2.1. Subjects and Recruitment

Subjects were eligible for participation in this study if they 1) independently utilize a wheelchair, manual or electric powered, as their primary source of mobility, 2) are between the ages of 6-17 years old, and 3) were available to meet with study investigators as necessary. In order to represent a broad population, recruitment of subjects for this study was not limited on the basis of diagnosis. Intentions were to have acceptable data from 10 manual and 10 electric powered children wheelchair users, for a total of 20 community based wheelchair users. In order to obtain these numbers, 12 manual and 11 electric powered children were actually consented for this study, as data from two manual and one electric powered wheelchair users were unusable. The manual wheelchair users (n=10) in this study reported the disabilities of cerebral palsy (n=2) and spina bifida (n=8). This included four females and six males. The power wheelchair users (n=10) in this study reported the disabilities of cerebral palsy (n=4), Duchenne muscular dystrophy (n=2), spina bifida (n=3), and spinal cord injury (n=1). This included five females and five males. Overall, nine females and 11 males participated in the study.

Subjects for this study were recruited through several facilities and clinicians in the Pittsburgh area. This includes the University of Pittsburgh Medical Center (UPMC) Center for Assistive Technology, the Children's Institute, the Children's Hospital of Pittsburgh Spina Bifida Clinic, community disability organizations, local clinicians, and local durable medical equipment vendors. Recruitment involved study fliers and "word of mouth" by clinicians and study investigators. Parents of potential subjects were provided with contact information of study investigators and were asked to contact investigators if they were interested in having their child participate in the study.

2.2. Instrumentation

The Human Engineering Research Laboratories (HERL), in Pittsburgh, PA has successfully developed a datalogging device that records distance traveled, speed, and time of wheelchair usage (Spaeth 2000). This device is weather-resistant and portable and can be unobtrusively attachable to a power or manual wheelchair. The original design of the datalogger, which was used for the power wheelchair subjects in this study, utilizes a commercially available TFX-11 datalogger/computer board[a] that is held in a custom designed aluminum casing (Figure 1). Two 9-volt batteries power the device for up to two weeks. A magnet is attached to the tire or wheel hub of the wheelchair and a reed switch is attached to the frame of the chair opposite to the magnet.

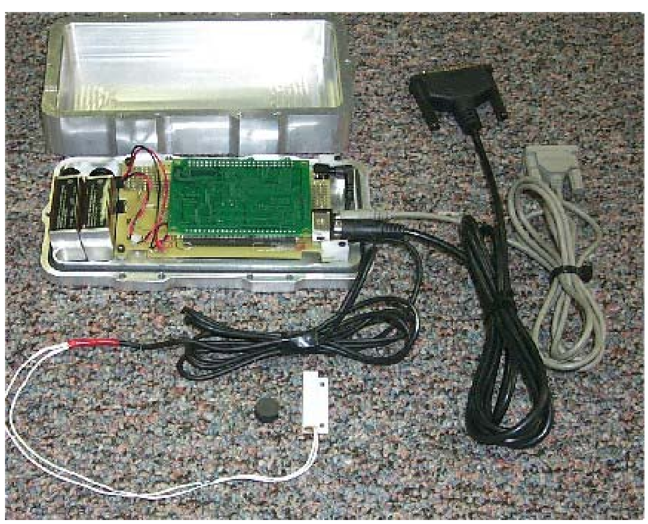

Figure 1: Datalogger for Power Wheelchairs

While the wheelchair is in motion, the data from the reed switch is recorded as a date/time stamp each time the magnet passes the reed switch. The recorded stamps are analyzed using a custom software program written in MATLAB,[b] assuming that the wheelchair has traveled a distance equal to the wheel circumference each time the magnet passes the reed switch. The software program thus uses the frequency and time of sensor hits to find the average distances and speeds traveled per hour.

A smaller second-generation datalogger has been designed and tested for use on manual wheelchairs (Spaeth 2004). These "mini-dataloggers" were used for data collection on the children using manual wheelchair in this study. The mini-dataloggers are 5 cm in diameter and 4 cm in depth and easily clip onto the spokes of a wheel (Figure 2). When the mini-datalogger enclosure rotates with the wheel, a magnet mounted on a pendulum swings past three miniature reed switches. The magnet passing a reed switch is recorded as a data/time stamp, as in the original design. The recorded stamps are analyzed in MATLAB,[b] assuming that the wheelchair has traveled a distance equal to one-third the wheel circumference each time the magnet passes the reed switch (i.e. three sensor hits in sequence represents one wheel rotation). The output of the program is distance and speed of the wheelchair in one hour increments.

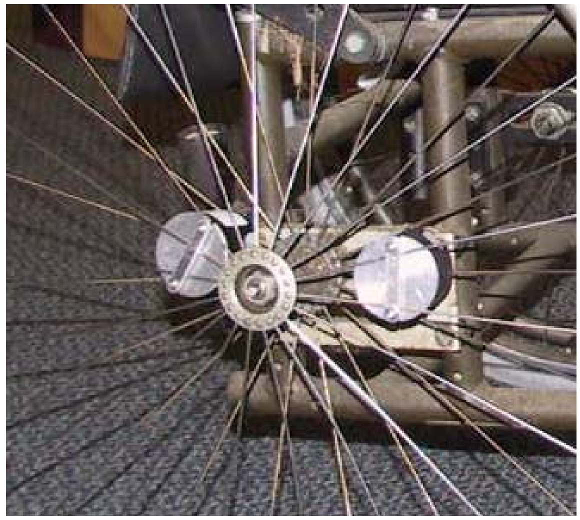

Figure 2: Mini-Dataloggers for Manual Wheelchairs

2.3. Protocol

This study protocol was approval by the University of Pittsburgh Institutional Review Board prior to beginning recruitment. A parent of the children subjects signed an informed consent form to allow their child to participate in the study. This was completed either in person or by mailings. After informed consent was obtained, the subjects or their parents provided information on basic demographics of the subject (age, contact information, diagnosis, etc,) and characteristics of their wheelchair using the two forms shown in Appendix A and Appendix B.

Each child's wheelchair was then instrumented with a datalogger. The datalogger was attached to wheelchair for five to seven days. During this time, the participants were instructed to go about their daily activities as usual. After the five to seven days, the datalogger was removed from the wheelchair by a study investigator at a mutually agreed upon location. A few of the manual wheelchair dataloggers were removed by an informed adult and returned to investigators by mail.

2.4. Data Management and Statistical Analysis

Once the datalogger was removed from a subject's wheelchair, the raw data were downloaded onto a personal computer. The raw data represent a list of date and time stamps when a magnet pass was detected by the sensor switch(es). These data were then analyzed in a custom written MATLAB©[b] program, which determines the average distance and speed traveled in one hour increments per a 24 hour period for each day of the study, as described in Cooper et al (2002). All data were entered into an Access[c] database for ease of management.

Comparisons were made within three groupings of the data. In examining the usage characteristics of children power wheelchair and manual wheelchair users (2 groups), comparisons were made between the average daily distance, speeds, age, and number of years in a wheelchair (continuous variables). Comparisons were made between the male and female children wheelchair users in the average distance and speeds traveled, as well as between weekday and weekend distance traveled.

All statistical analyses were completed using SPSS.[d] A skewness factor was calculated for each comparison data set to determine the normalcy of the data. Normally distributed data were assumed with a skewness factor greater than –1 and less than +1. The ages of the power and manual wheelchair users were normally distributed (skewness = -0.587) and an independent t-test was used to determine differences in the 2 groups. In all other data sets, a non-parametric Mann-Whitney U test was used. Significance between two groups was set at $P < 0.05$. Pearson correlation coefficients were used to analyze correlation between age, distance, and speed traveled.

3. RESULTS

Table 1 shows a comparison of the demographics between the manual (n=10) and power wheelchair (n=10) groups. The two groups were similar as no significant differences were found in the average subject age or the mean years of wheelchair use. Table 2 displays the types and Medicare Healthcare Common Procedure Coding System (HCPCS) codes of the wheelchairs used by the subjects in this study.

Table 1: Comparison of Demographics Between Manual and Power Wheelchair Groups

Variables	Total (n=20)	Manual (n=10)	Power (n=10)	*P*
Age (mean ± SD)	13.8 ± 2.6	13.8 ± 2.6	13.8 ± 2.7	0.796
Years in wheelchair (mean ± SD)	8.2 ± 3.1	8.6 ± 3.0	7.7 ± 3.4	0.535
Gender	9 females 11 males	5 females 5 males	4 females 6 males	

Table 2: Types and HCPCS Codes of Subject's Wheelchairs

	Manual Group	Power Group
HCPCS Code	K0005 (9) E1237 (1)	K0005 with E0983 (1) K0011 (5) K0014 (4)
Wheelchairs Used	Quickie 2[e] (6) Invacare MVP[f] (1) Invacare Terminator (1) Invacare Spyder (1) Quickie Zippy (1)	TiLite TRA[g] with E Fix[h] (1) Quickie P200 (1) Invacare/Action Ranger X (2) Permobil Entra[i] (2) Quickie Z-500 (1) Permobil C2KS (1) Permobil Chairman Stander (2)

Figure 3 displays the average distance traveled by the children power wheelchair users and manual wheelchair users over a 24 hour period. On an average day, the manual wheelchair users traveled 1583.6 ± 880.2 meters, while the power wheelchair users traveled 1524.5 ± 1057.0 meters. While the average distance for the manual wheelchair users is slightly larger, the difference is not significant (P = 1.000). The range of average distance traveled by manual wheelchair users was 882.2 to 3674.4 meters and the range for the power wheelchairs was 8.5 to 3929.1 meters. The children were active for an average of 16 hours per day, with the least activity between 11:00 pm and 7:00 am. The manual wheelchair users tended to travel further than power wheelchair users in the morning hours, while the power wheelchair users tended to drive further than manual users in the late afternoon and evening hours. In both the manual and power wheelchair users, the distance traveled, and thus the activity level of the children, continually decrease after 6:00 pm. On average, the manual wheelchair users started/stopped 161 times per day while the power wheelchair users averaged 126 starts/stops.

Figure 4 shows the comparison of the average speeds traveled in a 24 hour day period for children power and manual wheelchair users. The manual wheelchair users traveled at an average speed of 0.67 ± 0.16 meters/sec over the day period and power wheelchair users traveled on average 0.63 ± 0.16 meters/sec. In comparison, these average speeds are not significantly different (P = 0.684). The range of average speeds for manual wheelchair users was 0.39 to 1.42 meters/sec and the range for the power wheelchairs was 0.40 to 0.88 meters/sec.

Pearson correlation coefficient analysis showed that neither distance nor speed traveled was found to correlate with age (r = -0.186, r = -0.080) or number of years in a wheelchair (r = 0.365, r = -0.165) for the children manual wheelchair users. Similarly, for the children power wheelchair users, neither distance nor speed traveled was found to correlate with age (r = 0.111, r = 0.401) or number of years in a wheelchair (r = -0.409, r = 0.225).

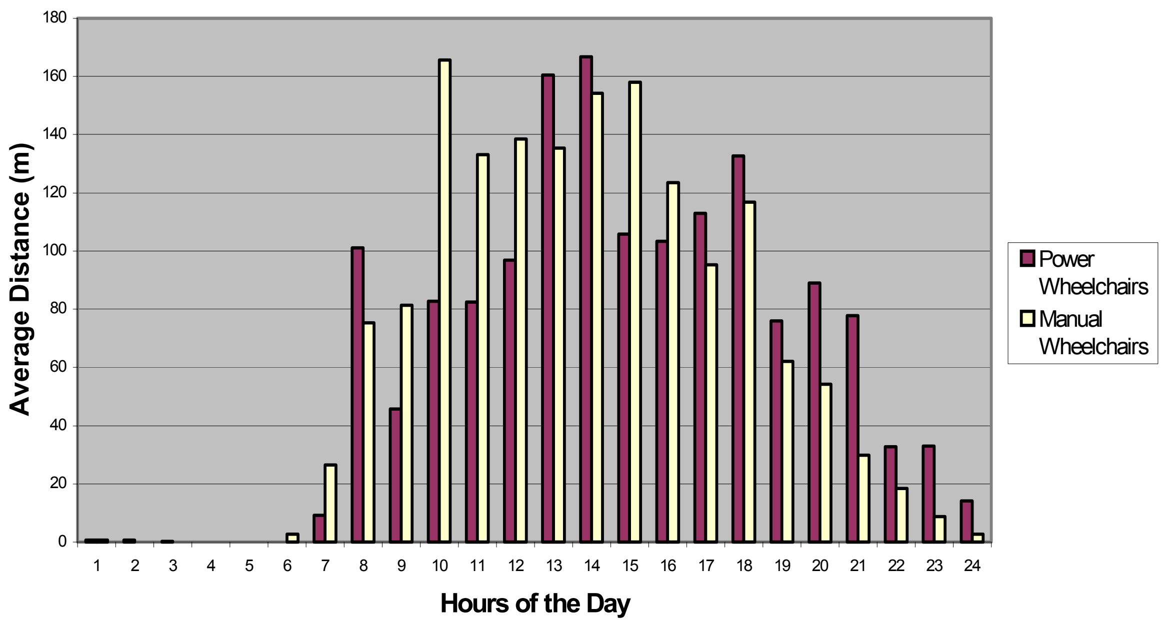

Figure 3: Average Distance per Hour for Children Wheelchair Users

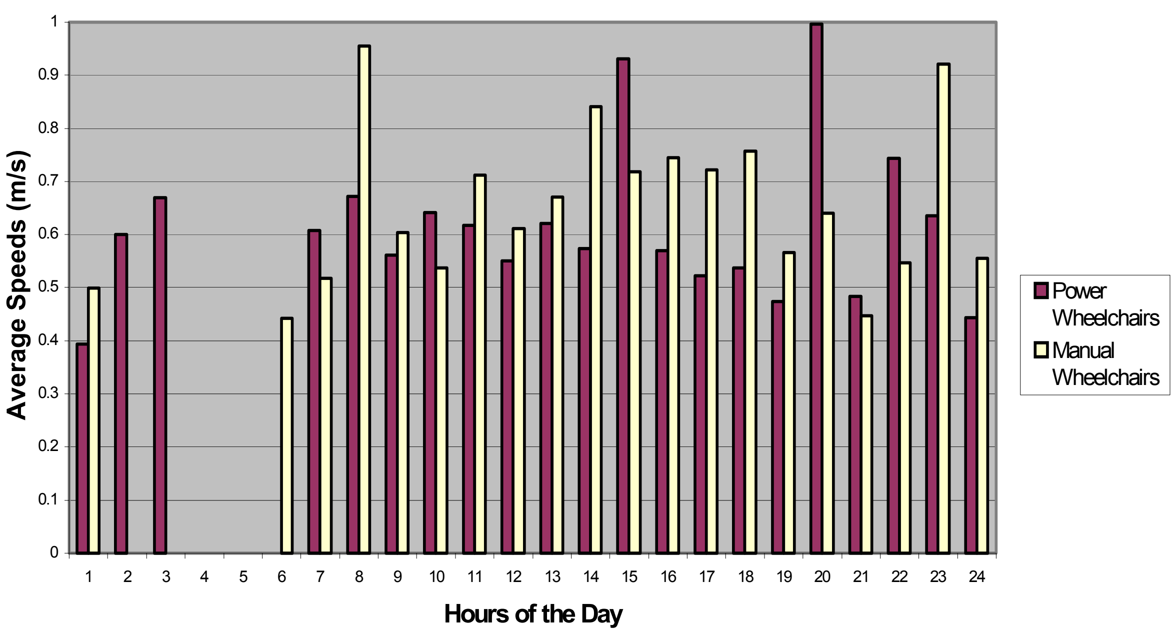

Figure 4: Average Speeds per Hour for Children Wheelchair Users

Regrouping the data from the 20 study subjects by gender allowed for a comparison between male (n=11) and female (n=9) children wheelchair users. Figure 5 shows the average distance traveled in a day for the male and female wheelchair users. The males, on average, traveled 1910.1 ± 1160.0 meters while the females traveled only 1118.9 ± 247.9 meters. This difference is significantly different (P = 0.046). This difference is especially apparent in the hours of high activity between 10:00 am and 6:00 pm. The range of average distance traveled by the males was 8.5 to 3929.1 meters and the range for the females was 882.2 to 1535.4 meters. Figure 6 depicts the average speeds traveled by the males and females. The males averaged 147 starts/stops per day while the females averaged 139 per day. On average, the speeds were similar (P = 0.131) between the males at 0.66 ± 0.14 meters/sec and the females at 0.60 ± 0.19 meters/sec. The range of average speeds traveled by the males was 0.41 to 1.12 meters/sec and the range for the females was 0.39 to 1.42 meters/sec.

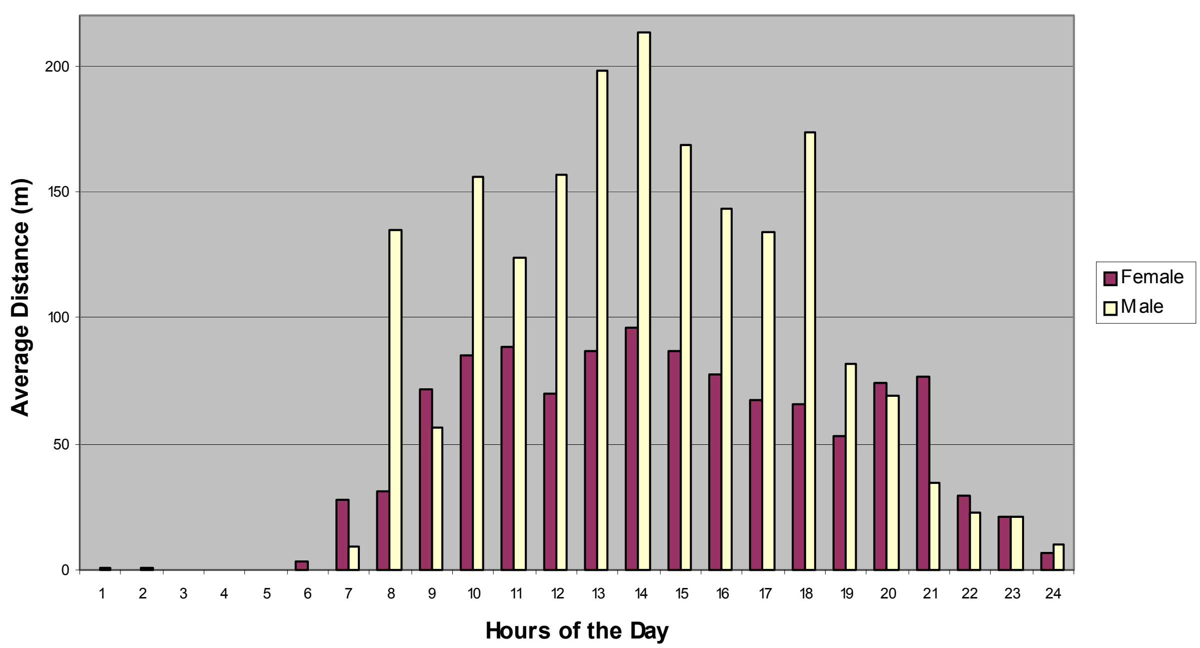

Figure 5: Average Distance Traveled per Gender

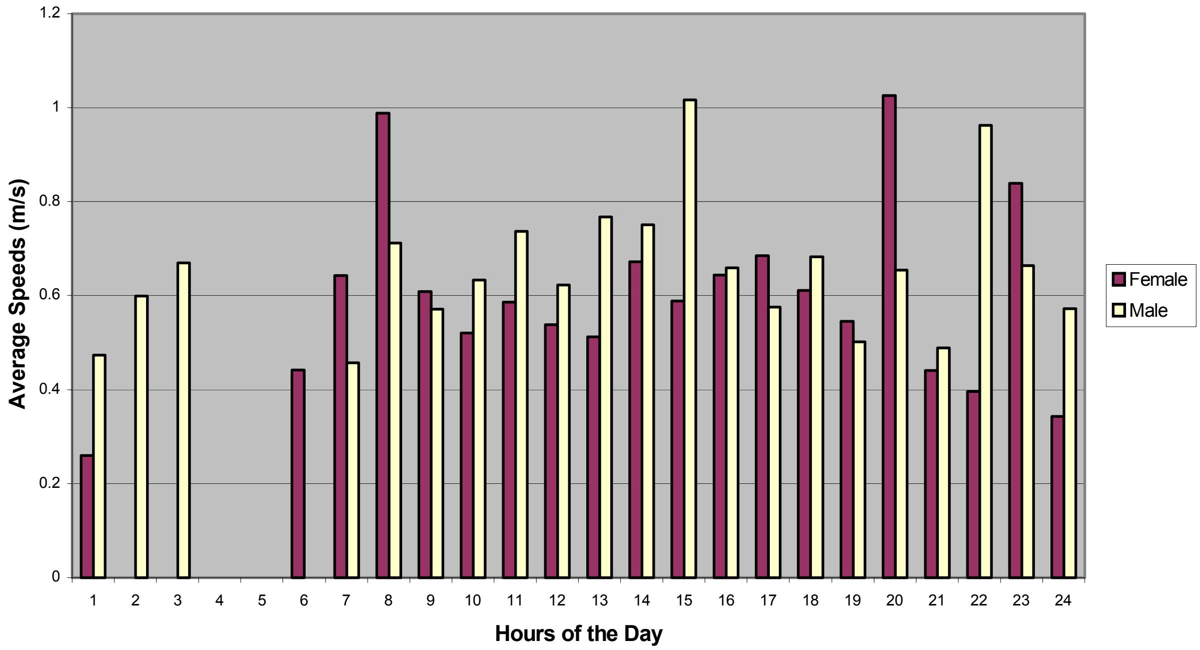

Figure 6: Average Speeds per Gender

Regrouping the data a second way from the 20 study subjects by day of the week allowed for a comparison between travel on weekdays (n=20) and weekend days (n=20) for children wheelchair users. The children were active for an average of 15 hours per day on the weekdays and 12.5 hours on the weekend days. In Figure 7, the average distance traveled in a day is displayed for the weekdays and weekend days. On average, the children traveled 1738.7 ± 1173.5 meters per day on the weekdays and 1088.9 ± 902.8 meters per day on the weekends. The weekday distance is significantly higher than weekend distance (P = 0.035). The weekday distances traveled ranged from 10.9 to 5341.5 meters while the weekend day distances ranged from 6.1 to 3324.4 meters. The difference is less obvious in the evening hours between the hours of 7:00 pm and midnight. Figure 8 shows the average speeds traveled on weekday and weekend days. The average speeds were similar ($P = 0.355$) on the weekdays, at 0.63 ± 0.14 meters/sec (range: 0.40 to 1.33), and on the weekends, at 0.56 ± 0.14 meters/sec (range: 0.34 to 1.19).

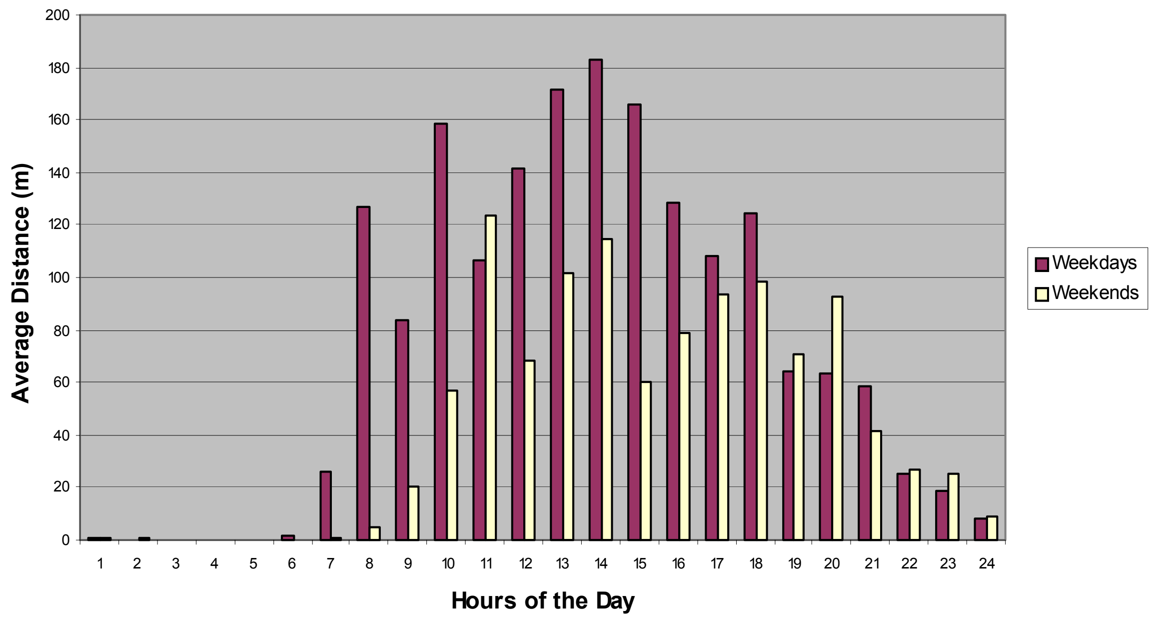

Figure 7: Average Distance Traveled by Children Wheelchair Users on Weekday and Weekends

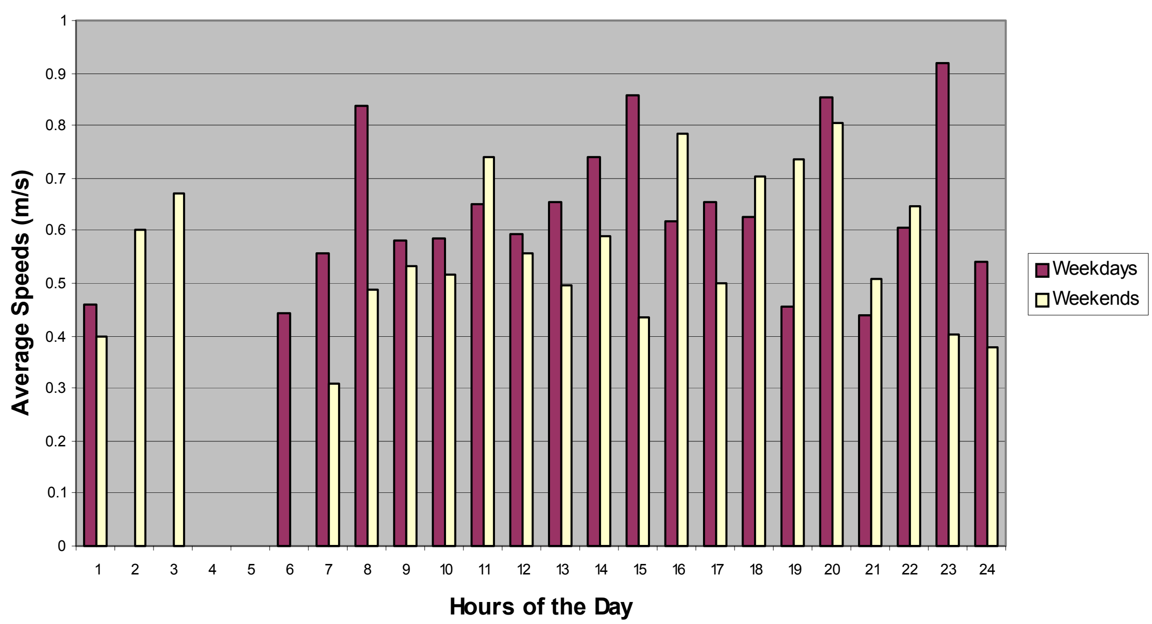

Figure 8: Average Speeds for Children Wheelchair Users on Weekdays and Weekends

In the new mini-datalogger design for manual wheelchairs, there are three sensors (0, 1, 2) that the rotating magnet passes. One rotation of the wheel is represented by three sensor hits in a numerical sequence (i.e., 012012). From the sequence, it can be determined whether the wheel is rotating forwards (012012) or backwards (210210). With this information, the distance traveled forwards and backwards can be separated.

The mini-datalogger was used to collect data for nine manual wheelchair subjects in this study. The average daily distance traveled in the forward and backward directions is shown for the nine subjects in Figure 9. On average, the subjects drove in the forward direction 93.2% of the time and backwards 6.8% of the time.

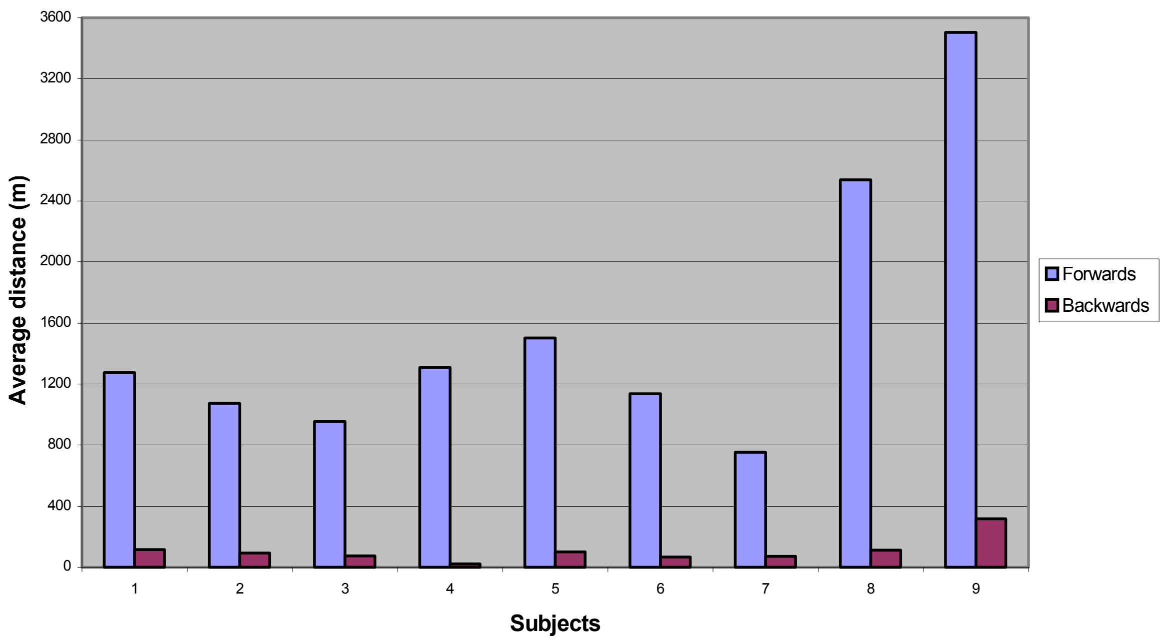

Figure 9: Average Distance Traveled in the Forwards and Backwards Directions

4. DISCUSSION

This study reports that children who use manual wheelchair traveled on average 1583.6 meters per day at an average speed of 0.67 meters/sec. Similarly, the children power wheelchair users traveled 1524.5 meters per day and at 0.63 meters/sec. No significant differences were found between the distance and speeds traveled for children manual and power wheelchair users. Although no other research has been done on the driving characteristics of children wheelchair users, various other studies have investigated the wheelchair usage of adults (over the age of 17). Cooper et al (2002) compared adult power wheelchair users from the National Veterans Wheelchair Games (NVWG) in San Antonio, Texas and community based power wheelchair users in the Pittsburgh, PA area. This study showed fairly high and consistent distance traveled per hour, especially between the hours of 9:00 am and 10:00 pm. The adults had little activity between the hours of 1:00 am and 5:00 am. The adult community based power wheelchair users were reported to travel an average of 1667 meters per day, which is only slightly further than the children power wheelchair users who traveled 1524.5 meters per day. In another study, Hoover et al (2003) compared the driving characteristics of adult manual and power wheelchair users from several NVWG events and from the Pittsburgh, PA community. Similar to this study with children wheelchair users, Hoover found that there was no difference in the distance or speed traveled between the manual and power wheelchair users. The wheelchair subjects in the study were participating in the NVWG, which includes periods of high activity, and thus they traveled further than the community based children subjects. The manual wheelchair adult subjects were found to travel at the average speed of 0.53 meter/sec and the power wheelchair users traveled at 0.71 meters/sec. The study showed activity mainly between the hours of 7:00 am and midnight. Cooper et al (2004) also studied the usage patterns of adult wheelchair users. The study included community based manual and power wheelchair users. It was shown that the power wheelchair users did travel a significantly further distance than the manual wheelchair users. For the overall group, the study did not find a relationship between age and the distance traveled for wheelchair users. In a study by Arva et al (2001), seven adult manual wheelchair users were found to have traveled an average of 1627.9 meters per day at averages speeds of 0.47 meters per second. Another study, conducted by Janssen et al (1987) in the Netherlands, used surveys and an odometer to investigate the distance traveled by manual wheelchair users. It was found that the wheelchair users traveled an average of 628.9 meters per day. In comparison overall, the children wheelchair users show similar driving characteristics in speed and distance traveled to adult wheelchair users.

In the children manual and power wheelchair user groups, the distance traveled, and thus the activity level of the children, is generally less after 4:00 pm than the daytime activity level. Also, the manual wheelchair users tended to travel further than power wheelchair users in the morning hours, while the power wheelchair users tended to drive further than manual users in the late afternoon and evening hours. The limited information collected in this study does not lead to a clear explanation for these tendencies. It may be that the subjects used alternate wheelchairs or modes of movement in the evening hours while most likely to be in the home. Palisano et al (2003) completed a study that investigates the modes of mobility utilized by children with Cerebral Palsy (CP) in the home, school, and outdoor environments. They found that for mobility at school, children with level III CP use manual or powered wheelchairs (34%), walk with support (15%), rolls/crawls/creeps (8%), are pushed in a wheelchair (39%), and are carried by an adult (4%). In the home setting, the children use manual or powered wheelchairs (18%), walk with support (7%), rolls/crawls/creeps (46%), are pushed in a wheelchair (10%), and are carried by an adult (18%). Thus, in the home, children were less likely to use wheelchairs for mobility (28% vs. 73% at school), and more likely to be carried/crawl/walk (71% vs. 27%). One might think that power wheelchairs would be used less in the home environment because of their larger size and space required to maneuver. However, the children power wheelchair users traveled further in the evening hours as compared to the manual users. This could indicate that many parents have adapted the home environment for full accessibility for their children in power wheelchairs. Also, the manual wheelchair users may find mobility in the home difficult due to obstacles such as carpeting.

In exploring the differences gender has on children's wheelchair usage, this study indicates that males tend to travel longer distances per day and at higher speeds. The males, on average, traveled 1910.1 meters a day and females traveled 1118.9 meters. Though not significantly higher, the male children traveled at speeds of at 0.66 meters/sec compared to the females, who traveled at 0.60 meters/sec. This result appears to support the findings of other research studies, involving non-disabled children, in that males are more active than their female counterparts (Santos 2003, Baranowski 1993, Finn 2002). Social attitudes and gender stereotypes may be prevalent even about children with disabilities. Also, the males may have more muscle mass and upper body strength than the females for manual wheelchair propulsion. Collecting additional data on what types of activities the children participate in each day could provide more insight into explaining these differences.

The children appear to be more active on weekdays as compared to the weekends. For reference, some of the subjects were tested during the school year while others were tested during the summer months when school is out. They were active for an average of 2.5 additional hours on weekdays. On average, the children traveled 1738.7 meters per day on the weekdays and 1088.9 meters per day on the weekends. The different is less obvious in the evening hours between the hours of 7:00 pm and midnight. The average speeds were similar on the weekdays and on the weekends. During the school year, the children might generally have earlier bedtimes during the weekdays than on weekends, but they also seem to wake up earlier during weekdays, as to get ready for school. Also, they can travel large distances through the hallways of their school in order to get to different classrooms. During the summer months, the children's schedule and activity level may depend more on their parent's schedule. The weekend activity level may vary greatly between different children depending on how many activities they may be involved in and also on the activity levels of their family members. Another possible explanation is that the children use alternative modes of mobility when in the home or when they do not have to go outside the home.

Of the children manual wheelchair users in this study, nine children used wheelchairs coded by Medicare as K0005 (ultra lightweight wheelchair). The K0005 wheelchairs tend to be more durable and have few serious frame failures as compared to K0004 wheelchairs. K0005 wheelchairs are also more cost effective to own (Fitzgerald 2001). The axel position can be adjusted on K0005 wheelchairs to create appropriate body positioning for efficient propulsion and lessened strain on the upper extremities. Nine power wheelchair subjects also utilized higher end wheelchairs in the K0011 (Standard lightweight frame power wheelchair with programmable control) and K0014 (Other motorized/power wheelchair base) categories. Some of the children also utilize power wheelchairs equipped with the standing function and advanced technology alternative drive controls. It appears that these children have reasonable access to new technology available related to wheelchairs.

With this study, there are a few limitations to note. The sample size of subjects is small at only 20 children, 10 manual and 10 power wheelchair users. This makes statistical analysis difficult because breaking down the subjects into specific groups depending on wheelchair type, gender, etc., may result in groups with two to three subjects. Data collected from additional subjects would provide for more representative averages for distance and speed calculations. The subjects in this study were recruited at different times during the year so the subject pool is mixed between collection during summer months and months when the children are in school. While in school, the children's schedules are more regular in times when they wake up, go to bed, and how much activity they are involved with during school hours. The collection period for this study was only five to seven days. During one week, the children may have a day with extreme wheelchair use particular to their specific activities. Collecting data for two or more weeks would provide a more average sample of their activity levels. This study did not investigate whether the children utilize more than one wheelchair during the day. They may have a wheelchair they use for the majority of the time and another wheelchair they use at home or for different situations, such as transportation in family vehicles. If the children do in fact use multiple wheelchairs, this study would have underestimated their activity levels. Also, technical problems with the dataloggers created some data analysis issues. However, ongoing work with the design of the datalogger will hopefully limit these problems.

For future studies, various changes can be made in the study protocol in attempt to control some of the limitations mentioned above. Daily activity log information should be collected to gain insight as to how the children use their wheelchairs. It could also be learned what type of activities the children participate in and how much of their daily activity is based at home and how much is within the community. The data collection period should be increased to at least two weeks. If the child utilizes more than one wheelchair, data could be collected from multiple wheelchairs to have an accurate total of wheelchair usage. Another possible addition to the study would be to test the subjects for two sessions, one during the summer time and another time when they are in school. Including any differences would more accurately predict a yearly summary of children's wheelchair usage. Other subjects could also be included in the study protocol, such as children in manual wheelchairs who are unable to independently propel or drive themselves and children who utilize manual wheelchairs with pushrim activate power assist units. It would also be interesting to collection information from the children manual wheelchair users about upper extremity pain related to wheelchair propulsion. From interacting with this population of children under the age of 18, it quite disturbingly seemed that several manual users had issues with shoulder pain. Some children manual users and their parents expressed interest in learning more about powered mobility and pushrim activated power assist wheelchairs (PAPAWs). Several studies have already shown the upper extremity repetitive strain injuries and pain are prevalent in many adult manual wheelchair users (Boninger et al 2000). For a follow-up study, it would be interesting to examine the activity level of children before and after obtaining a wheelchair or a change in type of wheelchair since there is no such information available.

5. CONCLUSIONS

Among information about children with disabilities who use wheelchairs for their mobility needs, there is little quantitative data with respect to the actual utilization characteristics of wheelchairs. Using datalogging devices, daily distance traveled, traveling speeds, and movement time data was recorded and analyzed for children who use manual and power wheelchairs. It was found that children manual and powered wheelchair users travel similar total distances per day and at speeds that are not significantly different. The average distance and speeds traveled by the children wheelchair users are comparable to the reported distances and speeds for adult wheelchair users. According to gender, the male children traveled further per day and at faster speeds than the females in this study. Children wheelchair users appear to use their wheelchairs more on the weekdays as compared to the weekend days, as noted by larger distances and faster speeds traveled. Further studies should record data for a longer period of time and collect information on the daily activities of the subjects to investigate how and where the children use their wheelchairs.

APPENDIX A

DEMOGRAPHICS FORM 1

Participant Contact Information (Taken after Consent)

[Date: ______-Time:______]

Name: ____ Age: ________

Address: _______________________________________ Diagnosis: ________

____

Phone Number: _________________________________

Information Regarding Your Wheelchair

Wheelchair Make: ____________________________ Model: __________________

Battery Supply Currently Used (If applicable): __ Gel __ Lead Acid

Average Amount of Time Before You Charge Your Battery (if applicable)? _________

Number of Years utilizing Wheelchair: ___________

Age of Current Wheelchair: ____________ Wheel Diameter: ____________

Additional Comments:

____

____

____

____

APPENDIX B

DEMOGRAPHICS FORM 2

0=No, 1=Yes, -1=missing data, -2=N/A

General Intake Information

(To be completed once subject has signed consent)

IRB#___________________________ **Date/Time:______________**

Subject ID_________________________

SS#_______________________________

DOB:_____________________________

Age:______________________________

Gender: (circle) Female (1)/Male (0)

Veteran circle: YES (1)/NO (0) **Ethnic Origin:**

_1_ African American
_2_ Asian American
_3_ Caucasian
_4_ Hispanic
_5_ Native American
_6_ Other

Injury Level or Disability: _______________________________

Date of Injury or Onset of Disability:______________________

Are you currently using: ________ Manual w/c _________ Power w/c

Type of Wheelchair: _____________________Model:___________________

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