Monitoring Power Upright and Tilt-In-Space Wheelchair Use

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ABSTRACT

This study examines the use of power upright and power tilt-in-space (TIS) wheelchairs. An occupancy detector, wheel revolution counter, and position sensor comprise the Wheelchair Activity Monitoring Instrument as used in this study. On average, subjects sat in their wheelchairs for 10 hours per day, spent 50 (±24) minutes wheeling with an average daily distance traveled of 0.84 miles. The majority of mobility bouts were less than 30 seconds and shorter than 25 feet. Subjects with TIS used their tilt feature (at least a 15° change in position) 16±10 times and spent between 0 and 108 minutes at a fully tilted (>40°) position daily.

KEYWORDS

Activity monitoring, power wheelchair, tilt-in-space, data logger

INTRODUCTION

Information about peoples' daily activities is often collected with observation and self-report measures such as diaries and surveys. Although these approaches are valuable, they can be burdensome and limited in accuracy [1] and they only provide a broad overview of activity. In addition to understanding average activity, it is important to be able to describe the activity patterns throughout the day. Whether activity occurs in many short bouts or over few long bouts may have implications for understanding activity and use of assistive technology.

Little literature is available concerning the use of power wheelchairs. In fact, to date, only a single paper has discussed the actual amount of time spent driving a wheelchair. The authors found that community members who used wheelchairs wheeled approximately 1-1.5 miles per day. Their average travel speed was less than 1.5 mph [2].

This study aims to describe the use of power upright and power TIS wheelchairs in terms of wheeling and variable positions using the Wheelchair Activity Monitoring Instrument (WhAMI). In particular, the data describe patterns of mobility and tilt feature usage throughout the day in addition to daily summaries.

METHODS

A convenience sample of adults ages 18-60 with some affiliation to the location spinal cord injury rehabilitation center (employees, gym members, and patients) who used power upright or power tilt-in-space (TIS) wheelchairs as their primary mobility devices were recruited for this study with IRB approval. Subjects signed informed consent forms prior to beginning their participation in the study.

Subjects' wheelchairs were instrumented with the WhAMI for 1-2 weeks (depending on scheduling availability). Wheel counts were recorded on a single wheel using a reed switch (2060 series, Reed Switch Developments Corp, Racine, WI) and 2-4 evenly spaced Neodymium magnets (K&J Magnetics, Inc., Warminster, PA). Position was measured with a uniaxial accelerometer (VTI Technologies, Finland) and seat occupancy was measured using different configurations of Controflex Ribbon Switches depending on the cushion (Tapeswitch, Farmingdale, NY). Data was recorded in two second epochs on a custom data logger known as the Science Monitor (Levo and Consonics, Switzerland). Data logged included the sum of wheel counts over the epoch, the state of occupancy as a binary value and the position of the accelerometer at the end of the epoch.

Post-processing of the data was done with custom code by GeoStats (Atlanta, GA) and in house using custom Matlab code. Wheel counts were converted to distances by:

$$\text{Distance} = \#\,Counts * \frac{WheelDiameter * \pi}{\#Magnets}$$

Using this data, mobility bouts were calculated. A mobility bout is defined as a bout of movement initiated when a subject travels a minimum of 2 feet within four seconds and continues until the subject travels less than 2.5 feet over 14 seconds. This allows for natural hesitations in movement but identifies pauses meant to accomplish tasks as ends of bouts. These values were identified empirically based on observation and data collection of people using power wheelchairs to perform typical office tasks such as checking their mail or making copies. Thus, bouts of mobility tend to serve as transitions between stationary activities. In some cases, however, longer bouts reflect the activity itself. Using the start time, distance traveled and duration of each bout, the following parameters were calculated: total daily travel distance, total daily travel time and number of daily bouts.

The position data was post-processed to identify tilt maneuvers defined as position changes of more than 15°. To count as a tilt maneuver, the position had to remain relatively constant (with a standard deviation of ± 2° or less) for at least 1 minute in both the original and final positions. Tilt maneuvers are defined to identify use of the chair's tilt feature and include both position changes to sit in a more tilted position, as well as return tilts to an upright seating position.

RESULTS

Data was collected from seventeen subjects, 10 male and 7 female, who used power upright (n=7) or power TIS (n=10) wheelchairs. Subject ages ranged from 20 to 64 years old. While most subjects had spinal cord injuries, others had cerebral palsy, multiple sclerosis, muscular dystrophy, and post-polio syndrome. Given the many challenges of instrumenting a wheelchair, not all data collection was successful. The data presented here reflects data for subjects for whom the sensor performed accurately over the course of instrumentation.

Occupancy: The wheelchair itself was used by subjects, whether as a seat or a mobility device for 10.2±2.2 hours per day (Table 1). Actual daily usage exceeded 17 hours on at least one day.

Table 1: Daily Occupancy Time in Hours

Subj #	Mean	Std	Min	Max
1	6.3	4.9	0.0	10.9
2	11.7	1.8	9.5	14.3
3	11.2	1.3	9.3	12.9
5	9.6	2.7	5.2	13.1
6	8.2	2.2	6.0	10.4
7	9.2	1.5	8.1	11.3
8	9.0	1.2	6.9	11.4
10	14.1	2.8	9.3	17.6
11	11.7	2.7	4.8	14.7
17	9.3	1.3	8.4	12.1

Mobility: Subjects averaged 50 minutes (±24) of wheeling daily, with days varying from 0 to 135 minutes over all days collected (Table 2). The corresponding daily distances averaged 0.84 miles (± 0.90

miles). The largest distance these subjects traveled in a given day was greater than six miles. Subject movements were split into bouts of mobility as defined in the methods. The average subject had more than 100 bouts on a given day. 69% of bouts lasted less than 30 seconds and had a distance of less than 25 feet. Only 12% of bouts lasted more than one minute and only 16% of bouts extended beyond 50 feet.

Table 2: Mobility Patterns in the Wheelchair

Total # Bouts				Travel Time (minutes)				Total Distance (miles)			
Mean	Std	Min	Max	Mean	Std	Min	Max	Mean	Std	Min	Max
47	31	0	88	17	15	0	38	0.33	0.44	0.00	1.18
282	91	166	441	74	30	32	119	0.90	0.43	0.38	1.66
69	24	19	111	88	36	17	135	3.45	2.11	0.49	6.35
91	32	36	148	51	24	15	94	0.97	0.54	0.19	1.90
59	23	25	98	26	12	9	47	0.23	0.16	0.07	0.58
212	96	53	405	77	31	14	121	0.77	0.31	0.15	1.24
77	19	35	108	68	33	12	117	0.73	0.44	0.08	1.35
69	13	48	100	39	8	30	56	0.66	0.15	0.46	0.99
87	17	58	108	36	9	25	58	0.44	0.16	0.25	0.87
140	45	81	261	53	19	31	107	0.38	0.19	0.19	0.95
51	25	7	114	22	12	2	52	0.40	0.23	0.03	0.97

Use of Tilt-in-Space Feature: Subjects used the TIS feature of their wheelchairs to perform tilt maneuvers an average of 16 ± 10 times per day (Table 3), but the daily values varied from 0 to 42. The amount of time spent in a fully tilted position (more than 40° of tilt from the horizontal) varied greatly across subjects (Figure 1) from 0 to 108 minutes with an average of 28 minutes per day. Five of the eight subjects monitored sat in a full tilt for less than 15 minutes daily.

Table 3: Number of Tilt Maneuvers Daily (Position Change in either direction >15°)

Subj #	Mean	Std	Min	Max
1	3	4	0	11
2	19	9	10	35
3	1	2	0	4
5	18	7	8	30
6	29	14	14	42
9	29	8	14	41
16	14	6	5	28
17	14	4	9	20

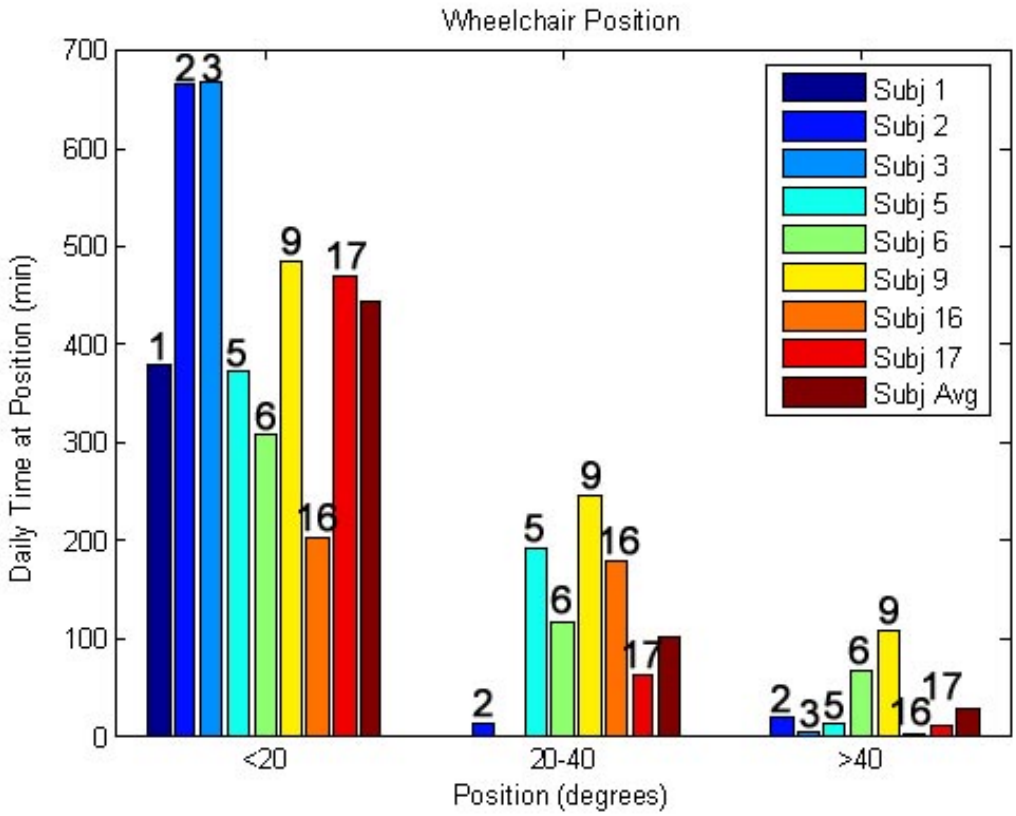
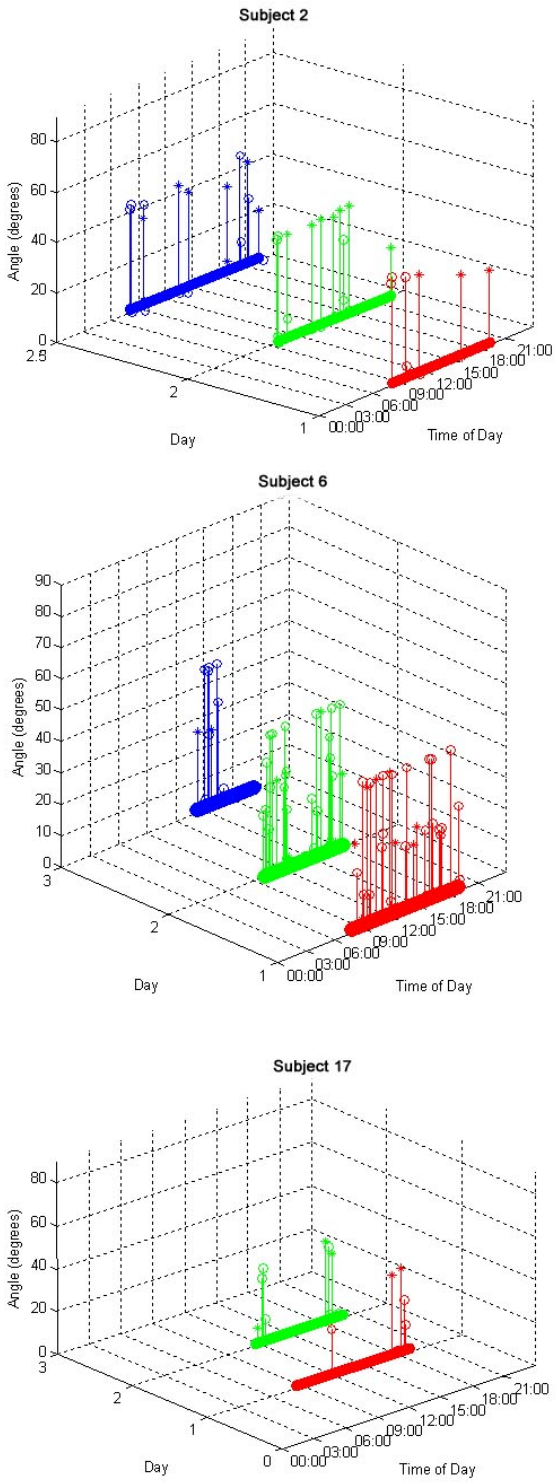


Figure 1: Average time spent at different positions daily varied over the eight subjects.

Figure 2 illustrates some sample subjects' use of the tilt feature. Subject 2 performs tilt maneuvers throughout his time in chair and usually holds the tilts for more than 20 minutes. However, on these days few tilt maneuvers were to a fully tilted position of greater than 40°. Subject 6 performs many more tilt maneuvers on some of the illustrated days, but the positions are often held for less than 20 minutes. Interestingly, this subject seems to have two preferred tilted positions: approximately 20° and 40°. Lastly, Subject 17 performs multiple tilt maneuvers in succession, but only towards the beginning and end of each day.

DISCUSSION

Power wheelchair users in this study traveled less than wheelchair users previously reported [2]. Physical activity literature reports that healthy ambulatory adults walk between 1.5 and 2.7 miles daily [1, 3, 4]. The wheelchair users in this study wheeled less than their ambulatory counterparts. Future work will integrate this data with self report in order to determine the cause of the discrepancy between wheelchair users and ambulatory adults. It may be that environmental barriers limit their mobility or that they choose to move less. Although an instantaneous velocity was not measured, the average speed during 69% of bouts was approximately 0.6mph. This is consistent with the findings of Cooper et. al. who found that average speeds were usually below 1.5 mph. In addition, data indicated that subjects used many small bouts of movement, averaging 100 bouts per day. This result supports the concept that mobility for people who use wheelchairs may function mostly as transitions between activities or spaces. Thus, an overall daily distance may not be the most effective measure of mobility without detailed bout information. While



some of the short bouts might be an artifact of the bout definition, the average speeds are not affected by the definition.

Given clinical suggestions that people do regular weight shifts as often as every 30 minutes, it is interesting to note that during the 10 hours of wheelchair occupancy daily (on average) subjects performed 16 tilt maneuvers. If we assume that tilt maneuvers alternate between tilts and returns to upright, this would imply an average of 8 tilts per day. Only one subject of those included had experienced pressure ulcers on the buttocks within the 30 days preceding the study. Figure 1 illustrates the fact that few of these tilts are complete (>40°). Future work should more closely relate disability, time of wheelchair occupancy and pressure ulcer outcomes to the number and time of tilts performed daily.

Figure 2: Tilt maneuvers for sample days from 3 subjects. Each line represents a tilt maneuver.
o = position was held for < 20 minutes,
* = position was held for > 20 minutes.
The thick band at the bottom of each day represents the time the subject was in the chair.

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REFERENCES
1. Bassett, D.R., Jr., A.L. Cureton, and B.E. Ainsworth, *Measurement of daily walking distance-questionnaire versus pedometer.* Med Sci Sports Exerc, 2000. **32**(5): p. 1018-23.
2. Cooper, R.A., et al., *Driving characteristics of electric-powered wheelchair users: how far, fast, and often do people drive?* Arch Phys Med Rehabil, 2002. **83**(2): p. 250-5.
3. Chan, C.B., et al., *Cross-sectional relationship of pedometer-determined ambulatory activity to indicators of health.* Obes Res, 2003. **11**(12): p. 1563-70.
4. Schneider, P.L., S.E. Crouter, and D.R. Bassett, *Pedometer measures of free-living physical activity: comparison of 13 models.* Med Sci Sports Exerc, 2004. **36**(2): p. 331-5.