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Use of Accelerometers to Examine Sedentary Time on an Acute Stroke Unit

Anna E. Mattlage, BS¹, Sara A. Redlin, DPT¹, Michael A. Rippee, MD², Michael G. Abraham, MD², Marilyn M. Rymer, MD³, and Sandra A. Billinger, PT, PhD¹

¹University of Kansas Medical Center, Dept of Physical Therapy and Rehabilitation Science, 3901 Rainbow Blvd, Mail Stop 2002, Kansas City, KS 66160

²University of Kansas Medical Center, Dept of Neurology, 3901 Rainbow Blvd, Kansas City, KS 66160

³University of Kansas Hospital, 3901 Rainbow Blvd, Kansas City, KS, 66160

Abstract

Background and Purpose—Observational studies demonstrate low levels of physical activity during in-patient stroke rehabilitation. There is no objective measure of sedentary time on the acute stroke unit and whether sedentary time is related to functional outcomes. The purpose of this study was to characterize sedentary time after acute stroke and determine whether there is a relationship to functional performance at discharge.

Methods—Thirty-two individuals (18 males; 56.5 ± 12.7 years) with acute stroke were enrolled within 48 hours of hospital admission. An accelerometer was placed on the stroke-affected ankle to measure 24-hour activity and was worn for 4 days or until discharge from the hospital. Performance of activities of daily living, walking endurance, and functional mobility was assessed using the Physical Performance Test (PPT), Six-Minute Walk Test (6MWT), and Timed-Up and Go (TUG), respectively.

Results—Mean percent time spent sedentary was $93.9 \pm 4.1\%$ and percent time in light activity was $5.1 \pm 2.4\%$. When controlling for baseline performance, the mean time spent sedentary per day was significantly related to PPT performance at discharge ($r = -0.37$; $p = 0.05$), but not the 6MWT or TUG.

Discussion and Conclusions—Patients with acute stroke were sedentary most of their hospital stay. To minimize the potential negative effects of inactivity, our data suggest that there should be an emphasis towards increasing physical activity during the hospital stay. **Video Abstract available** for more insights from the authors (See Video, Supplemental Digital Content 1).

Corresponding Author: Sandra A. Billinger, PT, PhD, University of Kansas Medical Center, Dept of Physical Therapy and Rehabilitation Science, 3901 Rainbow Blvd, Mail Stop 2002, Kansas City, KS 66160, 913-945-6685, 913-588-4568 (fax), sbillinger@kumc.edu.

Part of this work was previously present at the 2014 International Stroke Conference

Preliminary aspects of this work were previously present at the 2014 International Stroke Conference

INTRODUCTION

Older adults recovering from an acute illness in the hospital spend approximately 83% of their day lying in bed and this high level of inactivity has been termed an “underrecognized epidemic.”¹ What do we know about inactivity after acute stroke? In trying to understand activity patterns during stroke recovery, observational studies in Australia and Norway have also examined activity during inpatient stroke rehabilitation and have reported high levels of sedentary time.^{2,3} When observing activity in 10 minute intervals from 8:00 am to 5:00 pm, patients during in-patient stroke rehabilitation were seen in bed or sitting 76% of the day and standing or walking 23% of the day.² Further, greater time spent in bed has been associated with a poorer outcome on the modified Rankin Scale (mRS) at 3 months post-stroke.³ This evidence suggests that during an inpatient rehabilitation stay, individuals after stroke are spending a large majority of their time engaging in sedentary behavior, which could have a negative impact on functional recovery. Because the acute stroke hospital length of stay in the United States (U.S.) is considerably shorter than those conducted in the early mobilization trials (~14 days),^{4,5} it is imperative that we better understand activity patterns during the acute stroke hospital stay in the U.S. so that we can consider strategies aimed at decreasing sedentary time.

Direct observation of people hospitalized with acute stroke is an acceptable method for describing activities performed during the day. However, this method has the potential to miss capturing physical activity that occurs outside of the observed time. For example, the observation studies in people with stroke have typically been conducted during the weekday and during usual work hours (i.e.: 8:00 am to 5:00 pm).^{2,3,5} This limits documentation of activity in the evening hours, nighttime, or on weekends. However, using an objective measure such as accelerometry would allow for continuous 24-hour monitoring (including sleep hours) without additional personnel burden for observation of activity. The accelerometers would provide information on intensity of activity such as light or vigorous activity, steps, and characterization of physical activity patterns in patients with acute stroke. To our knowledge, no objective quantification of physical activity using accelerometers has been conducted during the acute stroke hospital stay in the U.S.

Therefore, the purpose of this study was to objectively assess sedentary time using triaxial accelerometers during the acute U.S. hospital stay of individuals with stroke. We examined whether the amount of time sedentary was related to functional performance at discharge. Based on previous research,¹ we hypothesized that individuals with acute stroke would spend more than 80% of their hospital stay sedentary. Further, we hypothesized that greater mean time spent sedentary over a course of a day would be moderately and significantly related to poorer functional performance on the Physical Performance Test (PPT), 6 Minute Walk Test (6MWT), and Timed-Up and Go (TUG) at discharge from the hospital.

METHODS

Study Design

This study used a prospective design with a sample of convenience. Approval of the project was obtained from the Human Subjects Committee at University of Kansas Medical Center. Institutionally approved written informed consent was obtained prior to study participation.

Participants

Participants between 20–80 years of age were enrolled into the study within 24 – 48 hours of their admission to the certified Comprehensive Stroke Unit at the University of Kansas Hospital with a diagnosis of acute stroke. Participants were admitted into either the neurological progressive care or neurological intensive care units of the hospital. Patients who are suspected of, or diagnosed with, stroke are commonly admitted to these floors. The neurological progressive care unit is staffed with 1 nurse for every 4 patients and several nursing aids across the floor. The intensive care unit is staffed with 1 nurse for every 2 patients as well as several nursing aids. Rehabilitation services are available 7 days per week. Therapy services on the weekends were identical in duration and intensity to those provided during the week day. A comprehensive list of participant demographics can be found in Table 1. Individuals were excluded if they were on physician ordered bed rest.

Overview

After consent an tri-axial accelerometer (ActiGraph GT3X+, ActiGraph LLC, Pensacola, FL) was placed on the stroke-affected limb at the ankle. When the Fugl-Meyer score was 34/34 on both legs ($n = 6$), we collected data from the right ankle. The accelerometer is more reliable when placed on the ankle vs the hip or spine to measure step count in older adults with and without an assistive device.⁶ The water-resistant accelerometers were worn for 24 hours per day until the day of discharge from the hospital, but no longer than 4 days. This timeframe was selected as the maximum length apriori since the average length of stay at XX Hospital for people with acute stroke was 4 days. Our research team would check on the participants throughout the day to make sure the accelerometers were correctly placed and the participants were comfortable with wearing the accelerometers. Nursing staff was given our 24-hour hotline number and if any issues such as non-compliance or skin irritation occurred, they would leave a message and the team would follow up.

The accelerometers monitored 24-hour, real-time activity in all three planes of movement in 10-second epochs. Analysis of sedentary time (in minutes) was performed (ActiLife Version 6.6.3; ActiGraph LLC, Pensacola, FL), including percent time spent in sedentary activity, and in light, moderate, and vigorous activity, steps per day, and time sedentary per day (TSPD). One day was defined as each 24-hour period starting immediately after consent. For example if a person was consented at 3pm, a day would be defined from 3pm until 2:59pm the next day and each day thereafter until discharge. If discharge occurred prior to a “day” then sedentary time was calculated based on the time the accelerometers were worn and not a full 24 hour period as this would bias results. Cut points for intensity of activity were based on information previously reported and validated in adults.⁷ These were based on the following: light, 1951 counts; moderate, 1952 – 5724 counts; and vigorous activity, 5725

counts.⁷ Sedentary time was defined as any activity that does not amount to more than 99 counts (per analysis software). Baseline functional assessments were performed after placement of accelerometers. Follow-up testing was conducted on the day of discharge or four days after baseline testing, whichever came first.

Information regarding participants' lesion size and location, previous medical history, current medications, weight, height, BMI and total therapy minutes for physical and occupational therapy were obtained from each participant's electronic health record. In addition, we gathered information regarding their physical and occupational therapy minutes. The Fugl-Meyer Assessment (FMA) was used to assess motor performance of the lower extremity.⁸ Total score on the lower extremity FMA is 34, and a higher score is indicative of lower stroke impairment. Functional assessments included: PPT, 6MWT, and TUG.

The PPT, an assessment of performance of activities of daily living, has been reported as a valid and reliable test used in many populations including individuals with dementia, Parkinson's disease and those who are elderly.⁹⁻¹³ Although data has not been published in acute stroke, the PPT has been used in individuals who have experienced transient ischemic attack and stroke.¹⁰ The PPT is a test in which the participant completes 9 tasks of activities of daily living. Each task is timed and then scored on a scale of 0 – 4 depending on their time, with 0 indicating unable to complete the task without assistance and 4 indicating completion of the task in the fastest time category. The total score on the PPT is 36, with a higher score indicative of better performance in activities of daily living. The 6MWT was performed according to previous guidelines outlined by the American Thoracic Society.¹⁴ Individuals were asked to walk as far as they could for 6 minutes and the distance walked in meters was recorded. A longer distance walked in 6 minutes is indicative of better walking endurance. Methods of the motor portion of the FMA and the TUG have been described previously.^{8,15} For the TUG, individuals started the test in a seated position. They were instructed to stand up, walk 3 meters to and around a cone, walk back to the chair, and sit down. A faster time on the TUG suggests higher functional mobility. Participants were allowed to rest as needed between functional tasks.

Data Analysis

Descriptive statistics were performed to obtain sample mean percent time spent in sedentary, light, moderate and vigorous activities, sample mean steps per day (SPD), sample mean TSPD, sample mean score on PPT, sample mean distance on the 6MWT, and sample mean time on the TUG. Mean percent time spent sedentary per hour was derived from ActiLife software and then plotted using SigmaPlot (Systat Software Inc, San Jose California). Mean percent time spent in sedentary, light, moderate, and vigorous activities was reported as an overall percent time over the duration of the hospital stay across participants. TSPD was expressed as $100 * (\text{total minutes spent in sedentary time} * 1,440 \text{ minutes}^{-1})$. To assess the relationship between TSPD and functional performance of each variable (PPT, 6MWT, and TUG) at discharge we used a Pearson Correlation. To understand the strength of the relationship between TSPD and functional performance, we used criteria defined by Portney and Watkins:¹⁶ Pearson's coefficient (r) = 0.00 – 0.25, little to no relationship; r = 0.25 –

0.50, fair relationship; $r = 0.50 - 0.75$, moderate to good relationship; and $r > 0.75$, good to excellent relationship. Since admission (or baseline) functional scores have been reported as important predictors of discharge scores in stroke,¹⁷ we took a more conservative approach and controlled for baseline performance in our data analysis for the functional assessments. Statistical methods for the linear regressions were based off of methods previously used.¹⁸ Briefly, we used a multistep, hierarchical linear regression with TPSD as the predictor variable and the PPT score at Time 2 as the response variable controlling for baseline PPT performance. Standardized residuals generated from the linear regression were then plotted. P-values were considered significant at $p \leq 0.05$. All statistical analyses were performed using SPSS (IBM Statistics Software Version 20 Armonk, New York).

RESULTS

We screened 683 individuals with an acute stroke and enrolled 38 participants in our study. Of the 38 enrolled participants, six were not included in the analysis. The reasons for non-enrollment and exclusion from data analysis are outlined in Figure 1. Thirty-two people (18 males; mean age of 56.5 ± 12.7 years) were used for data analysis except for the Timed Up and Go ($n = 23$). If participants were unable to stand up from the chair using the armrests to initiate walking, they were coded as “unable” and not included in the data analysis examining the relationship between sedentary time and functional performance at discharge. These individuals were included in the primary aim, which was describing activity during the acute hospital stay.

Participants spent a mean of 2.5 ± 0.9 days enrolled in our study. Twenty-eight individuals were discharged from the hospital prior to 4 days of enrollment. Therefore, 6 individuals completed 4 full days of accelerometer monitoring. Additionally, 8 individuals were enrolled the same day as their admission to the hospital and 26 were enrolled after their admission date, but within 48 hours.

Characterization of Sedentary Time

Our results suggest that people after acute stroke spend the majority of their time sedentary and almost no time in moderate or vigorous activity (see Table 2). Participants took a mean of 1907 ± 1594 steps per day. On average, 22.6 ± 15.9 minutes per day were spent in physical therapy and 15.2 ± 12.7 minutes per day was spent in occupational therapy. The total accumulated therapy minutes for physical and occupational therapy are presented in Table 2.

Sedentary behavior per hour was lowest during the hours of 9:00 – 11:00 am and 2:00 – 4:00 pm. Between the hours of 9:00 and 11:00 am, mean percent time spent sedentary per hour was at its lowest at 91% (Figure 2) while light activity accounted for 7%. During this time, participants walked a mean of 337 steps per hour.

Sedentary Time and Functional Outcome

Baseline performance for all functional measures is presented in Table 1. A multistep hierarchical linear regression revealed a significant, weak relationship between TPSD and discharge performance on the PPT ($r = -0.37$; $p = 0.05$) when adjusting for baseline

performance (Figure 3). However, when examining the relationship between TSPD and discharge performance on the 6MWT ($r = -0.20$; $p = 0.29$) and TUG ($r = 0.23$; $p = 0.37$), no significant relationship was observed when adjusting for baseline performance. From baseline to discharge, participants improved their PPT score, 6MWT distance, and TUG time a mean of 42%, 37%, and 12%, respectively.

DISCUSSION

The primary finding of this study was stroke patients spend the majority of the acute hospital stay sedentary. To our knowledge, this is the first study within the U.S. healthcare system to objectively quantify sedentary time using accelerometers during an acute stroke hospital stay.

Characterization of Sedentary Time

We hypothesized that stroke patients would spend 80% of their time sedentary as measured by accelerometers. We reported that the mean daily time spent sedentary was approximately 94% of their hospital stay. Our findings are similar to previous observational studies during in-patient rehabilitation¹⁹ in that the majority of the time is spent sedentary. Our study differs from previous studies in that we used accelerometers to continually assess activity level rather than behavioral mapping and observation.¹⁹

We report that time spent sedentary per day was high (94%) or 22.5/24 hours. Since we used 24-hour monitoring with accelerometers, this does include nighttime when patients were sleeping. The methods used in this study allowed us to capture all movement and activity during a 24-hour period in a continuous and objective manner without adding bias through observation. Typically, adults 60 years of age and older sleep for an average of 7.4 hours (30% of their day) between the hours of 10:48 pm + 1 hour and 6:54 am + 1 hour.²⁰ Sedentary time for our participants was highest within the timeframe that was reported by Klerman and colleagues.²⁰ However, some of our participants were not completely sedentary during usual times of sleep (see Figure 2).

Our study suggests that people hospitalized with an acute stroke spend a higher percentage of time sedentary than what is reported in the literature for an acute medical illness.¹ Given the negative effects of inactivity, patients with acute stroke appear to be at even greater risk for complications. Bed rest studies have demonstrated negative vascular adaptations²¹ and loss of muscle mass which decreases muscle strength.²² Further, people after acute stroke demonstrate poor cardiopulmonary fitness²³ and previous work has suggested that activities during rehabilitation are not performed at intensities that would elicit improvements in cardiopulmonary fitness.²⁴ Therefore, efforts to increase physical activity and minimize decline from sedentary behavior should be encouraged. Using a multidisciplinary team approach to reduce sedentary time such as early mobilization during the acute hospital stay may slow the further decline of cardiopulmonary health and allow people post-stroke to engage more efficiently in rehabilitation. Due to the stroke-related impairments that often exist, such as hemiparesis and loss of muscle mass,^{25,26} novel strategies for decreasing the amount of time spent sedentary in the hospital are critical. Further, the recent publication from the American Heart Association/American Stroke Association for Physical Activity

and Exercise Recommendations for Stroke Survivors suggests that we need to better understand physical activity patterns during acute stroke and conduct research to gain a better understanding of a dose response to “slow or prevent loss of cardiopulmonary fitness.”²⁷

While our study is the first to use accelerometers in acute stroke in the U.S., others have examined physical activity during inpatient rehabilitation and community living. Prajapati and colleagues used accelerometers to assess self-selected walking activity in subacute stroke in one single day on the inpatient rehabilitation unit.²⁸ The 8 participants ranged from 13 days to 68 days post-stroke and all could ambulate with or without an assistive device independently. The authors report that while their participants were independent with their ambulation (with/without assistive device), they spent little time (about 10%) of their day in activity such as walking. This similar pattern appears to remain consistent when individuals post-stroke return home. Roos and colleagues monitored walking activity using activity monitors in people post-stroke and otherwise healthy older adults dwelling in the community.²⁹ Their findings also support that community-dwelling individuals spend less time in bouts of walking during the day after stroke when compared to healthy adults. Our data suggest that sedentary time begins during acute stroke recovery. Therefore, physical therapists and other healthcare providers should work with people after stroke to minimize inactivity and meet the recommended minutes for physical activity and exercise.²⁷

Sedentary Time and Functional Outcome

This is the first study to examine the relationship between sedentary time using accelerometry and functional performance measures. We hypothesized that we would see a moderate correlation between functional outcome measures and sedentary time. Baseline performance likely influences performance at discharge. Therefore, we chose to be conservative and control for baseline performance on all outcome measures in our analysis. We report that the PPT had a fair and significant relationship with sedentary time. This may be due to the comprehensive activities (balance, walking, feeding, dressing) that are included in the PPT. The 6MWT and TUG (n = 23) had little to no relationship with sedentary time. The 6MWT and TUG are walking activities and perhaps not sensitive to detecting change in a few days following an acute stroke. We must also consider that sedentary time may be higher early after stroke as patients are being evaluated by the therapy team regarding walking performance. Therefore, people after stroke may not be encouraged to move about during this time or wait until therapy or nursing is available to assist.

Limitations

There are several limitations to the study that must be considered when interpreting results. The sample size for this pilot study was small but provides preliminary data to inform large scale studies of in-hospital sedentary time and the relationship to functional outcome measures such as the 6MWT and TUG. We used the device on the ankle to provide the most accurate measure for step counts.⁶ However, our primary outcome was physical activity levels not step counts. Therefore, we do not know how accurate the device is for assessing this specific parameter. We did not track the time of day that physical and occupational

therapy occurred. Therefore, we do not know how much “activity” time was self-initiated or occurred during therapy time but our data does provide information regarding continuous activity during the acute hospital stay. The PPT is a measure of physical performance and consists of simulated activities of daily living but has not been validated in acute stroke. Finally, we did not gather information regarding other comorbidities or prior orthopedic injury, joint replacement, or low back pain. It is possible that comorbid conditions could have contributed to reduced mobility during the stroke hospital stay.

Future work should begin to elucidate the benefits of early physical activity and how stroke recovery may benefit from incorporating physical activity early after stroke. A recent review by Zeiler and Krakauer³⁰ made several excellent points regarding the importance of the “sensitive period” in the early phase of stroke recovery. The authors discussed the available literature suggesting that enriched environments and engaging in activity (task specific training) enhances recovery from stroke. The data we present suggest that early after stroke the majority of the stroke patients are sedentary and are not spending their time engaging in activity that could be optimal for recovery. Most of the activity occurred early in the morning, which again leaves the remainder of the day inactive and patients possibly alone in their room. Considering ways to encourage more activity whether through early mobility or spending time out of their room would be advantageous.

CONCLUSION

Patients after an acute stroke spent the vast majority of their time sedentary during the hospital stay. Further, sedentary time was inversely related to performance in our outcome measures. Given the well-documented and rapid onset of the negative effects of inactivity, our data suggest that there needs to be a focus of reducing inactivity upon admission. Therapists, with their clinical understanding of movement after stroke, are key providers to initiate and guide increasing activity and mobility.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
Participant Enrollment Flow Chart
Flow chart to describe the reasons for non-enrollment and exclusion from data analysis.

Figure 2.
Daily Sedentary Activity Pattern
Graph of mean percent time spent sedentary per hour over the course of the day.

Figure 3.

Time Sedentary per Day vs. PPT Score at T2

Scatter plot of the time sedentary per day plotted against performance on the PPT at Time 2.

Longer times in sedentary behavior are associated with poorer performance on the PPT at discharge ($r = -0.37$; $p = 0.05$). Variables are adjusted for performance on PPT at Time 1.

Abbreviations: PPT - Physical Performance Test

Table 1

Participant Demographics

Characteristics, n = 32	Number or Sample Mean (SD)	Range
Male/Female	18/14	
Age (years)	56.5 (12.7)	(29 – 80)
Body Mass Index	28.3 (5.2)	(16.9 – 39.3)
National Institutes of Health Stroke Scale	3.7 (4.6)	(0 – 21)
Lower Extremity Fugl Meyer Score	25.5/34 (10.1)	(0 – 34)
Days of Activity Monitoring	2.5 (0.9)	(1 – 4)
Race/Ethnicity		
White/Caucasian	23	
African American	5	
Hispanic	2	
Asian	1	
Native American	1	
Functional Performance	Baseline	Discharge
Physical Performance Test score	15.3/36 (10.3)	18.7/36 (11.6)
6 Minute Walk Test (meters)	126.8 (131.8)	191.1 (150.4)
Timed-Up and Go (seconds)	22.0 (21.8)	18.2 (17.1)

Table 2

Activity Characterization and Functional Performance

	Number or Sample Mean (SD)	Range
Daily Mean Percent Time in Activities		
Sedentary	93.9 (4.1)	(80 – 99)
Light	5.1 (2.4)	(0 – 10)
Moderate	0.7 (0.7)	(0 – 3.3)
Vigorous	0.2 (0.4)	(0 – 1.4)
Time Sedentary per Day (minutes)	1354.7 (58.6)	(1154 – 1428)
Total Accumulated Therapy Minutes		
Physical Therapy	53.6 (50.6)	(0 – 230)
Occupational Therapy	34.5 (31.6)	(0 – 133)