Ambulatory Activity of Stroke Survivors
Measurement Options for Dose, Intensity, and Variability of Activity

Patricia J. Manns, PhD, PT; Evan Baldwin, MScPT, MSc

Background and Purpose—Walking activity is an important part of exercise prescription for stroke survivors. The purpose of this study was to: (1) compare ambulatory activity parameters in subacute stroke survivors over three time periods; and (2) discuss options for measurement of ambulatory activity data with respect to absolute activity, intensity of activity, and variability and pattern of activity.

Methods—Ten subacute stroke survivors participated (mean±SD; age: 66±15 years; time from stroke to discharge: 75±31 days). Data collection was completed across three time periods, predischarge, 2 weeks postdischarge, and 6 weeks postdischarge. The Step Activity Monitor (Cyma Corporation) was used to measure daily activity parameters. Parameters representing dose, intensity, and variability/pattern of activity were determined using MatLab.

Results—Minutes of activity and length of activity bouts significantly increased from predischarge to 6 weeks postdischarge (P=0.030).

Conclusions—The measurement of a variety of ambulatory activity parameters may aid clinicians and stroke survivors to determine whether exercise recommendations are being met with daily activity. (Stroke. 2009;40:864-867.)

Key Words: stroke ■ ambulatory activity ■ activity recommendations

General deconditioning and metabolic abnormalities are common in stroke survivors, emphasizing the potential importance of aerobic exercise in reducing the risk for secondary conditions. Aerobic exercise recommendations for stroke survivors include walking at moderate intensities, for 20 to 60 minutes per day, at least 3 of 7 days per week. Objective ambulatory activity outcomes may assist clinicians and stroke survivors to determine whether recommendations are being met. Measurement of ambulatory activity with the step activity monitor (SAM) has been described for older adults and stroke survivors. Studies report absolute ambulatory activity in steps per day with daily steps ranging from 1389 to 2837. Intensity of activity in stroke survivors has been reported in one investigation as almost equally split between low (<15 steps per minute) and moderate intensity (between 16 and 30 steps per minute), with only 6% of activity at high intensity (>30 steps per minute). A recent study with older adults with and without functional limitations additionally reported variability of activity. To date, there have been no studies that describe options for SAM measurement of absolute, intensity, and variability of activity in stroke survivors in the same report. The purpose of this study was 2-fold: (1) to compare ambulatory activity parameters in stroke survivors over 3 time periods (predischarge, 2 weeks postdischarge, and 6 weeks postdischarge); and (2) to present and discuss options for measurement of ambulatory activity data with respect to absolute activity, intensity of activity, and variability and pattern of activity.

Materials and Methods

Study Participants

Individuals with subacute stroke were recruited from a local rehabilitation hospital stroke unit. Inclusion criteria were first incident cerebrovascular accident and a discharge destination of their own home. Participants were excluded if they had: (1) significant aphasia; (2) preexisting conditions that impacted ambulatory ability (ie, Parkinson disease, limb amputation, rheumatoid arthritis); (3) significant cognitive impairment; (4) inability to walk >10 m with or without a walking aid; or (5) no motor impairment. Ethics approval was obtained from the Health Research Ethics Board, and all participants signed informed consent before participation. Characteristics of the participants were described with demographic data (age, gender, time since stroke, walking aid use). The Chedoke-McMaster Stroke Assessment was used to characterize lower extremity impairment with scores below 7 out of 14 indicating movement primarily in synergy. The Functional Independence Measure (FIM) was completed and motor FIM scores that represent the sum of the walking and the stairs items were reported.

Ambulatory Activity Data Collection

A step activity monitor (SAM; Cyma Corporation) was used to measure ambulatory activity. These monitors are valid for the measurement of ambulatory ability in people with stroke when walking on level surfaces, uneven surfaces, outdoors, and on stairs, as long as the monitor is positioned on the nonparetic leg. SAMs use a uniaxial accelerometer to determine number of strides per day, and intensity, variability, and pattern of activity can be calculated. Ambulatory activity was monitored at each of 3 different time periods: predischarge (time 1), 2 weeks postdischarge (time 2), and 6 weeks postdischarge (time 3). Two days were monitored at time 1.

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and 3 days at each of time 2 and 3. Monitored days at time 1 were restricted to weekdays (full in-hospital days). Mean daily parameters are reported for each time period. Using the SAM software, the monitor was set to the participant’s height, typical walking speed (ie, slow, normal, fast), and leg motion (ie, dynamic/fidgety, normal, gentle/geriatric). The settings on the SAM were the same at all 3 time periods. Participants wore the SAM on the ankle of the nonparetic leg. Participants were instructed to wear the SAM from the time of rising in the morning until the time they went to bed at night, excluding time spent bathing or participating in water activities. Oral and written instructions were provided regarding proper SAM placement and wearing schedule.

Data Analysis
SAM data were downloaded via USB port. Each output file contained the number of strides in each of the 1440 minutes in a day (midnight to midnight). An algorithm was written using MatLab to allow calculation of parameters related to absolute activity, intensity of activity, variability, and pattern of activity (see Table 1 for list). Absolute activity was represented as the number of steps walked per day (summation of number of strides in each active minute with a stride count >1, multiplied by 2), absolute minutes of activity per day (total number of 1-minute intervals with stride count >1), and absolute number of activity bouts. Activity bouts were defined as counts of less than 100 per minute10 were inactive minutes. Accelerometer data provides support for all analysis, we chose to label minutes in which there was only one first active minute to the last active minute over a 24-hour period. In a day the monitor was worn) was calculated as the time from the event when the participant switched from inactivity (stride count = 1), multiplied by 2), absolute minutes of activity per day (total number of 1-minute intervals with stride count >1), and ended when they returned to inactivity. Intensity of activity was characterized as the number of active minutes within defined parameters divided by the total number of active minutes (minutes with stride count >1), and expressed as a percentage. Low intensity activity parameters were reported in Table 1. The average time monitored per time period was 774.2 minutes (Time 1), 798.3 (Time 2), and 908.9 (Time 3). Time monitored at time 3 was significantly greater than time 1 (P=0.025), but not different than time 2 (P=0.106). Absolute minutes of activity were significantly greater at time 3 as compared to both time 1 and time 2. Length of activity bouts were significantly longer at time 3 as compared to time 1 but there was no difference in the absolute number of activity bouts across the three time periods.

Results
Participant characteristics are displayed in Table 2. FIM motor score improved significantly from admission to discharge in the rehabilitation hospital, and that improvement was attributable primarily to improvements in the performance of stairs (Table 2). Daily ambulatory activity parameters are reported in Table 1. The average time monitored per time period was 774.2 minutes (Time 1), 798.3 (Time 2), and 908.9 (Time 3). Time monitored at time 3 was significantly greater than time 1 (P=0.025), but not different than time 2 (P=0.106). Absolute minutes of activity were significantly greater at time 3 as compared to both time 1 and time 2. Length of activity bouts were significantly longer at time 3 as compared to time 1 but there was no difference in the absolute number of activity bouts across the three time periods.

Discussion
This study provides important information regarding the measurement of dose, intensity, and variability of ambulatory activity.

Table 1. Daily Ambulatory Activity Parameters

<table>
<thead>
<tr>
<th>Pattern/variability of activity</th>
<th>Dose of activity</th>
<th>Intensity of activity</th>
<th>Length of activity bouts, minutes</th>
<th>Absolute activity, minutes/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV, %</td>
<td>84.4 (8.3)</td>
<td>62.6 (8.6)</td>
<td>6.2 (5.0)</td>
<td>182.6 (38.5)</td>
</tr>
<tr>
<td>Length of activity bouts, minutes</td>
<td>3.3 (0.5)</td>
<td>76.3 (10.8)</td>
<td>7.3 (10.7)</td>
<td>57.6 (15.9)</td>
</tr>
</tbody>
</table>

Scores are daily mean (SD). Low intensity activity = 15 strides or less, moderate intensity activity = >15 to <40 strides, and high intensity = ≥40 strides. CV indicates coefficient of variation (SD/mean × 100).

<table>
<thead>
<tr>
<th>Table 2. Participant Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample n=10</td>
</tr>
<tr>
<td>Age, y</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Time from stroke to discharge, days</td>
</tr>
<tr>
<td>Median, range</td>
</tr>
<tr>
<td>Admission motor FIM</td>
</tr>
<tr>
<td>Walking score</td>
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<tr>
<td>Stairs score</td>
</tr>
<tr>
<td>Discharge motor FIM</td>
</tr>
<tr>
<td>Walking score</td>
</tr>
<tr>
<td>Stairs score</td>
</tr>
<tr>
<td>CMSA lower extremity score</td>
</tr>
<tr>
<td>Walking aid use, n</td>
</tr>
</tbody>
</table>
activity across time for a sample of stroke survivors. With respect to dose of activity, we found that daily minutes of ambulatory activity but not the absolute number of steps per day increased significantly from hospital discharge to 6 weeks postdischarge (Table 1). Our finding that participants wore the monitor for longer periods at time 3 confounds the interpretation of the change in the number of minutes of activity per day. However, both the increase in minutes of daily activity and the differential wearing time may reflect expected recovery and adjustment during the first 6 weeks home (ie, the participants spent more time out of bed).

No change over time in the number of steps per day differs from a previous study with stroke survivors where daily ambulatory activity improved from 2 weeks to 3 months postdischarge (1536 steps/per day to 2765 steps per day). In addition, 2765 steps per day at 3 months postdischarge is on average half as many steps as our sample walked. These differences may seem surprising in light of similar motor FIM scores between samples, however Shaughnessy et al did not report time that the monitor was worn, our participants wore the monitor for 72 hours as opposed to 48 hours, and the time period between measurements was shorter in the current study (ie, less time for improvement). The difference in steps per day in the samples may in part reflect the variability seen in individuals poststroke, and the many factors that may contribute to activity poststroke. Recommended dose of activity in steps per day has been reported as 10 000 steps per day for people without disabilities and 3500 to 5000 steps per day for people with disabilities or chronic disease. However, the recommendation for people with disabilities has not been tested empirically. Future studies could examine associations between steps per day, metabolic outcomes, and functional outcomes in stroke survivors to more accurately provide recommendations.

Intensity of activity as measured by SAM has been reported by Michael and Macko in a sample of 79 community dwelling stroke survivors who walked on average 1389 steps per day. We used the same definition of low-intensity activity and found that 63% to 68% of activity was low-intensity activity in our sample, compared to the previous study where 45% of activity was low intensity. This finding indicates that although our participants took more steps, those additional steps were for the most part at a low intensity. It is unlikely that low-intensity stepping would fulfill activity recommendations for intensity of activity, though no studies to date have quantified energy expenditure (as a percent of peak oxygen uptake) of the various walking intensities recorded on the SAM. Another measurement option may be to calculate intensity of activity as a percent of peak activity (ie, the highest 1-minute stride count). Because of the varying levels of impairment in people with stroke, a relative measure of exercise intensity may be valuable. Studies with people with diabetes, who also tend to walk more slowly, have emphasized the potential importance of a relative measure of intensity in activity prescription.

We report for the first time with stroke survivors variability and pattern of activity. Cavanaugh and colleagues suggest that older adults who demonstrate reduced variability of ambulatory activity “may not have as much capability to perform a range of ambulatory tasks under a variety of environmental conditions.” It is possible that interventions that focus on increasing variability of ambulatory activity may lead to improvements in functional abilities. This question requires further study. CV did not demonstrate differences over time in our sample, and it may be a problematic outcome in instances where someone is consistently active without variation (results in a lower CV than someone who is less active but may have more spurts of activity throughout the day). It remains to be seen whether higher coefficients of variability (CVs) are desired, or whether a more useful outcome related to pattern of activity may be length of activity bouts.

Length of activity bouts increased by half a minute from time 1 to time 3 and may reflect increased capacity for activity, and a change in pattern of activity. Unlike absolute activity (measured in steps per day, minutes per day, or number of activity bouts), length of activity bouts is less affected by differential daily wearing time of the monitor. We do not know whether an increase in the length of activity bouts by half a minute is clinically significant. However, using our data for time 3, and a mean of 61 daily activity bouts, the increase in the length of activity bouts amounts to an extra 30 minutes of activity per day. As such length of activity bouts is an outcome that requires further study, as a potential target outcome for a walking intervention. A recent study with diabetic participants used accelerometry to measure breaks in sedentary time (ie, activity bouts), and found that more interruptions in sedentary time were associated with better metabolic outcomes. Activity-inactivity profiles can be provided by the SAM and may provide important avenues for new research.

Summary
Our findings provide information about ambulatory outcomes reflecting dose, intensity, variability, and pattern of activity over time in a group of stroke survivors. The findings are limited by the small sample size and to a relatively healthy community dwelling group of stroke survivors. We provide suggestions for measurement of achievement of activity targets in stroke survivors which may be useful if interventions target activity behavior in addition or separate from aerobic and strength targets for exercise.

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Disclosures
None.

References
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