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A step activity monitoring program improves real world walking activity post stroke

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Abstract

Purpose—The purpose of this study was to examine whether the walking activity of persons with stroke could be increased through participation in a step activity monitoring program and to assess whether this occurred through a change in the structure of walking activity.

Method—16 individuals living with chronic stroke (>6 months post stroke) wore a StepWatch Activity Monitor (SAM) and completed a 4 week goal centered activity monitoring program. Descriptors of step activity were averaged across baseline and the last week of monitoring, and were used to analyze the changes. Descriptors of step activity included: steps per day, bouts per day, steps per bout, total time walking per day, and the number of short (≤40 steps), medium (41–500 steps), and long (>500 steps) walking bouts.

Results—As a group, the number of steps per day significantly increased over the 4 weeks of activity monitoring (p=0.005). Subjects also demonstrated a significant improvement in the total time walking (p=0.023), and the number of medium (p=0.033) and long (p=0.050) walking bouts. At the baseline and the final assessment, more than half of the bouts were short bouts of walking (67.6%±8% and 68.2%±8% respectively).

Conclusions—A goal centered step activity monitoring program can improve daily walking activity after stroke through increases in the amount of total time walking, and medium and long walking bouts.

Keywords

stroke; physical activity; walking

In the United States, each year approximately 795,000 people have a stroke[1]. In the year following the completion of conventional physical therapy, many stroke survivors report a 43% decrease in mobility and physical activity[2]. Studies have shown that daily walking activity in persons with chronic stroke (>6 months) is well below the activity level of even the most sedentary adults (<5,000 steps/day)[3]. The normal decline in aerobic fitness is

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worsened by inactivity, such that cardiovascular capacity of most stroke survivors is below the level needed for activities of daily living[4, 5]. Moreover, declines in activity lead to an increased risk of co-morbidities, including subsequent stroke[6]. It is therefore important that interventions are developed to improve physical activity after stroke.

Step activity monitoring programs have been shown to be effective in improving daily step activity in persons with a variety of diagnoses including diabetes, Chronic Obstructive Pulmonary Disease and obesity (for a review see Bravata et al, 2007)[7]. Key components of an effective step activity monitoring program appear to be daily step activity monitoring and providing participants with a daily step goal[7]. Whether such a program would result in increased daily walking in persons with stroke has not been tested.

The goal of improving walking activity in those who have had a stroke may be facilitated by understanding the structure of daily walking activity following stroke. A recent study found that, like in neurologically intact individuals, shorter bouts of walking (<40 steps) made up 75% of daily walking after stroke[8]. However, after stroke the number of these short bouts of walking was significantly less than in neurologically intact adults[8]. Longer bouts of walking, which make up less of the total percentage of walking, were also significantly reduced in those with stroke[8]. This indicates that after stroke, fewer bouts of walking may be the contributing factor to overall fewer steps per day and that increasing the number of walking bouts each day may be one strategy for increasing overall daily step activity[8].

The purpose of this study was to examine whether a step activity monitoring program could be used to increase daily walking activity in persons post-stroke and if so, how walking activity was altered to achieve the increase. We hypothesized that 4 weeks of a goal centered step activity monitoring program would result in an improvement in daily step activity in persons post-stroke. We further hypothesized that this improvement would occur through an increase in the number of walking bouts, rather than through an increase in the number of steps per bout.

Methods

Participants were recruited from local physical therapy clinics, stroke support groups, and newspaper advertisements. Individuals age 55–80 were included in the study if they had sustained a stroke, were able to walk without assistance (the use of orthotics or assistive devices were allowed) and were able to communicate with the investigators. Individuals post stroke were not included in the study if they had experienced more than one stroke, additional neurologic diseases, chest pain, shortness of breath without exertion, and unexplained dizziness in the past 6 months. All participants post stroke received medical clearance prior to beginning the study and signed an informed consent approved by the Human Subjects Review Board at University of Delaware prior to participation.

Data was collected while subjects wore a calibrated StepWatch Activity Monitor (SAM) (Orthocare Innovations, Seattle Washington). Previous studies have shown excellent reliability and accuracy of the SAM in persons post-stroke[9]. The SAM was placed above the ankle on the non-paretic lower extremity and calibrated to the participants' height and walking characteristics per manufacturer's instructions. To calibrate the SAM, participants walked 30 strides at their self-selected pace and 10 strides at a slightly faster pace. If the number of steps differed from manual counting by > 2 strides, the sensitivity of the SAM was adjusted until accuracy was obtained. The number of strides was counted in each consecutive 10 second interval (changed from the SAM default interval of 60 seconds).

During the initial session subjects were verbally educated and then demonstrated understanding in donning/doffing the SAM unit. They were given verbal and written instructions on the wear and care of the SAM unit, along with contact information for researchers incase questions arose at home. Participants wore the SAM for all waking hours, except during bathing and swimming activities. A baseline mean number of steps per day were recorded for 6 days and a weekly goal was then set for 25% above baseline. For an additional 4 weeks, participants filled out a weekly Step Activity Log and attended a weekly counseling session where step data was downloaded and reviewed for wear-compliance and goal achievement. Individual barriers to activity and strategies to improve activity were discussed weekly; subjects were encouraged to use these strategies to increase steps during routine daily life around their home and community. Examples include getting up to change the television station instead of using the remote, walking to the furthest bathroom in the home, walking to get the mail or retrieving one's own drink or food instead of relying on a caregiver. Participants were also encouraged to increase longer walking bouts through tactics such as walking from the car parked further from the store or traveling to a park or mall and walking for exercise at least a few days per week.

Initially, the subject's goal was to increase the number of steps per day by 25%[10]. If the participant's weekly goal was achieved at least 3 days during a week, the participant was encouraged to increase activity by 25% of the week's mean steps, until 10,000 steps were achieved, then the goal became consistently performing 10,000 steps daily. If participants did not reach their weekly goal, the goal remained the same.

To obtain further information on participants' walking patterns, data from the SAM was analyzed using a custom MATLAB program (MathWorks, Natick, MA). We first determined the start and end of a walking bout based on methods from previous studies[8, 11]. The start of a walking bout was operationally defined as 2 strides in a 10 second interval and the end of a walking bout was defined as zero strides in a 10 second interval. These algorithms prevented leg movements during rest and standing from being counted as strides. Once walking activity was determined to occur as part of a walking bout, the number of strides from the SAM output was doubled to obtain the total number of steps per day. Other variables calculated included bouts per day, median steps per bout, and total time walking. To analyze walking in the context of "real-world" community mobility, we analyzed the number of bouts related to certain community distances, based on the findings of Andrews et al (2010)[12]. They found that going to a physician's office, post office, or pharmacy required walking between 98–255 meters. We consider these medium distances. Activities such as shopping in a grocery store, department store, or superstore required individuals to walk between 512–922 meters, which we considered long distances. We divided those distances by the mean adult step length (when walking at speeds matched to those post-stroke) of 0.5 meters[13] and operationally defined a *medium-distance bout* as containing 41 to 500 steps and a *long-distance bout* as containing 500 or more steps. We operationally defined a *short-distance bout* as containing ≤40 steps based on previous studies[8, 11]. We calculated the amount of short, medium, and long bouts using these definitions for the baseline week and each week of the study.

For each subject, the descriptors of step activity were calculated each day and the mean values across the baseline (BL) week were then compared to the activity during the last week of monitoring (Final). Steps per day, bouts per day, median steps per bout, total time walking, and the number of short, medium, and long bouts of walking were analyzed over the duration of the step activity monitoring program. The data was not normally distributed, so a non-parametric Wilcoxon signed rank test was used to compare baseline data to data from the last week of monitoring. Statistical significance was accepted at $p \leq 0.05$.

Results

A total of 23 subjects were enrolled in the study. Two subjects completed the baseline week but dropped out of the study due to difficulty with donning and doffing the SAM and/or consistency in wearing the unit. Two subjects completed the baseline week and 2 weeks of the activity monitoring program before dropping out of the study due to poor transportation and a death of a family member, respectively. This left 19 subjects that completed the activity monitoring program. Data was excluded for 3 subjects, 2 due to not returning the SAM with a minimum of 3 full days/week of captured activity as per study protocol and the other due to admittedly inflating her baseline step activity. This resulted in 16 subjects included in data analysis (Table 1).

As a group, the number of steps per day significantly increased over the 4 weeks of activity monitoring ($p=0.005$, Table 2). The data was further analyzed to understand whether the structure of walking activity changed with the overall improvement in steps per day or whether the general structure of walking remained the same.

Participants demonstrated a significant improvement in the total time walking ($p=0.023$), and the number of medium ($p=0.033$) and long ($p=0.05$) bouts of walking (Table 2). At the baseline and the final assessment, it was noted that more than half of the bouts were short distance bouts of walking (67.6%±8% at baseline and 68.2%±8% at the final week). The number of bouts per day ($p=0.127$), median steps per bout ($p=0.864$), and the number of short ($p=0.109$) bouts of walking did not significantly change (Table 2).

Discussion

To our knowledge, this is the first study to demonstrate that participation in a goal centered step activity monitoring program can result in improvements in walking activity (steps per day) in people post-stroke. As a group, increases in daily walking activity were achieved not by increasing the median number of steps per bout, but rather through increases in the quantity of medium and long walking bouts. Additionally, short bouts of walking comprised more than half of the daily bouts of walking before and after the step monitoring program.

Previous studies that have examined the effect of an intervention on daily walking activity post-stroke have shown mixed results. In a study of a circuit-based rehabilitation program for individuals post stroke, improvements were observed in walking endurance but not daily walking activity[14]. Similarly, in a study examining the effects of a 6 month, 3x/week community based group exercise program in persons post-stroke, balance and walking endurance improved, but daily step activity did not[15]. Improvements in walking activity of ~900 steps/day was shown with fast treadmill training for 4 weeks in a group of chronic stroke survivors discharged from physical therapy due to a plateau in their progress [16]. The changes in the fast treadmill training study are on par with those observed in this study (~1100 steps/day increase on average).

Despite their increased daily walking at the end of the step activity monitoring program, many of the subjects in this study continued to walk less in a day than older adults without disability [8, 17]. There were also 3 subjects who did not have an increase in walking activity (Table 3). Previous studies have found that a lack of social support and/or transportation may be barriers to participation in exercise after stroke[18]. Each of these 3 participants reported difficulty overcoming similar barriers with “real world” walking. For example, one of the subjects indicated that he was afraid to walk without his caregiver present. The other 2 subjects reported difficulty implementing the suggested community walking strategies due to time management problems and/or transportation issues. This suggests that important components of goal centered programs aimed at improving “real world” walking activity after stroke may be identifying perceived barriers to increased activity and working cooperatively to develop successful strategies to overcome these barriers. As hypothesized, the median number of steps per bout did not change; rather, persons with stroke increased the number of medium and long walking bouts per day. Short bouts continued to comprise more than half of the daily bouts of walking after the step monitoring program. This is not surprising since other studies[8, 11, 17] have found that in multiple groups of people, the majority of walking occurs in short (<40 steps) bouts of walking. Based on this, during the counseling session subjects were encouraged to use the strategies discussed to increase steps during routine daily life around their home and in the community. Using many of these approaches, participants were able to increase medium and long walking bouts. Most participants improved in their number of short walking bouts as well, but this did not reach statistical significance, in large part due to the 3 subjects in Table 3 who did not increase daily walking with the program. This suggests that individuals post stroke have the *capacity* to walk more and reinforces the idea that in addition to the important components of goal-setting and monitoring[7], identifying and developing strategies to overcome perceived barriers may be critical for the success of real world walking programs for individuals post stroke.

Study Limitations

Our findings should be considered in light of the study limitations. This study was conducted without a control group. It is therefore possible that the improvements in daily walking could simply be a result of the fact that subjects were participating in a study where they received attention and had nothing to do with the specific intervention. This seems unlikely, however, as improvements in step activity are generally not found with standard rehabilitation interventions, where the amount of attention and frequency of visits is higher than in the present study[14, 15] This study was also a small sample of convenience and as such the group may have been more motivated to improve their overall activity, resulting in greater improvements than would be observed in a more general population of those post-stroke. In addition, while our goal of a 25% weekly step per day increase was motivating to most participants, the best goal setting strategy to maximize motivation and outcomes in those post-stroke is not known. Perhaps, a more achievable weekly goal would have been even more motivating to participants. Lastly, the SAM units do not provide immediate visual step count feedback. Participants met with investigators weekly to download data and review their daily step counts. As a result, participants reported that they had to "calibrate" themselves to understand how it felt to walk a certain distance and this may have made it more difficult for them to increase their walking activity.

Conclusions

A goal centered step activity monitoring program resulted in increased daily walking activity in our tested sample of stroke survivors. The increase in activity was achieved through improvements in walking at a variety of distances. To avoid the cycle of inactivity ↔ disability/co-morbidities, future randomized controlled trials are necessary to determine the optimal features of a step activity monitoring program that maximize activity while subsequently enhancing community participation after stroke.

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Table 1

Subject Characteristics at the Pre-Training Evaluation

Subject	Gender	Age *(years)*	Side of Stroke	Time Since Stroke *(months)*	Self Selected Gait Speed (m/s)	Assistive Device
1	M	70	R	60.2	1.05	None
6	M	64	R	71.2	0.86	NBQC
14	M	62	L	53.5	0.92	None
53	M	74	L	94.9	0.63	None
98	M	69	R	49.1	0.33	SPC
136	M	60	R	28	0.39	SPC
154	M	76	R	18.2	0.90	None
170	M	78	R	144	0.47	SPC
177	M	68	R	10.6	0.77	None
187	F	58	R	17.9	0.91	None
246	M	44	R	28.7	1.14	None
257	F	69	R	91.4	0.47	None
258	M	75	R	14.7	0.21	NBQC
300	F	70	L	79.7	0.23	None
317	M	80	R	26	0.98	None
350	M	40	R	6.5	0.72	None

Male (M); Female (F); Right (R); Left (L); Narrow based quad cane (NBQC); Single point cane (SPC)

Table 2

Group Means of the Descriptors of Step Activity

	Number of Steps Per Day	Number of Bouts Per Day	Median Steps Per Bout	Total Time Walking (hours)	Number of Short Bouts	Number of Medium Bouts	Number of Long Bouts
Baseline	5,205 SD 2,571	134 SD 64	22.8 SD 6.3	1.80 SD 0.73	92 SD 49	41 SD 18	0.45 SD 0.41
Final	6,372 SD 2,998*	143 SD 66	22.1 SD 5.5	2.07 SD 0.82*	99 SD 49	44 SD 22*	0.79 SD 0.73*

Short Bouts: ≤40 steps; Mediums Bouts: 41–500 steps; Long Bouts: >500 steps

* Represents a significant difference between baseline and the final week of the step monitoring program ($p \leq 0.05$)

Table 3

Outlier-Individual Subject Scores

Subject Number	Number of Steps Per Day		Number of Bouts Per Day		Median Steps Per Bout		Total Time Walking (hours)		Number of Short Bouts		Number of Medium Bouts		Number of Long Bouts	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
1	6,841	4,651	145	80	24	20	2.34	1.29	96.2	53	48.2	24.5	1	2
154	7,337	6,087	169	132	19	20	2.25	1.72	117.8	95	50.2	35.8	0.8	1.3
170	4,742	5,346	107	94	22	31	1.49	1.52	66.25	52	40.3	41.7	0.4	0.3

Short Bouts: ≤40 steps; Mediums Bouts: 41–500 steps; Long Bouts: >500 steps