Activity patterns in people with neurological conditions

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ABSTRACT

Walking is often impaired following a neurological insult; however, little is known how daily activity patterns are affected. The aims of this pilot study were to describe activity patterns of individuals with neurological conditions and examine the relationship between activity patterns and clinical walking tests. Twenty-two participants with neurological conditions were recruited and fitted with a StepWatch to record all steps taken over seven days. Daily activity patterns were compared to a sample of healthy adults and the relationship between clinical walking tests and activity patterns was evaluated. The activity patterns of adults with neurological conditions were similar to healthy adults with a high frequency of low numbers of steps in a row, interspersed with short rest periods. However, a greater proportion of activity bouts involved short duration activity (<30seconds) in people with neurological conditions (71% of all bouts) when compared to healthy individuals (60% of all bouts). Adults with neurological conditions had significantly different daily activity patterns (average steps, p<0.001; average minutes of activity, p<0.001; total number of activity bouts, p<0.001; variability of activity, p<0.001) to healthy adults and older adults with functional limitations. Because walking bouts are shorter and more frequent, it could be inferred adults with neurological conditions do not cover as much distance as healthy adults. The only significant correlation between clinical walking tests and activity patterns was between the Rivermead Mobility Index and average daily steps (r=.45; p<0.01). The findings from this study may assist in the development of more specific walking rehabilitation, including retraining acceleration and deceleration together with the ability to cover distances required for functional community ambulation.

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INTRODUCTION

Walking is an important aspect of independent functioning needed for many activities of daily living and community participation. It is therefore important that walking can be quantified to determine an individual's functional walking ability. This is generally achieved by using objective (e.g. six minute walk test and self selected gait speed tests) and self-reported (e.g. ABILOCO and Rivermead Mobility Index) tests in a clinical setting.

Recently, accelerometry, such as the StepWatch Activity Monitor™ (StepWatch) (Orthocare Innovations, Prosthetics Research Study, Seattle, WA, USA), has been used to quantify aspects of walking ability over extended periods of time in real world environments. The StepWatch is a valid and reliable tool (de Bruin et al 2008) which records information about the quantity and rate of stepping, together with more specific aspects of walking activity over a period of time, including total steps, steps in a row, walking bout durations and rest period durations (Coleman et al 1999, Storti et al 2008).

The StepWatch is worn on one leg and has an inbuilt custom sensor to detect acceleration, position and timing to determine one step. The sensitivity of the StepWatch means it can be used to assess slow or altered gait patterns in populations known to have impaired walking abilities (Busse et al 2009, Mudge and Stott 2009).

Although activity monitors are typically used to provide information about total steps and cadence, they can provide more information about overall activity patterns. However, to date, only two studies have used the StepWatch to quantify and describe specific aspects of walking and activity patterns in this way (Cavanaugh et al 2007, Orendurff et al 2008).

Orendurff et al (2008) investigated the length of walking bouts in time, number of sequential steps and rest periods of ten healthy, sedentary employed adults (aged 36.6 SD 14.8 years) in an urban environment during normal daily living. The study found that 60% of all walking bouts lasted for 30 seconds or less and walking bouts of two minutes or more occurred only one percent of the time. Forty percent of all walking bouts entailed fewer than 12 sequential steps and 75% of all walking bouts had fewer than 40 sequential steps. Rest periods were typically very short; 50% were 20 seconds or less (Orendurff et al 2008). In summary, the study found that healthy individuals take part most frequently in walking bouts comprised a low number of steps, in short duration, interspersed with short rest periods.

Cavanaugh et al (2007) collected StepWatch data over six days in thirty healthy younger adults (aged 36.6 SD 2.6 years), twenty-eight healthy retired older adults (aged 83.7 SD 2.3 years) and twelve older adults (aged 79.3 SD 4.5 years) with functional limitations. All participants lived in the community. Average daily values for number of steps, number of minutes spent active, number of activity bouts, variability of minute to minute activity and randomness of minute-to-minute activity fluctuations were calculated. Healthy older adults had a lower number of activity bouts than younger adults. Older adults with functional limitations had lower numbers of steps, number of active minutes, number of activity bouts and variability when compared to healthy younger adults. This study revealed that activity bouts, activity duration, step count and variability decrease with age and functional limitation (Cavanaugh et al 2007).

Although activity patterns have been explored in healthy individuals and older adults with functional limitations, activity patterns of individuals with neurological conditions have not been described. It is known that individuals with neurological conditions often experience reduced or impaired walking ability (Pearson et al 2004), however, little is known about whether this change alters daily activity patterns in those with a neurological condition. It is also not clear how these activity patterns relate, if at all, to clinical outcome measures. Significant relationships between the two may provide clinicians with further insight into an individual's mobility outside a clinical environment.

The aim of this study was to describe the daily activity patterns of individuals with neurological conditions, in particular, walking bout duration, sequential step count and rest period duration. A further aim of the study was to examine the association between activity patterns and clinical walking tests and also to compare the activity patterns of individuals with neurological conditions to those of healthy adults from previously reported studies (Cavanaugh et al 2007, Orendurff et al 2008).

METHODS

The study was approved by the Institutional Ethics Committee (EA1_0408) and informed consent was given by each participant. Participants were recruited through community support organisations and private rehabilitation clinics for convenience. The inclusion criteria were a diagnosis of a neurological condition for more than six months, the ability to walk independently with or without the use of a walking aid and aged over 18 years. Participants were excluded if they had Parkinson's disease or other conditions resulting in inconsistent step length from step to step, which could lead to an inability to calibrate the StepWatch. People with other health conditions known to alter or limit normal activity patterns were also excluded (e.g. cardiorespiratory disease).

Participants took part in a one hour session at a university to administer the following tests: The Rivermead Mobility Index (RMI) (Collen and Wade 1991), Activity-specific Balance Confidence Scale (ABC) (Powell and Myers 1995), ABILOCO (Caty et al 2008), the six minute walk test (Flansbjer et al 2005), self-selected and fast gait speed tests (Bohannon 1992). A StepWatch was calibrated and attached to each participant's less affected ankle and tested at fast, self-selected and slow gait speeds to check calibration and recalibrate if needed until 100% accurate at these speeds. The StepWatch was set to record all steps taken by the less affected leg in ten-second intervals, 24 hours a day, for seven consecutive days. An explanation regarding care of the StepWatch was provided, together with instructions on how the monitor was to be worn. On completion of the seven days, if any data from the StepWatch were missing, the StepWatch was re-calibrated and worn by the participant for additional days to complete seven days of monitoring.

The StepWatches were collected from participants at the end of the monitoring period and the data downloaded to the StepWatch software. Daily average walking bout duration, sequential step count, rest period duration, minutes of activity, number of activity bouts, variability of activity and total step count were calculated for each participant.

A walking bout was defined as a period of time in which sequential steps occurred in subsequent ten-second intervals, consistent with Cavanaugh et al (2007). A walking bout ended when no steps were recorded in the subsequent ten-second interval. A rest period was defined as a period of time in which no steps occurred in the prior or subsequent ten-second interval. An error was considered when only one step (a singleton) was recorded in a ten-second interval, when no prior or subsequent steps appeared in an adjoining ten-second interval. Therefore, all singletons were removed and two foot-offs of the same foot (4 SD 1 steps) was the lowest step count included in the calculations. Variability of activity was defined as the dispersion or spread of activity and was calculated based on minutes of activity and divided by the coefficient of variation (CV = 100 x standard deviation/mean) (Cavanaugh et al 2007).

The data calculated were then compared with that of previously reported healthy adults (Orendurff et al 2008). Permission was granted and raw data obtained for the comparison of younger adults, older adults and older adults with functional limitations (Cavannagh et al 2007). The calculated data were also compared with the clinical walking tests.

Statistical Analysis

The Kolmogorov–Smirnov test was used to test variables for normality. The level of association between the variables was investigated using the Spearman rank correlation coefficient for variables without a normal distribution, and the Pearson correlation coefficient for variables following a linear distribution, with significance accepted at the 0.05 level. The correlation coefficients were interpreted as 0.90, very high; 0.70 to 0.89, high; 0.50 to 0.69, moderate; 0.30 to 0.49, low; and less than 0.29 as little, if any correlation (McDowell 2006). Calculations were performed using SPSS, Version 17.0. Kruskal Wallis one-way analysis was used to test for similar medians among differing samples in data not normally distributed and one way ANOVA for normally distributed data.

RESULTS

Twenty-two adults with a neurological condition were recruited. The data from one participant was excluded as it was incomplete, leaving data from 21 participants for analysis. Individual participant information is shown in Table 1. The results of the clinical walking tests and self report questionnaires were not normally distributed and are reported in Table 2.

Daily activity

The comparison of data obtained from adults with neurological conditions from this study and Cavanaugh et al's (2007) data of younger adults, older adults and older adults with functional limitations is shown in Table 3. The differences in the means showed significant differences in the daily activity patterns

Table 1: Individual Participant Information

Age	Sex	Ethnicity	Neurological Condition	Mobility Aid	Height (cm)
48	F	European NZ	Myotonic Dystrophy	Nil	173
43	F	European/ British	Cerebral Palsy	Nil	166
44	F	Chinese	Spinal Cerebellar Ataxia	Nil	148
48	F	European NZ	SCI (T5)	SPS, Frame, W/Chair	163
61	M	European NZ	MS	SPS, Frame, W/Chair	175
36	M	European NZ	GBS	Nil	178
60	F	European NZ	MS	Frame in community	160
48	M	European NZ	Stroke	Nil	174
43	M	Maori Chinese	Stroke	Nil	171
61	M	European NZ	Stroke	Nil	167
57	F	European NZ	Stroke	SPS	163
21	M	European NZ	SCI (C2)	Nil	174
43	F	European NZ	MS	Nil	165
40	M	European NZ	MS	Nil	181
77	M	European NZ	Stroke	Nil	177
25	F	European NZ	SCI (C6/7)	SPS	176
71	M	European NZ	Stroke	Nil	177
81	F	European NZ	Stroke	Nil	163
53	F	Chinese/Hong Kong	Stroke	Quad Stick	153
62	F	Maori	Stroke	SPS indoor, w/frame outdoor	166
19	M	NZ European/Australian Aboriginal	Cerebral Palsy	SPS, Frame, W/chair	19
20	M	European NZ	Cerebral Palsy	Frame, W/chair	19

Key: F = female, M = male, NZ = New Zealand, SCI = spinal cord injury, MS = multiple sclerosis, GBS = Guillain Barrè Syndrome, w/chair = wheelchair, w/frame = walking frame, SPS = single point walking sticks

Table 2: Results of initial clinical walking tests and self-report questionnaires

Clinical Test	Median	Range
Rivermead Mobility Index	13.2	9-15
ABILOCO (raw score)	11.5	5-13
Activities-Specific Balance Confidence Scale	72.1%	16.0-98.8%
6 Minute Walk Test	309m	80-545m
Self-selected Gait Speed	1.0m/s	0.2-1.4m/s
Self-selected Step Length	0.48m	0.15-0.67m
Fast Gait Speed	1.3m/s	0.3-2.0m/s
Fast Gait Step Length	0.59m	0.17-1.1m

Abbreviations: m = metres, m/s = metres per second.

between the groups. Individuals with neurological conditions had a significantly different average number of daily activity bouts ($p < 0.001$), minutes of activity ($p < 0.001$) and variability of activity ($p < 0.001$) than the healthy younger and older adult, and older adult with functional limitations samples. However, adults with neurological conditions had similar average daily step counts to healthy adults and older adults, but showed a significant difference from older adults with functional limitations ($p < 0.001$).

Walking and rest bout durations

The average values of steps in a row, frequency of walking bouts, walking bout durations and rest bout durations of adults with neurological conditions were calculated. The data were then compared with Orendurff et al's (2008) data from healthy individuals.

Steps in a Row: Adults with neurological conditions participated in short duration walking bouts with a high occurrence (17.3%) of low numbers of steps in a row (4 SD 1) (Figure 1). Twelve (SD 1) or fewer steps per bout accounted for 44% of all walking bouts, and 40 (SD 1) steps or fewer accounted for 75% of all walking bouts. Healthy individuals show a similar pattern of sequential steps. The lowest step count of 4 (SD 1) steps was also the most frequent, totalling 17% of all walking bouts. Forty percent of all walking bouts were 12 (SD 1) steps or fewer. Similarly, 75% of all walking bouts had step counts of 40 (SD 1) steps or fewer.

Table 3: Comparison of activity patterns between differing populations

Variables of Activity Patterns	Adults with Neurological Conditions	Healthy Younger Adults[a]	Healthy Older Adults[a]	Older Adults with Functional Limitations[a]
Total Steps	9,997*	11,075	9,982	7,682
Total Minutes of Activity	197**	400	336	298
Total Number of Activity Bouts	227**	77	68	63
Variability of Activity (%)	38**	100	93	85

[a] Data reproduced with permission from Cavanaugh et al 2007.

* Significant difference between adults with neurological conditions and older adults with functional limitations (p<0.001)

** Significant difference between adults with neurological conditions, and healthy older and younger adults and older adults with functional limitations (p<0.001)

Figure 1: Frequency of sequential step counts in individuals with neurological conditions

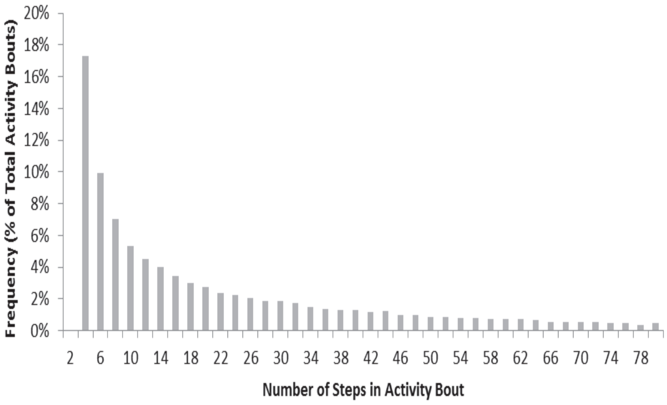
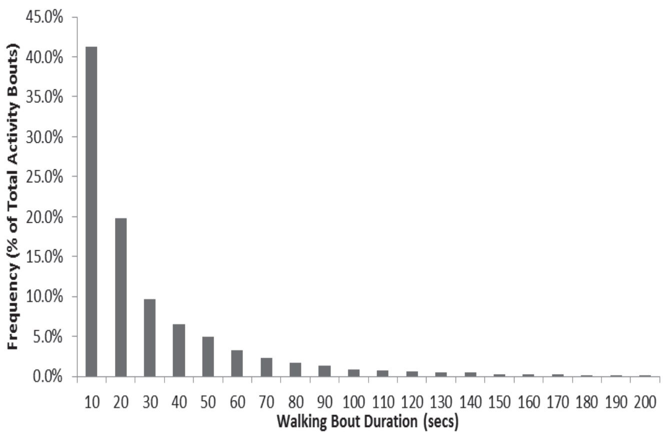


Figure 2: Frequency of walking bout durations in individuals with neurological conditions



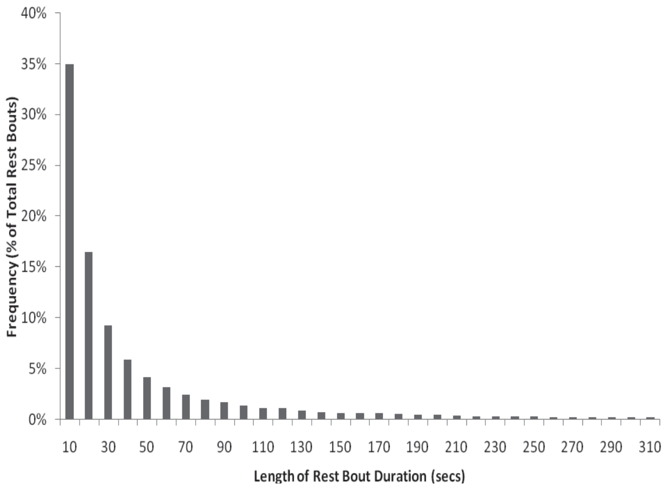
Walking Bout Duration: Figure 2 shows that individuals with neurological conditions have a high frequency (41%) of short duration bouts (10 seconds). Healthy individuals, similarly engage most frequently in short duration bouts (10 seconds and 20 seconds, occurring 20% and 26% respectively).

Rest Bout Durations: Individuals with neurological conditions most commonly took rest periods of short duration (10 – 20 seconds) throughout the day, encompassing 52% of all rest bouts daily (Figure 3). Rest bouts up to 3 minutes in length total, 88% of all rest bouts, similar to the patterns of rest taken by healthy individuals. Rest durations of 10 or 20 seconds accounted for 50% of all rest bouts. As the rest duration increases, the frequency of rests decreases in both groups.

Relationship between the daily walking activity of individuals with neurological conditions and clinical walking tests

In general, the clinical walking tests (self-selected and fast gait speed tests and 6MWT) and the self-report questionnaires (RMI, ABILOCO and ABC) showed little to low correlation with walking activity in individuals with neurological conditions (Table 4). The only significant, but low correlation was between the total number of steps per day and the RMI (r=.45; p<0.01).

Figure 3: Daily frequency of rest bout durations for individuals with neurological conditions



DISCUSSION

Our findings show that while individuals with neurological conditions and healthy adults have a similar number of total

Table 4: Association between activity patterns and clinical walking tests for people with neurological conditions (Spearman correlation r-values)

	6MWT	SSGS	FGS	RMI	ABILOCO	ABCS
Total Steps	.178	.159	.093	.449*	.208	.428
Total Minutes	.022	.087	-.023	.212	.109	.227
Variability	.229	.344	.329	.155	.226	.174
# of Bouts	-.045	.073	-.055	.121	.172	.11

*Significant 0.05 level (2-tailed).

Total Minutes = total minutes of activity, Variability = variability of activity, # of Bouts = total number of activity bouts.

Abbreviations: SSGS, Self-selected gait speed; FGS, fast gait speed.

steps; the number of steps in a row and the length of rest periods taken over the course of a day differ. Individuals with neurological conditions take more short duration walking bouts per day. These activity bouts are shorter and occur more frequently than those of healthy adults.

Possible reasons for shorter walking bouts within the neurological sample include poor levels of fitness and/or inefficient and disrupted gait patterns. It is well known that people with neurological impairments have reduced cardiorespiratory fitness, which is likely to limit walking endurance (Kelly et al 2003). Increased energy expenditure caused by gait disturbances associated with neurological conditions, together with decreased walking endurance may contribute to shorter activity bouts (Macko et al 1997).

Individuals with neurological conditions generally have a shorter step length (Brandstater et al 1985, Reid et al 2011). The mean step length of participants in this study was 0.48 metres at self-selected speed, which is almost half that previously reported for healthy adults (Bilney et al 2003). An increased number of activity bouts may be one way in which individuals with neurological conditions compensate for covering a reduced distance during activity bouts. So shorter bout duration and decreased step length together may be associated with the higher number of daily activity bouts taken by adults with neurological conditions.

Achieving functional distances is important for successful integration within the community (Lord et al 2004). Research suggests that 300 metres was the minimum distance required for safe community ambulation (Lerner-Frankiel et al 1986), however, there is some question whether this distance is underestimated (Andrews et al 2010). Even with the increase in the number of daily activity bouts described in this study group, the time spent active is still almost half that of healthy adults. This suggests adults with neurological conditions may not be achieving functional distances and may not be able to access important community locations.

The variability of activity patterns of individuals with neurological conditions is much lower than that reported for healthy adults (Cavanaugh et al 2007, Orendurff et al 2008). Low variability of activity suggests that individuals with neurological conditions participate predominantly in orderly and repetitive activities. Other studies have shown that individuals with neurological conditions often function closer to their maximal functional capacity than healthy adults (Dean et al 2001). It also suggests a reduced ability to adapt to unexpected changes in the environment, which would again impact on functional independent living (Cavanaugh et al 2007). Given this, adults with neurological conditions may use a less flexible and more ordered daily structure as a strategy to ensure completion of activities.

Gait speed and endurance have previously been shown to correlate with total steps per day (Busse et al 2006, Mudge and Stott 2009), however, we found little to no correlation between the clinical gait tests and total steps or other measures of activity patterns. Although our participants walked at a similar speed to participants in previous studies (Busse et al 2006, Mudge and Stott 2009), they took a relatively high number of steps per day, in the magnitude of what would be expected from healthy older adults (Cavanaugh et al 2007). This may account for the low correlation.

Clinical Implications

The results of this study may assist practitioners to target very specific aspects of walking retraining. For example, daily activity patterns in individuals with neurological conditions were made up of a large number of short bouts of activity, similar to healthy adults. This shows that initiation and termination of gait are undertaken multiple times each day together with speed modulation, which requires acceleration and deceleration with each bout. This suggests that, as well as training walking speed in one direction, changing speed and direction may also need to be assessed and trained in order to prepare individuals with neurological conditions for community walking.

Based on the activity patterns described in this study, early rehabilitation may need to include the retraining of initiation, acceleration, deceleration and termination of gait. Retraining should also occur in multiple bouts of short duration, which are interspersed with short periods of rest to replicate the described patterns of activity. This initial training would be seen as a preparation for longer bouts or endurance training as is needed for achieving the distances required in the community.

Later gait rehabilitation can be targeted more specifically by increasing the length of walking bout duration, improving step length, and establishing longer distances walked in order to achieve the patterns and distances undertaken by healthy older and younger adults. This would assist individuals with neurological conditions to achieve functional community distances, and therefore independence within the community setting.

Limitations

The heterogeneity of neurological conditions and small sample size may have limited the appearance of relationships and patterns within the data. In saying this, the information from this pilot study could be used for further studies looking at more homogeneous populations or larger sample groups. This study also cannot be generalised to people with inconsistent step length from step to step due to the inclusion criteria, which limits the findings of the study.

Other factors may have influenced walking activity during the collection of data. Health concerns and unfavourable environmental conditions may have limited the amount of activity undertaken. On the other hand, factors such as individual behaviour and wanting to achieve "good results" may have caused increased walking activity. However, apart from individual behaviour, these factors represent normal features of daily activity and, as such, may not be considered a limitation. Recollection of data was not performed on the particular days of the week that were missed during the initial seven days. This may have had an impact on individual results, as certain days may have been significant for individual routines.

Further research should focus on whether rehabilitation changes activity patterns over the course of the rehabilitation period. If not, investigations into whether activity patterns or aspects of activity patterns are amenable to change may be required. For example, changes may be dependent on a number of factors such as disease progression, the severity of the neurological condition, the use of assistive devices and behavioural influences.

CONCLUSION

The StepWatch was used to describe the activity patterns of individuals with neurological conditions demonstrating that participants were active for shorter durations, with fewer steps in a row, which was interspersed with short periods of rest compared to healthy adults. Participants also covered less distance than previously reported by healthy adults. This information may assist in the development of more specific walking rehabilitation. Training should include retraining acceleration and deceleration, and focusing on increasing the duration of walking in single bouts, together with the ability to cover distances required for functional community ambulation.

KEY POINTS

- Adults with neurological conditions walk in bouts with low step counts interspersed with short, frequent rest periods, similar to healthy adults.
- Adults with neurological conditions take a higher number of short duration bouts than healthy individuals do.
- While adults with neurological conditions had a similar number of total steps per day to previously reported data from healthy adults, overall variability and activity levels were less.
- Rehabilitation may initially need to include a focus on more specific aspects of walking, such as acceleration and deceleration and short bursts of activity, as well as achieving functional walking distances.

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