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A technique to record the sedentary to walk movement during free living mobility: A comparison of healthy and stroke populations

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Research highlights

- A novel method for measuring movement transitions during everyday life is presented.
- Healthy participants walk after standing up on almost every occasion (92%).
- Typically this is a single action sedentary to walk movement.
- Stroke survivors walk less frequently after standing up (66%).
- Typically walking from a sedentary positon is performed in a hesitant and/or separated pattern in stroke survivors.

Abstract: Background

Hesitation between moving from a sedentary posture (lying/sitting) to walking is a characteristic of mobility impaired individuals, as identified from laboratory studies. Knowing the extent to which this hesitation occurs during everyday life would benefit rehabilitation research. This study aimed to quantify this transition hesitation through a novel approach to analysing data from a physical activity monitor based on a tri-axial accelerometer and compare results from two populations; stroke patients and age-matched unimpaired controls.

Methods

Stroke patients living at home with early supported discharge (n=34, 68.9YO ± 11.8) and age-matched controls (n=30, 66.8YO ± 10.5) wore a physical activity monitor for 48hrs. The outputs from the monitor were then used to determine the transitions from sedentary to walking. The time delay between a sedentary posture ending and the start of walking classified four transition types: 1) fluent (<=2s), 2) hesitant (>2s<=10s), 3) separated (>10s) and 4) a change from sedentary with no registered walking to a return to sedentary.

Results

Control participants initiated walking after a sedentary posture on 92% of occasions. Most commonly (43%) this was a fluent transition. In contrast stroke patients walked after changing from a sedentary posture on 68% of occasions with only 9% of transitions classed as fluent, (p<0.05).

Discussion/Conclusion

A new data analysis technique reports the frequency of walking following a change in sedentary position in stroke patients and healthy controls and characterises this transition according to the time delay before walking. This technique creates opportunities to explore everyday mobility in greater depth.

Keywords: sedentary to walk, stroke, free-living mobility, physical activity monitor

Introduction

Everyday life involves frequent transitions between postures and movements, such as sitting to standing and standing to walking. Variability within and between individuals performing these transitions is a hallmark of normal movement and a consequence of the abundance of motor solutions available to healthy individuals(1). In general, and irrespective of environmental and task specific factors, this motor flexibility allows healthy individuals to perform manifold daily activities without hesitation. However, limited motor flexibility, resulting from impairments observed in conditions like stroke, Parkinson's disease and, more generally, age related frailty, can result in stereotypical, slow and hesitant transitions(2-4). To date movement transitions, e.g. sit-to-stand and sit-to-walk have been studied under controlled laboratory conditions (3-5) employing detailed biomechanical and muscle activation measurement techniques, while this provides important understanding of movement at the body functions and structure level (6) it provides only limited understanding of everyday movement activity. Studying these transitions during everyday life could help resolve problems such as the recovery of community mobility after stroke (7). Activity monitors can classify postures (8) and measure the time taken to change postures. Taken together these parameters allow the reporting of transitions in movement such as sit/lying (sedentary) to walk, during free-living.

The aim of this study was to test a new method for quantifying a sedentary to walk transition using the time period between a sedentary posture (sitting/Lying) and a bout of walking with populations of differing levels of mobility.

Methods

Participants

Data were extracted from two physical activity studies, providing two contrasting populations:

1) Stroke patients (n=34), including 31 infarcts and 3 haemorrhagic, recently (<14days) discharged from being an in-patient (median length of stay 44 days (IQR 18 to 62)) but still receiving rehabilitation input as part of their early supported discharge (ESD). Eleven individuals were living alone .They were aged 68.9±11.8years, height 1.67±0.2m and weight 73.1±18.6kg, 18 were male and there were variable levels of mobility (Modified Rivermead Mobility Index, median 34, IQR 30-37). The original study (UKCRN15472) was approved by the West of Scotland Ethics committee (13/WS/0150).

2) An age matched control group (n=30) was recruited consecutively from the local community. They were aged 66.8±10.5 years and included 18 males. Ethical approval was granted by the Glasgow Caledonian University, School of Health and Life Sciences, Ethics Committee.

Data were collected from all participants in the same manner, an activity monitor (dimensions 45mm, 25mm, 5mm, and <15g in weight) consisting of a triaxial accelerometer (activPAL3, PAL Technologies Ltd, Glasgow, UK) was attached, using Tegaderm™ (3M, Neuss, Germany), to the anterior aspect of the participant’s thigh (unaffected side for stroke patients and right side for controls). All participants were asked to continue their everyday activities as normal. After a minimum of 48 hours of continuous recording during the working week (Monday – Friday) the activity monitor was removed and the stored data downloaded for processing. The average monitoring period was 92.26 hours (SD 40.61) for the stroke group and 164.80 hours (SD 12.80) for the control group.

Data processing

The activPAL3 samples data at 20Hz, these data are then classified into events using proprietary algorithms. The use of a single sensor limits the system's ability to differentiate between a lying and seated position, therefore events were identified as sedentary (either sitting or lying), standing and walking. Consecutive stride events were combined to give walking events. Each event has a start time and duration associated with it. The output from the device has been validated for classification of sedentary, standing, and walking activities in a range of populations (9).

The sedentary to walk (STW) transition time was then calculated as follows:

Start time of the walking event – end time of the previous sedentary event.

Based on this calculation four different categories of STW transition were determined using values gathered from laboratory studies (3, 10, 11).

1) Fluent STW: walking starts within 2s of a change in posture from sedentary. This time frame was based on healthy older adults being able to complete an entire (initiation to end) sit-to-walk transition within 1.8-2.3s (2, 3, 11). Two seconds was therefore considered a reasonable, maximum, time delay to consider it a single fluent movement.

2) Hesitant STW: the walking event starts between 2s and 10s after the end of a sedentary event. Adults at risk of falling and stroke survivors can perform the whole STW transition, on average, within 10s (95% CI), including pauses in the movement (10, 11). Ten seconds was

therefore considered a reasonable maximum time delay, to consider it a single, if hesitant, movement.

3) Separated STW: Walking occurring after a sedentary event with a substantial delay (>10s). This value was selected to be reflective of a disconnected sedentary to walk movement based on a hesitant STW being within a maximum of 10s.

With a further classification of:

4) Sedentary to stand to sedentary (STSTS): There was a change from sedentary recorded without a subsequent bout of walking before a return to sedentary.

See figure 1 for illustration of these transitions using raw accelerometer data.

Insert figure 1

To explore the validity of these definitions the whole dataset (stroke and healthy age matched controls) was separated into discrete time bins (0-2, 2-4, 4-6, 6-8, 8-10, 10-15, 15-20, … >40) and plotted against the percentage of transitions for that group.

Statistical analysis

Statistical differences for the percentages of these transitions between the groups were tested using the Mann-Whitney Test, and an alpha level of 0.05 was set for significance. Dependence between the Modified Rivermead Mobility Index and the physical activity monitor was explored with Spearman's rank correlation, all statistical tests were carried out with Minitab (Penn, USA).

Results

Walking followed a transition from sedentary on 91.8% of occasions in the control group compared to 68.0% (SD 11.9) in the stroke group. Only a median of 9.14% (IQR, 4.50-17.46) of the transitions performed by the stroke group per day were fluent (<2s delay between standing up and walking) compared to a mean of 43.96% for the controls, see table 1 and figure 1. In contrast 33.9±19.5% of transitions in the stroke group were categorised as STSTS compared to just 8.20±5.42% in the control group. These differences were statistically significant for both the fluent ($p<0.001$) and the STSTS ($p<0.001$). There were no significant differences between the groups for hesitant and separated transitions. Hesitant transitions accounted for 22.87±6.54% and 23.94±13.56% for controls and stroke respectively ($p=0.69$) while separated transitions accounted for 25.97±6.18% and 30.12±13.00% for controls and stroke respectively ($p=0.11$). There was a good positive correlation (Spearman rho 0.55, $p=0.01$) between the Modified Rivermead Mobility Index and percentage of daily fluent STW transitions, indicating stroke survivors with better mobility performed a greater percentage of fluent STW transitions.

Insert Figure 2

Insert table 1

Discussion

We present a new method for measuring and categorising transitions between sedentary postures and walking during everyday living. Using transition time we categorised; 1) a fluent sedentary to walk transition (<2s), 2) a hesitant transition (2-10s), 3) a separated transition (>10s, but walking does occur) and finally 4) a sedentary to stand to sedentary (STSTS) transition (i.e. no walking occurs). When applied to two populations, with (stroke) and without (healthy control) mobility impairment, this categorisation technique revealed significant differences, illustrating its potential value to mobility screening and rehabilitation research.

Using this technique, for example, it is evident that the primary reason for standing up in everyday life is to walk; 92% of the sedentary-to-stand transitions were followed by walking in healthy individuals. This finding supports the use of mobility tests that combine sit to stand and walking (12), as a better reflection of real world mobility. The advantage of the presented technique is that it can measure an individual's actual mobility at home over long periods of time, improving the measurement validity. Using the transition definitions a more detailed profile of an individual's mobility can be gained; fluent transitions, for example were much more common (43%) in the healthy older adults compared to the stroke population (9%), and better scores on the Modified Rivermead Mobility Index for the stroke patients were reasonably well correlated (r=0.55) with the percentage of daily fluent STW transitions. These findings may be useful in detecting subtle changes in mobility.

Limitations

Limited clinical information on the stroke sample prevented a more robust analysis of factors such as stroke severity, the use of assistance and psychological factors such as fear of falling. The data were all derived from single site acceleration signals and the accuracy of the classification algorithms may be at risk with very slow moving individuals such as stroke survivors. Finally we recognise that in the absence of definitive free-living cut-off values the presented values of less than 2s, between 2 and 10s, and greater than 10s, whilst based on literature, may need to be adjusted in future as more data becomes available. To facilitate development of this technique we have presented the percentage data for 2 second bins (figure 2) to allow future researchers to explore different cut –off points.

Conclusion

A novel technique for classifying movement transitions in everyday life found statistically significant differences in the type of transition (fluent, hesitant and separated) performed by groups with differing levels of mobility, creating opportunities to further understand community mobility.

Conflict of interest

One of the authors (Granat) would like to disclose their membership of the board of the company (Paltechnologies) which manufacturers the physical activity monitors (ActivPal) used in the study. Apart from this the authors confirm that there have been no conflict of interest in the conduct of this study and writing of this paper.

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Figure 1: Illustration of transitions using raw accelerometer data.

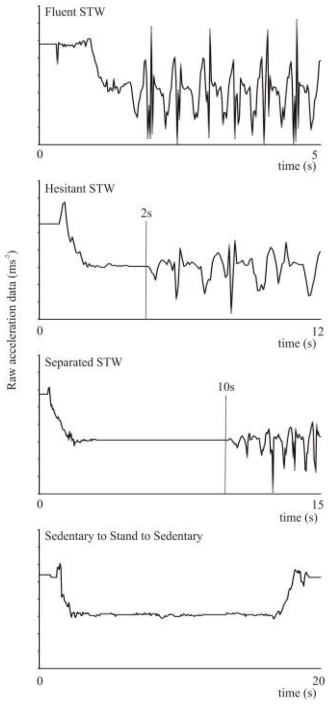

Figure 2: Sedentary to walk transition categories expressed as a percentage of total and separated into time bins.

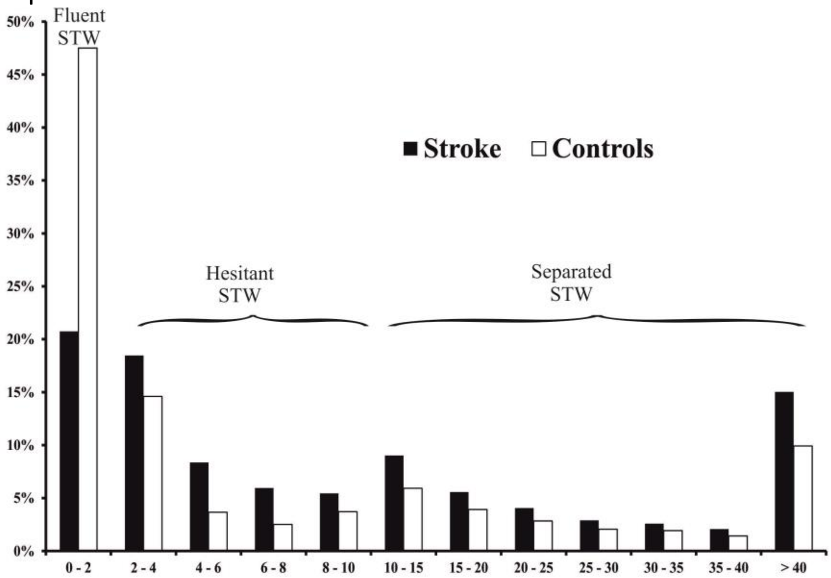

Table 1: Average (variance) number of daily transitions according to group with percentages of total

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	All (N=64) Mean (SD)	Stroke (n=34) Mean (SD)	Controls (n=30) Mean (SD)	Comparison p-value
Fluent STW	14 (11) 26.54% (18.92)	4 (2.14-11.56)* 9.14% (4.50-17.46)*	22 (9) 42.96% (12.58)	<0.001 <0.001
Hesitant STW	9 (14) 23.44% (10.78)	14 (18) 23.94% (13.56)	5 (6) 22.87% (6.54)	0.004 0.595
Separated STW	18 (16) 28.17% (10.51)	8 (8) 30.12% (13.00)	28 (15) 25.97% (6.18)	<0.001 0.74
Sedentary to stand to Sedentary	8 (16) 21.85% (19.50)	14 (20) 33.88% (19.54)	2 (6) 8.20% (5.42)	<0.001 <0.001

*median and IQR range reported as data were not normally distributed