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Defining ambulatory bouts in free-living activity:

Impact of brief stationary periods on bout metrics

Gillian Barry[1,2], Brook Galna[2], Sue Lord[2], Lynn Rochester[2] and Alan Godfrey[2]

[1] Department of Sport, Exercise and Rehabilitation, Northumbria University, Newcastle upon Tyne, UK

[2] Institute of Neuroscience | Newcastle University Institute for Ageing, Clinical Ageing Research Unit, Newcastle University, Campus for Ageing & Vitality, Newcastle upon Tyne, UK

Corresponding Author

Dr Alan Godfrey,

Institute of Neuroscience | Newcastle University Institute for Ageing,

Clinical Ageing Research Unit,

Newcastle University,

Campus for Ageing and Vitality,

Newcastle upon Tyne.

NE4 5PL.

Email: alan.godfrey@newcastle.ac.uk

Fax: (+44) 191 248 1245

Abstract

The aim of this study was to assess the effect of varying the maximum resting period between consecutive ambulatory bouts in community-based outcomes. Ambulation was assessed in 97 community-dwelling older adults (mean (SD) age 69.2 (7.7) years) using an accelerometer (activPAL™) worn on the upper thigh for 7 consecutive days. The volume, pattern and variability of ambulation were calculated over a range of maximum resting periods (1-30s). Outcomes with a maximum resting period from 1-6s did not vary due to device functionality. Non-linear regression (power law, $r^2 > 0.99$) showed that increasing the maximum resting period from 6-30s resulted in changes in volume (increased duration spent walking, and decreased number of bouts), variability (S_2 increased) and pattern (α decreased), and a linear relationship with an increase in average bout length. With a MRP of 6 seconds, 6% of the cohort achieved the public health guidelines of 150 minutes of ambulation/week accumulated in bouts ≥10minutes, which increased to 40% using a maximum resting period of 30s. Modifying the maximum resting period impacts on volume, pattern and variability measures of community based ambulation, and attainment of public health guidelines. This highlights the need for standardised algorithms to aid interpretation and explicit reporting of the maximum resting period to aid comparison between studies.

Highlights

- Maximum resting period (MRP) was assessed in community-based ambulation
- Ambulation was objectively assessed with an accelerometer in 97 adults for 7 days
- MRP impacts on volume, variability, pattern outcomes and attainment of guidelines
- Standardised algorithms are needed to aid ambulatory interpretation

1. Introduction

Body worn monitors (BWM) provide continuous and objective measures of community-based ambulation (walking) [1, 2]. Simple BWMs consist of a uni-axial accelerometer with low sampling rates that can quantify the volume, variability and pattern of walking. Moreover, simple BMW configurations facilitate longitudinal (≥7days) monitoring by preserving battery life and memory. These devices (e.g. activPAL™[1]) have been used to quantify free-living ambulation in a range of studies [3-7].

Public health recommendations state older individuals should accumulate at least 150 minutes/week of ambulation in bouts ≥10 minutes [8]. Assessing adherence can help quantify the ambulatory activity of a population, inform health policy and measure the efficacy of interventions [9]. However, different interpretations of what constitutes a single bout of walking might influence outcomes. For example, if a person pauses (e.g. 10s) due to environmental factors e.g. pedestrian crossing or opening a door: should this be considered one long bout or two shorter bouts, (Figure 1A)? Decisions regarding the maximum resting period (MRP) between consecutive bouts of ambulation have not been investigated, despite having the potential to impact measures of community ambulation. Although somewhat controversial regarding the effectiveness of the recommended duration and intensity of activity for older adults (150min/week, ≥10min bouts), there is a need to understand how altering the maximum resting period influences the estimates of bout lengths during community ambulation.

The aims of this exploratory study were to assess the effect of varying the MRP on: i) the volume, variability and pattern of community-based ambulation; and ii) on attainment of public health recommendations. To address these aims, we investigated the effect of varying the MRP on ambulatory data captured using a BWM over 7 days in a cohort of older adults.

2. Methods

2.1 Participants

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[1] activPAL™, PALTechnologies LTD., Glasgow, UK

Participants were recruited as controls to the ICICLE-Gait study [10] (N = 97, 47 females; mean (SD); age 69.2 (7.7) years; height 1.6 (0.09) m; weight 76.8 (15.92) kg; and BMI 27.3 (4.47) kg/m^2), which is part of a larger study, ICICLE-PD[2] [11, 12]. None of the participants had a history of major psychiatric, cognitive impairment, stroke or movement disorder. The study was approved by the Newcastle and North Tyneside 1 Research Ethics Committee and Newcastle upon Tyne Hospitals NHS Foundation Trust. All participants gave informed written consent.

2.2 Assessment of community ambulatory activity

Ambulatory activity was measured using an activPAL™ BWM (53.0 × 35.0 × 7.0 mm, 20 g, 10Hz/0.1s) worn on the upper thigh. It identifies changes in posture from sedentary (sitting or lying) to standing and ambulation [3]. It was attached to the skin with the manufacturer recommended PALstickies[3] (hydrogel adhesive) and covered with Hypafix[4] tape to ensure it remained in place. The device was worn continuously for 7 days (24hours/day). Participants were instructed to remove the device only during bathing and were provided with replacement adhesives and tape to re-attach the device.

2.3. Data processing

A complete flow representation of the data analysis is presented in Figure 1B. A MATLAB® program analysed the Excel[5] event files (generated from activPAL™ software) which contained the times spent sedentary, standing and ambulatory. The program identified all ambulatory/standing bouts between sedentary bouts and grouped (reclassified) standing as ambulatory behaviour if the duration between the two consecutive ambulatory bouts was less than or equal to the MRP. The MRP was adjusted between 1s to 30s in 1s increments (Figure 1a). Once new bouts of ambulation were created, all outcomes were re-calculated.

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[2] Incidence of Cognitive Impairment in Cohorts with Longitudinal Evaluation – Parkinson's disease
[3] PAL Technologies, Glasgow, UK
[4] BSN Medical Limited, Hull, UK
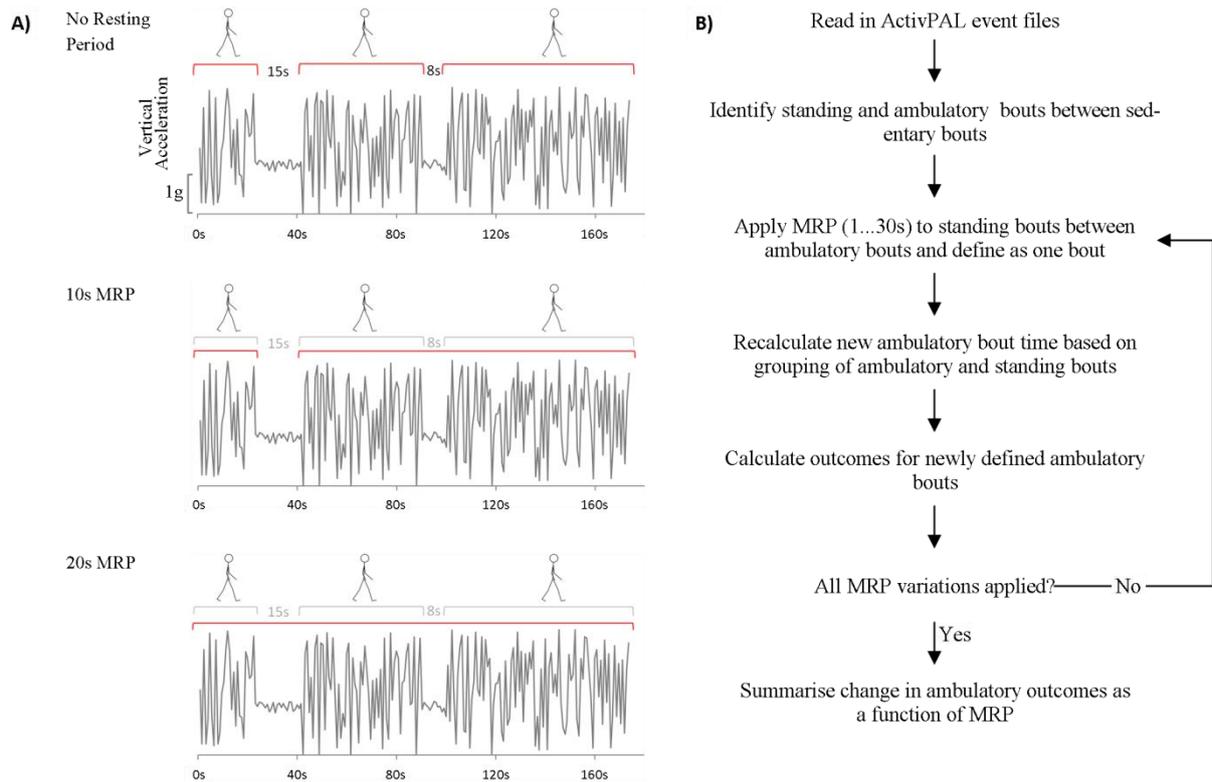[5] Microsoft Corp., Redmond, WA, USA

Figure 1: Panel A illustrates an example raw activPAL acceleration trace over 180 seconds showing brief rest periods of non-ambulatory activity (e.g. pedestrian crossing or opening a door) separating bouts of ambulation (red lines), and how ambulatory bouts are redefined when allowing for a Maximum Resting Period (MRP) between consecutive ambulatory bouts. (Participants recruited from Newcastle-upon-Tyne and Gateshead, UK, June 2009 – December 2011). Panel B shows the data analysis process to redefine bouts of ambulation for varying MRPs.

2.4 Ambulatory outcomes

Ambulation was defined by established outcome measures analysing volume, pattern and variability [2, 13]:

i. Volume: percentage of time spent ambulatory; number of ambulatory bouts; and average bout length.

ii. Pattern: alpha (α) describes the distribution of bouts according to their duration and is related to the power law distribution [14]. A larger alpha indicates the distribution of ambulatory bouts is derived from a greater proportion of shorter bouts.

iii. Variability (S_2): represents the 'within person' variability of bout length.

Both average bout length and S_2 were calculated using a maximum likelihood technique because data were log-normally distributed [13].We also calculated the proportion of participants who

achieved the public health recommendations of at least 150 minutes of activity accumulated in bouts ≥ 10 minutes over 1 week.

3. Results

We found no change in any of the outcomes with a MRP between 1-6s. Subsequent investigation revealed this was due to device functionality and its method of classifying periods of brief standing as stepping during ambulation. Therefore, all subsequent analysis focussed on MRPs of 6-30s. Non-linear regression (power law, $r^2 > 0.99$) showed that increasing the MRP in 1s increments from 6-30s resulted in an increasing greater proportion of time spent ambulatory, which was made up of fewer bouts; increased bout variability (S_2); and altered pattern of bouts (decreased α) (Figure 2A-E, next page). There was also a linear (r^2. >0.99) relationship with increasing average bout time. In relation to public health recommendations, 6% of the cohort achieved at least 150 minutes of activity per week from bouts >10 minutes using a MRP of 6s. This increased to 40% of the cohort using a MRP of 30s (Figure 2F).
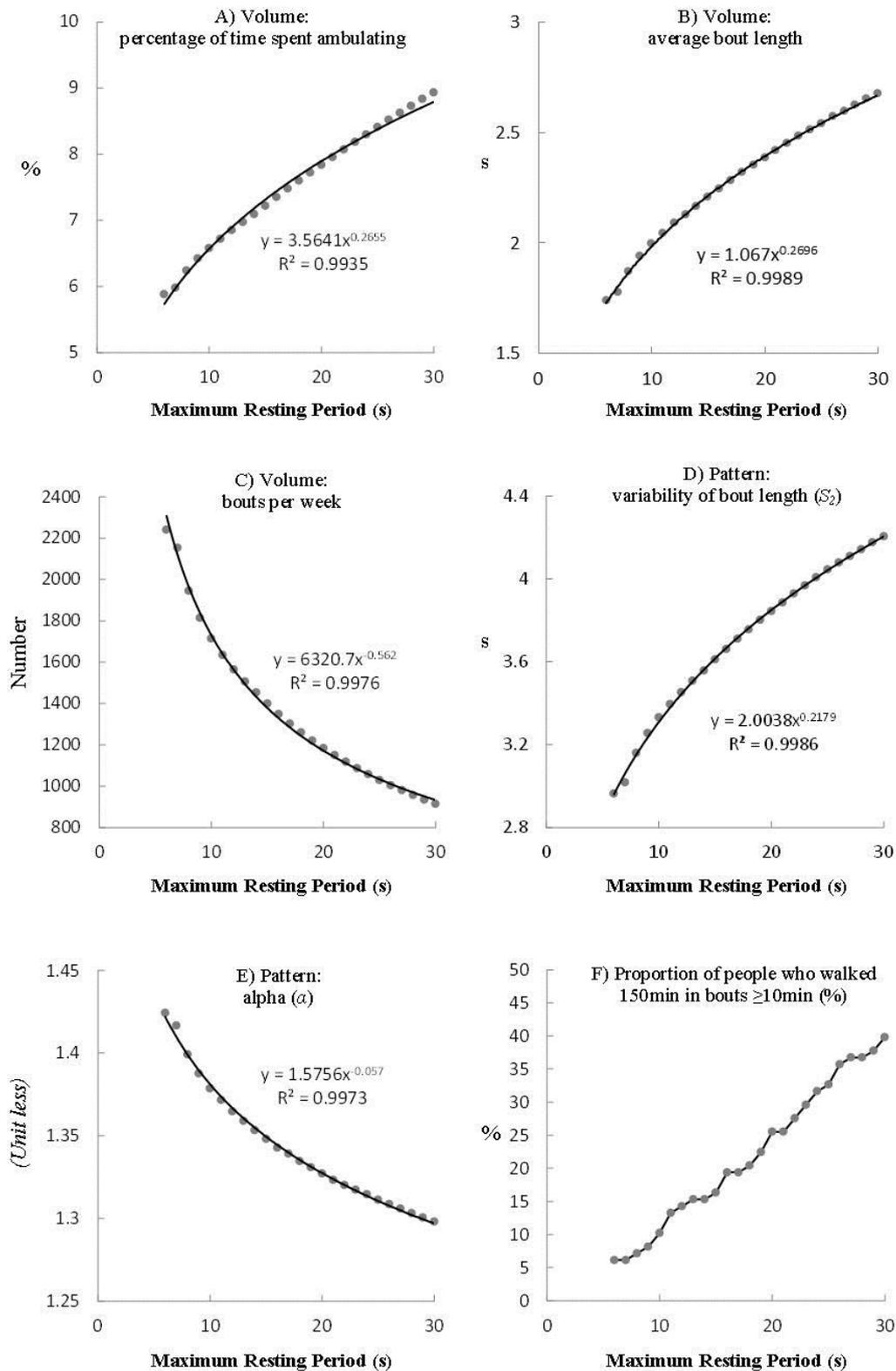
Figure 2: Panels illustrate the effect of increasing the Maximum Resting Period (MRP) from 6-30s (grey circles) on the volume (A-C), variability (D) and pattern (E) of ambulatory activity in 97 community-dwelling older adults. Power-law regression lines are displayed by a solid black line. Panel F shows the proportion of participants who achieved the health guidelines of 150 minutes per week of ambulatory activity made up of bouts ≥ 10 minutes as a function of increasing the MRP. (Participants recruited from Newcastle-upon-Tyne and Gateshead, UK, June 2009 – December 2011).

4. Discussion

Our findings confirm that varying the MRP between successive ambulatory bouts significantly influences volume, variability and pattern of community-based ambulation. In addition, the findings suggest that comparison between studies using different methods to address short resting periods of non-ambulatory activity between bouts of ambulation is difficult. However comparison may be possible using the regression equations reported in Figure 2A-E and warrants further investigation. Future standardisation will also aid comparison between studies.

Current guidelines [8] state that in order to maintain good health people should perform 30 minutes of activity for five days of the week (150 minutes/week) which can be achieved in bouts ≥10 minutes. With this in mind, we assessed how many people achieved these recommended levels of activity, adjusting the MRP to account for brief periods of non-ambulatory activity due to environmental factors such as pausing for traffic or navigating crowded walkways. Six percent of our cohort achieved the recommended volume of activity when analysing their data with a MRP of 6s, which increased to 40% with an MRP of 30s. Increasing the MRP to account for rest periods of up to 30seconds may be more representative of ambulation in the community, particularly in urban areas. However, the impact of these short rest periods on the relevant physiological measures of activity also need to be taken into consideration when developing standardised protocols.

We found that ambulatory activity outcomes did not vary with the MRP ranging from 1-6s (activPAL™). Although unexpected, subsequent investigation of the raw accelerometer signal revealed this was due to the algorithm put in place by the manufacturer, where brief periods of standing (1-6s) during walking were already classed as ambulatory. This can be seen a limitation of low resolution BWM as well as the reliance on propriety software to interpret and analysis accelerometer data from commercial devices. Therefore, the use of low resolution BWMs is questionable if investigators are interested in quantifying very short periods of ambulation that may frequently occur in community based-activities [15]. This could have important implications in bespoke intervention-based studies involving pathological cohorts where accurate recording of short bouts of ambulation may be critical for disease management or falls prevention strategies. Future work should investigate the change in outcomes due to MRP <6s while also assessing different commercial BWM.

Conclusion

We recommend: i) that there is a need for standardised algorithms to aid interpretation of community-based ambulation based on MRP derived from different BWM; and ii) authors (and manufacturers) explicitly report the methods of accounting for short periods of standing between successive walking bouts.

Acknowledgements

Conflict of interest

There are no conflicts of interest.

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