Discerning the contribution of balance and mobility to ambulatory activity in community-dwelling octogenarians: A preliminary report

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ABSTRACT

Adults are encouraged to maintain levels of physical activity throughout their life span. This study describes gait performance and ambulatory activity (as a key component of physical activity) in 15 community-dwelling octogenarians and examines the association between activity measured continuously for 5 days with a tri-axial accelerometer and clinical measures of balance and functional mobility. Outcomes represented macro features of ambulatory activity and included volume, pattern and variability of activity. Micro gait outcomes were derived from each walking bout and represented 14 discrete spatio-temporal characteristics of gait. Participants walked a median of 9,294 steps/day (range 5,121-18,231). For macro outcomes, the strongest associations were established for Timed up and Go (TUG) single and dual task times and mean bout length (r_s = -.66, p = 0.006, and -.68, p = 0.005 respectively; Spearman's rho), and TUG dual task and accumulation of walking bouts (alpha) (α) (r_s = -.67, p = 0.006). For micro outcomes, there was a positive correlation between step velocity and the Activities Balance and Confidence Scale (r_s = .67 p = 0.006), and a negative correlation between step velocity and TUG single task (r_s = .71, p = 0.003). TUG dual task showed a positive association with step time asymmetry (r_s = .65 p = 0.008) and swing time asymmetry (r_s = .66, p = 0.004). For this group of active octogenarians, associations between ambulatory activity and functional mobility were stronger than for balance.

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Key Words: Older adults, Ambulatory activity octogenarians, Physical activity, Balance, Gait

INTRODUCTION

Older adults are encouraged to retain an active lifestyle, and the health benefits of physical activity do not appear to diminish across the life span. Research in very senior adults supports the importance of continued activity into advanced years (Stessman, Hammerman-Rozenberg, Cohen, Ein-Mor, & Jacobs, 2009; Yates, Djoussé, Kurth, Buring, & Gaziano, 2008). Significant associations have been reported in octogenarians for physical activity and lower levels of disability (Activityhor et al., 2014; Stessman et al., 2009); and between physical activity and white matter integrity (Burzynska et al., 2014; Tian et al., 2015). However, clinical predictors of activity in this age group are less well defined than its benefits. Identifying those who will achieve greater levels of activity and gain from the experience is clinically challenging. Physical activity is multifaceted and embedded in a complex interplay of behavioural, cultural and social drivers which cannot be measured by single assessments in the laboratory or clinic.

Recent advances in wearable sensor technology go some way towards ameliorating the problem. Body worn sensors enable continuous measurement of activity in an unobtrusive and broadly acceptable way, and are superior to questionnaires which are blunt instruments prone to bias and inaccurate recall (Forsén et al., 2010). Data from wearable sensors typically focus not only on the volume of activity such as daily step count or minutes per day active but also more nuanced measures such as accumulation of activity bouts and variability of bout distribution (Del Din et al., 2017). Together these features have been described as the 'macro' level of activity. A further advantage of wearable sensors is that detailed gait characteristics (features such as step length, step variability, step asymmetry) can be measured simultaneously, producing data with more ecological validity than that collected in the clinic or laboratory where assessments are independent of context and influenced by test protocol and attentional drive (Del Din, Godfrey, Galna, Lord, & Rochester, 2016; Giannouli, Bock, Mellone, & Zijlstra, 2016; Robles-García et al., 2015; Weiss et al., 2013). These detailed features comprise the 'micro' level of gait.

Research examining the relationship between clinical measures of balance, mobility and physical activity measured by accelerometry in octogenarians is limited. Previous studies indicate there is little relationship between activity volumes and physical performance measures. Hall et al. (2017) found weak to moderate associations between daily step count and physical performance measures (usual gait speed, chair stands and 6-minute walk) for those aged 80 – 90+. Others found either weak or no correlation between volumes (daily step count, walking duration or activity bout lengths) and measures of balance (Berg Balance Scale) and mobility (Short Physical Performance Battery, chair stands, Timed Up and Go, Four Square Step and Dynamic Gait Index) for those aged 70 – 80+ (van Lummel et al., 2015; Weiss et al., 2013). Stronger associations were reported for selected micro gait characteristics and physical performance measures in a study comparing physical activity in fallers and non-fallers (Weiss et al., 2013).

Studies to date do not include a detailed clinical assessment of balance, balance self-efficacy, or a comprehensive range of 'free-living' micro gait characteristics. The question warrants further investigation to more fully inform clinical practice. This study examines the association between balance performance, balance self-efficacy, functional mobility, and physical activity in community-dwelling people over 75 years of age. We derived 'macro' gait characteristics (volume counts, pattern and distribution of ambulatory activity) and 'micro' gait characteristics (14 spatio-temporal gait characteristics) from body-worn sensor data worn continuously for five days. In this study we measure ambulatory activity as a core component of physical activity. The term physical activity comprises multiple features of which walking, gardening and swimming are the most popular for this age group (Ministry of Health, 2013).

METHODS

Participants

Fifteen healthy, community-dwelling older people with an age range of 78-90 years (84.7 SD 3.8 years), volunteered for this study. Exclusion criteria were those with a neurological condition (e.g., Parkinson's disease, stroke), cognitive impairment (e.g., dementia), cardiothoracic or orthopaedic conditions affecting mobility, walking, or safety, and poor English affecting one's ability to give informed consent. Ethical approval was obtained from the AUT Ethics Committee (AUTEC reference number 17/312) and all participants provided written consent.

Equipment

Participants wore a single tri-axial accelerometer-based body-worn sensor for 5 days (Axivity AX3, York, UK), secured on the lower back at the fifth lumbar vertebrae (L5) using double-sided tape, and covered with Hypafix (BSN Medical Limited, Hull, UK). Participants were advised to continue with their usual everyday activities other than swimming. The sensor was programmed to sample at a frequency of 100 Hz (range ±8 g).

Clinical measures

Age, sex, weight, and height and falls history over the previous 12 months were obtained. Due to the small sample size we did not collect ethnicity data.

Balance and mobility measures

Balance confidence (self-efficacy) was measured using the Activities-specific Balance Confidence (ABC) Scale, a 16-item self-report questionnaire that asks participants to rate their balance confidence whilst performing activities (Powell & Myers, 1995). To increase relevance, item 16 was changed from rating confidence when walking on icy sidewalks to rating confidence when walking on slippery sidewalks (Mak, Lau, Law, Cheung, & Wong, 2007). Balance performance was measured using the 14-item Mini-BESTest, which assesses anticipatory postural transitions, postural responses, sensory orientation, and dynamic gait (Franchignoni, Horak, Godi, Nardone, & Giordano, 2010). Functional mobility was measured using the Timed Up and Go test (TUG) (Podsiadlo & Richardson, 1991), which incorporates rising from a chair, a turn, and a short walk under single and dual task conditions.

Physical activity (micro and macro) measures

Macro and micro outcomes have been described elsewhere (Del Din et al., 2017; Del Din, Godfrey, Galna, et al., 2016). Macro characteristics include volume, pattern and variability of ambulatory activity. Volume was quantified as total daily step count. Pattern was quantified as number of daily walking bouts (minimum bout length defined as three steps), the mean length of walking bouts (s), and alpha (α) as the distribution of ambulatory bouts (a lower α indicates that the distribution is derived from a greater proportion of longer bouts). Bout length variability was described as the within subject variability of bout length. A high variability indicates a more varied pattern of walking (Chastin & Granat, 2010; Del Din et al., 2017; Lord et al., 2011).

Micro (spatio-temporal) outcomes included 14 gait characteristics which conform to a validated model of gait (Lord, Galna, & Rochester, 2013; Lord et al., 2012). Mean values were calculated for step time, stance time, swing time, step length and step velocity. Standard deviation from all steps was calculated to determine step time variability. Step time asymmetry was calculated as the absolute difference between consecutive left and right steps. The validated algorithms used for gait detection and data segmentation techniques have been described in full previously (Del Din, Godfrey, & Rochester, 2016; Godfrey, Del Din, Barry, Mathers, & Rochester, 2014).

Data Processing and Analysis

Raw data were uploaded to an encrypted, secure platform (eScience Central online facility maintained by Newcastle University, UK) for storage and blinded processing (Simpson et al., 2017). Data were analysed using MATLAB (version 2015a), and reported in Microsoft Excel (Version 2016). Descriptive statistics for participant characteristics and activity outcomes were reported as means, standard deviations (SD), medians and inter-quartile range (IQR). Scores from the ABC Scale, the Mini-BESTest and the TUG were correlated with macro and micro outcomes using Spearman's rho (r_s). In view of multiple testing, a p value of 0.01 was considered significant. Data were analysed using SPSS Version 25.

RESULTS

All participants who volunteered for the study were recruited. The participants' ABC Scale, Mini-BESTest scores and TUG scores are described in Table 1, and indicate a highly-functioning group of older adults. Only two participants reported a fall within the past 12 months, with one person reporting a total of three falls.

Table 2 describes macro characteristics for all participants, and Table 3 describes spatiotemporal gait characteristics for all participants. Ambulatory activity for these mostly octogenarians was high, with similar values for all participants apart from one highly active individual, who walked on average over 18,000 steps a day, and was active for 237 minutes of the day. Participants walked with an average gait speed of 1.01 ms $^{-1}$ which is comparable to age-referenced data (Beauchet et al., 2017). TUG single task scores were comparable to those reported for non-fallers (Weiss et al., 2013), although balance confidence scores were considerably higher (80% compared with 53% confidence).

For macro outcomes there were moderate, negative correlations between mean bout length and TUG single and dual task times (r_s = -.66, p = 0.006, and -.68, p = 0.005 respectively), suggesting those with more proficient mobility walked for longer bouts. There was also a moderate positive correlation between alpha (α) and TUG dual task (r_s = -.67, p = 0.006), indicating that people with better TUG (lower scores) undertook a greater proportion of longer walking bouts. There was no correlation between total volume of ambulatory activity (number of steps, total time walked or percentage of walking time) and physical performance measures.

Table 1: Participant characteristics

Characteristic	Mean (SD)	Median (IQR)	Range
Personal characteristics			
Male/female (4:11)			
Age (years)	84.7 (3.8)	84.0 (82.0 - 89.0)	78.0 – 90.0
Weight (kg)	63.7 (9.4)	61.7 (56.4 – 69.9)	50.1 – 85.4
Height (cm)	160.1 (9.5)	158 (153 - 164)	147 – 180
Fallen within last 12 months yes/no (2:13)			
Number of falls	2.0 (1.4)	2.0 (1.0 – 2.0)	1.0 – 3.0
Balance			
ABC Scale (%)	80.2 (18.5)	84.4 (67.8 – 98.1)	35.8 – 99.4
Mini-BESTest (0 - 28)	19.1 (3.4)	19.0 (16.0 - 22.0)	13.0 – 25.0
Functional Mobility			
TUG single	10.2 (2.3)	10.0 (9.0 - 12.0)	6.0 - 15.0
TUG dual	17.6 (7.2)	14.0 (12.0 - 25.0)	9.0 - 31.0

Notes: ABC Scale, Activities Balance and Confidence Scale; TUG, Timed up and Go test

Table 2: Free-living macro gait characteristics for all participants

	Mean (SD)	Median (IQR)	Range
Number of steps per Day	9522 (3148)	9294 (7273 - 10594)	5121 - 18231
Total Walking Time per Day (min)	138.9 (42.2)	130.5 (113.4 - 164.7)	71.5 – 237.6
Percentage Walking Time	9.6 (2.9)	9.0 (7.8 – 9.0)	5.0 - 16.0
Bouts per Day	633.0 (175.0)	569.0 (515.0 - 569.0)	571.0 - 922.0
Mean Bout Length (sec)	13.1 (1.6)	13.0 (11.9 – 14.2)	10.3 - 16.8
Variability (S_2)	0.755 (0.04)	0.762 (0.73 - 0.77)	0.68 – 0. 85
Alpha (α)	1.66 (0.04)	1.65 (1.64 - 1.69)	1.62 - 1.74

Notes: SD, standard deviation; IQR, inter-quartile range

Table 3: Free-living micro gait characteristics for all participants

Gait characteristic	Mean (SD)	Median (IQR)	Range
Pace			
Step Velocity (m/s)	1.01 (0.09)	1.01 (.92 – 1.08)	0.87 – 1.16
Step Length (m)	0.57 (0.03)	0.56 (0.54 - 0.60)	0.50 – 0.67
Swing Time Var (s)	0.13 (0.01)	0.13 (0.12 – 0.14)	0.11 – 0.15
Variability			
Step Velocity Var (m/s)	0.33 (0.03)	0.32 (0.30 – 0.37)	0.27 – 0.39
Step Length Var (m)	0.14 (0.01)	0.14 (0.13 – 0.14)	0.13 – 0.15
Step Time Var (s)	0.16 (0.02)	0.16 (0.15 – 0. 17)	0.13 – 0.18
Stance Time Var (s)	0.17 (0.02)	0. 12 (0.16 - 0.19)	0.14 – 0.19
Rhythm			
Step Time (s)	0.59 (0.03)	0.59 (0.57 – 0.61)	0.56 – 0.64
Swing Time (s)	0.45 (0.03)	0.45 (0.43 – 0.48)	0.42 – 0.51
Stance Time (s)	0.74 (0.03)	0.75 (0.71 – 0.76)	0.69 – 0.78
Asymmetry			
Step Time Asy (s)	0.10 (0.01)	0.09 (0.09 – 0.11)	0.08 – 0.13
Swing Time Asy (s)	0.09 (0.01)	0.09 (0.08 – 0.09)	0.07 – 0.11
Stance Time Asy (s)	0.10 (0.01)	0.10 (0.09 – 0.10)	0.08 – 0.12
Postural Control			
Step Length Asy (m)	0.09 (0.01)	0.88 (0.08 – 0.10)	0.08 - 0.11

Notes: SD, standard deviation; IQR, inter-quartile range; Var, Variability; Asy, Asymmetry

For micro outcomes there were correlations between gait speed (step velocity) and the ABC Scale and TUG single task (r_s = .68, p = 0.006; r_s = .72, p = 0.003 respectively), suggesting those with more balance confidence and proficient mobility walked more quickly. TUG dual task showed a positive association with step time asymmetry (r_s = .65, p = 0.008) and swing time asymmetry (r_s = .66, p = 0.004) suggesting participants with poorer dual task capacity walked with a more asymmetric gait. There were no correlations between ambulatory activity and the Mini-BESTest, or between macro and micro features of ambulatory activity.

DISCUSSION

This preliminary study examined the relationship between ambulatory activity and clinical measures of balance and functional mobility in a group of older, community-dwelling adults. A key finding was that functional mobility measures, namely single and dual task TUG rather than balance performance or balance self-efficacy, were significantly associated with more sustained bouts of walking and a more flexible pattern of activity. These findings support the analysis of activity outcomes beyond volume metrics; namely, the pattern and variability of walking bouts (Del Din et al., 2017). These more nuanced metrics showed that participants with good functional mobility were able to walk for longer bouts and with a more flexible pattern of activity.

The lack of association between volumes of activity and physical performance measures concurs with earlier reports (van Lummel et al., 2015; Weiss et al., 2013). Others have found associations between laboratory-based gait speed measures (Giannouli et al., 2016; Hall et al., 2017) (which we did not measure) and step count, although comparisons are limited due to methodological differences.

Our findings for gait asymmetry are challenging to interpret in this non-pathological cohort, but may reflect a more general, age-related deficit that influences temporal but not spatial features of gait. It may also indicate that activity comprised of mostly indoor walking, including asymmetrical events such as turning. Further work on a larger sample will help clarify this association and its relevance. The lack of association between gait variability and physical performance measures was also surprising, given the prominent contribution of variability to older adult gait and to falls risk (Ayoubi, Launay, Annweiler, &

Beauchet, 2015; Hausdorff et al., 2017). However, interpretation of gait variability is difficult because it may represent different constructs. On the one hand, increased gait variability may denote pathology (Ayoubi et al., 2015) or it may reflect adaptive strategies required for moving about complex environments and for minimising falls risk (Brodie, Lord, Coppens, Annegarn, & Delbaere, 2015). Gait variability also responds preferentially to the environment in which it is measured. Del Din et al. (2017) reported an effect of pathology and falls status on 'free living' gait variability not evident in clinical or laboratory data. Analysis on a larger sample will enable a more discrete interpretation of these features.

Providing a context for activity measured in this study was not possible, and it is conjecture as to how much time was spent walking outdoors versus indoors. Some indication can be derived from bout length (a longer bout length is indicative of outdoor walking). The average bout length in our study was 13.1 seconds, considerably shorter than that reported for a cohort of 70 year old adults of 18.6 seconds (Del Din et al., 2017), despite a comparable number of bouts per day (633 in our study compared with 602 in the latter study).

Lack of association between the Mini-BESTest and any activity or gait characteristics was surprising, given the comprehensive clinical assessment of balance the Mini-BESTest provides. This may be partly due to the items on the scale which represent different constructs of balance, rather than a singular construct such as balance self-efficacy which is reflected by the ABCs. Finally, given the sample size, we cannot generalise these results to a larger population.

Future research

We aim to extend this study to include 50 participants, of similar age. The methodology will be highly comparable but will include a standardised cognitive test to enable stronger inferences concerning the role of cognition to PA.

CONCLUSION

This study describes levels of ambulatory activity in a high functioning group of octogenarians and provides insights into the clinical features associated with activity. Functional mobility under dual task conditions but not balance was associated with activity. Results suggest that TUG dual task may be a useful clinical tool when assessing activity in older people. Future research will extend these findings. Studies to date do not include a detailed clinical assessment of balance, balance self-efficacy, or a comprehensive range of 'free-living' micro gait characteristics. The question warrants further investigation to more fully inform clinical practice.

KEY POINTS

1. High levels of ambulatory activity were evident for this group of community-dwelling octogenarians.
2. Functional mobility rather than balance was associated with activity.
3. Metrics that describe the pattern of ambulatory activity provide a more nuanced analysis than volume metrics.

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