Changes in gait performance over several years are associated with recurrent falls status in community-dwelling older women at high risk of fracture

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Abstract

Background: gait analysis is a recommended geriatric assessment for falls risk and sarcopenia; however, previous research utilises measurements at a single time point only. It is presently unclear how changes in gait over several years influence risk of recurrent falls in older adults.

Methods: we investigated 135 female volunteers (mean age ± SD: 76.7 ± 5.0 years; range: 70–92 years) at high risk of fracture. Gait parameters (speed, cadence, step length, step width, swing time and double support phase) were assessed using the GAITRite Electronic Walkway System at four annual clinics over ~3.7 ± 0.5 years. Participants reported incident falls monthly for 3.7 ± 1.2 years.

Results: increasing gait speed (odds ratio: 0.96; 95% confidence interval 0.93, 0.99) and step length (0.87; 0.77, 0.98) from baseline to final follow-up was associated with reduced likelihood of being a recurrent faller over the study period. No significant associations were observed for baseline gait parameters (all P ≥ 0.05). At the second follow-up (2.8 ± 0.6 years), an increase in swing time (0.65; 0.43, 0.98) was associated with reduced likelihood, while an increase in double support phase (1.31; 1.04, 1.66) was associated with increased likelihood, for being a recurrent faller in the subsequent 1.3 years following this time point.

Conclusion: changes in gait parameters over several years are significantly associated with the likelihood of being a recurrent faller among community-dwelling older women at high risk of fracture. Further research is required to develop gait monitoring guidelines and gait parameter decline cut points that may be utilised by clinicians to identify older adults at risk of incident falls and sarcopenia.

Keywords: gait, falls, sarcopenia, older women, older people

Introduction

Gait analysis is a recommended geriatric assessment, because poor gait performance is an important risk factor for falls, and most falls occur during locomotion [1]. Gait speed is the most commonly investigated gait parameter, because it can be easily assessed in clinical settings [2], and accordingly, it is included as a primary measure in current recommendations for sarcopenia case finding [3–6].

While there is evidence that low gait speed is associated with falls risk, the relationship has been incompletely explored [7], and several studies have reported no, or
non-linear, associations between gait speed and incident falls [8–11]. Other gait parameters, including step length, step width and the proportion of the cycle in double-leg support, may predict falls risk in older adults [8].

Research has focused on relationships between gait parameters at baseline and the risk of falling over a subsequent time period. The use of baseline measurements to imply relationships over time has limitations. Given that gait performance declines with age, ongoing monitoring of gait may provide greater insight into associations with falls. Furthermore, in the context of sarcopenia case finding, gait performance assessment at only one time point may preclude identification of at-risk individuals who experience rapid declines in function over time, but who never fall below a distribution-based cut point [12].

The relationship between change in gait over time and falls risk is potentially an area of clinical importance, because monitoring of gait performance could be used to predict future fallers and target falls prevention strategies. The aim of this study was to investigate associations between baseline gait parameters, and their change over several years, with incident falls in community-dwelling older women at high risk of fracture. We hypothesised that change in gait performance would be associated with the likelihood of being a recurrent faller in this population.

Methods

Study design and participants

This study was completed as part of the Vital D study; a randomised controlled trial involving N = 2,258 women aged ≥70 residing in southern Victoria, Australia (Trial registration: ACTR12605000658617; ISRCTN83409867). The study was approved by the Barwon Health and University of Melbourne ethics committees, and participants provided written informed consent. The recruitment protocol has been described previously [13]. Participants at increased hip fracture risk were recruited between 2003 and 2005 and randomly assigned to receive a single oral dose of cholecalciferol (500,000 IU) or matched placebo each year for 3–5 years. Eligibility was determined by a score ≥5 points on an adapted algorithm including 19 risk factors for hip fracture [13]. This study utilised data from a subset of 150 participants invited to participate in four, approximately annual, clinical assessments and selected using random computer-generated participant ID numbers, independent of treatment allocation. Sub-study eligibility was restricted to participants residing in the Barwon Statistical Division due to their proximity to the study centre. One hundred and thirty-seven (91%) participants consented to participate in the sub-study. Figure 1 describes the recruitment process and loss to follow-up.

Measurements

Height and weight were measured with footwear removed using a wall-mounted tape measure and electronic scales. Dietary calcium intake and medication use were assessed by a questionnaire [14]. Serum 25-hydroxyvitamin D (25OHD; DíaSorin, Stillwater, Minnesota) was measured at each annual clinic. Quadriceps strength was measured at baseline using a validated hand-held dynamometer (Lafayette Nicholas Manual Muscle Testing System model 01163, SI Instruments, Hilton, Australia) [15], as previously described [9].

Gait parameters were evaluated at each assessment using the GAITRite® Electronic Walkway System (CIR Systems Inc., Clifton, NJ, USA), a valid and reliable tool for objective gait assessment [16]. Participants were instructed to walk along the walkway at a self-selected comfortable pace. Three-metre 'lead in' and two-metre 'lead off' distances were provided to achieve steady-state walking. Participants performed three trials with a rest period between each consecutive trial. Data from trials 2 and 3 were combined to provide a mean value for each gait parameter [16]. Gait parameters assessed were speed (cm/s), cadence (steps/min), step length (cm), step width (cm), swing time (%) and double support phase (%).

Falls ascertainment

Recent falls or unsteadiness, and fracture history since age 50 years, was determined by self-report at baseline [13], and participants completed the Modified Falls Efficacy Scale [17]. Following baseline, participants recorded incident falls daily using postcard calendars returned monthly to investigators for 3 to 5 years. Falls were defined as ‘an event reported either by the faller or a witness, resulting in a person inadvertently coming to rest on the ground or another lower level, with or without loss of consciousness or injury’ [18]. Falls were recorded on postcard calendars by writing ‘F’ if a fall occurred and/or fracture, and ‘N’ if not [13]. When a fall or fracture was indicated, a standardised questionnaire recording details was administered by telephone. Recurrent falls was selected as the outcome of interest, because physiological performance is known to be similar in non-fallers and single fallers, but significantly compromised in recurrent fallers [19]. Participants who reported ≥2 falls were classified as ‘recurrent fallers’, and participants who reported ≤1 fall were classified as ‘non-recurrent fallers’.

Statistical analyses

Independent sample t-tests or Mann–Whitney U tests, and χ2 tests, examined differences in baseline characteristics between non-recurrent fallers and recurrent fallers. Gait parameter changes during follow-up were analysed using repeated measures ANOVA with one between-subjects factor (recurrent faller/non-recurrent faller) and a repeated measures factor of time (four time points). Huynh–Feldt corrections were applied for analyses that violated the sphericity assumption for within-subjects analyses. Pairwise comparisons determined differences from baseline for subsequent time points when significant main effects for time were observed.

Logistic regression analyses determined the likelihood of being classified as a recurrent faller according to gait
parameters. We initially examined associations for gait parameters at baseline and for their change (calculated as baseline subtracted from follow-up value) at the final follow-up. In addition to linear trends, quadratic trends were tested by adding a predictor to the model based on the square of each gait parameter variable. Post hoc analyses were conducted to determine the association between change in gait parameters with the odds of being a recurrent faller after the first and second follow-ups, respectively. All analyses were adjusted for baseline age, BMI, years in the study, vitamin D, falls and fracture history, antidepressant/anti-anxiety and non-steroidal anti-inflammatory (NSAID) medication use, and the baseline value for the relevant gait parameter.

P values of <0.05 or 95% confidence intervals (CI) not including the null point were considered statistically significant. All analyses were performed using SPSS Statistics 19 (IBM, USA).

Results

One hundred and thirty-five women aged 77 ± 5 (range: 70–92) who participated at baseline and provided falls data for 3.7 ± 1.2 years (range: 0.2–5.2 years) were included in data analyses (Figure 1). Baseline characteristics are given in Table 1. Seventy-four (55%) participants were recurrent fallers, and of 61 non-recurrent fallers, 25 (41%) reported a single fall during the follow-up period. At baseline, recurrent fallers were significantly more likely to report a recent fall or unsteadiness, antidepressant/anti-anxiety and NSAID medication use, and also tended to be more likely to report a fracture since age 50 (P = 0.055) than non-recurrent fallers.

Ninety-nine (73%) participants attended all four clinics. Follow-up 1 was conducted 1.2 ± 0.5 years after baseline, and follow-ups 2 and 3 were conducted 2.8 ± 0.6 and 3.7 ± 0.7 years after baseline, respectively. Participants lost to final follow-up were significantly older (78.9 ± 6.0 versus 75.9 ± 4.3...
years; \( P = 0.008 \) and had slower gait speed (92.8 ± 27.7 versus 111.5 ± 20.9 cm/s; \( P < 0.001 \)) and lower quadriceps strength (7.1 ± 3.4 versus 8.5 ± 2.7 kg; \( P = 0.014 \)) at baseline. There was no differences in baseline vitamin D levels (\( P = 0.773 \)), or the proportion of vitamin D-supplemented individuals (58 versus 55%; \( P = 0.695 \)) or recurrent fallers (54 versus 55%; \( P = 0.942 \)), between included participants and those lost to follow-up.

Table 1 reports mean values for gait parameters at baseline and the three follow-up assessments. Gait speed and step length changed over time for both recurrent and non-recurrent faller groups although there were no differences...
Table 2. Odds ratios (OR) for recurrent falls during the study period according to baseline and change in gait

<table>
<thead>
<tr>
<th>Gait parameters</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (N = 131)</td>
<td>Recurrent faller after baseline (3.7 ± 1.2 years) (N = 73)</td>
</tr>
<tr>
<td>Gait speed (cm/s)</td>
<td>1.00 (0.98, 1.02)</td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>1.01 (0.98, 1.04)</td>
</tr>
<tr>
<td>Step length (cm)</td>
<td>0.97 (0.92, 1.03)</td>
</tr>
<tr>
<td>Step width (cm)</td>
<td>0.99 (0.87, 1.14)</td>
</tr>
<tr>
<td>Swing time (%)</td>
<td>1.02 (0.85, 1.23)</td>
</tr>
<tr>
<td>Double support phase (%)</td>
<td>0.98 (0.90, 1.08)</td>
</tr>
<tr>
<td>Change to follow-up 2</td>
<td>Recurrent faller after follow-up 2 (3.7 ± 0.7 years) (N = 99)</td>
</tr>
<tr>
<td>Gait speed (cm/s)</td>
<td>0.96 (0.93, 0.99)</td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>0.97 (0.91, 1.03)</td>
</tr>
<tr>
<td>Step length (cm)</td>
<td>0.87 (0.77, 0.98)</td>
</tr>
<tr>
<td>Step width (cm)</td>
<td>1.05 (0.81, 1.36)</td>
</tr>
<tr>
<td>Swing time (%)</td>
<td>0.72 (0.50, 1.05)</td>
</tr>
<tr>
<td>Double support phase (%)</td>
<td>1.20 (0.98, 1.47)</td>
</tr>
<tr>
<td>Change to follow-up 1</td>
<td>Recurrent faller after follow-up 1 (1.2 ± 0.5 years) (N = 106)</td>
</tr>
<tr>
<td>Gait speed (cm/s)</td>
<td>0.98 (0.95, 1.02)</td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>0.97 (0.92, 1.03)</td>
</tr>
<tr>
<td>Step length (cm)</td>
<td>0.92 (0.83, 1.04)</td>
</tr>
<tr>
<td>Step width (cm)</td>
<td>1.02 (0.76, 1.36)</td>
</tr>
<tr>
<td>Swing time (%)</td>
<td>0.95 (0.66, 1.35)</td>
</tr>
<tr>
<td>Double support phase (%)</td>
<td>0.99 (0.81, 1.21)</td>
</tr>
<tr>
<td>Change to follow-up 2</td>
<td>Recurrent faller after follow-up 2 (2.8 ± 0.6 years) (N = 104)</td>
</tr>
<tr>
<td>Gait speed (cm/s)</td>
<td>0.97 (0.93, 1.01)</td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>0.95 (0.90, 1.01)</td>
</tr>
<tr>
<td>Step length (cm)</td>
<td>0.87 (0.75, 1.00)</td>
</tr>
<tr>
<td>Step width (cm)</td>
<td>1.32 (0.91, 1.92)</td>
</tr>
<tr>
<td>Swing time (%)</td>
<td>0.65 (0.43, 0.98)</td>
</tr>
<tr>
<td>Double support phase (%)</td>
<td>1.31 (1.04, 1.66)</td>
</tr>
</tbody>
</table>

Logistic regressions adjusted for age, BMI, vitamin D, years in study, self-reported recent falls or unsteadiness, fractures since the age of 50 years, antidepressant/anti-anxiety and NSAID medication use, and baseline value for the relevant gait parameter. Bold values are significant at P < 0.05.

*Analyses include participants with complete data at this time point.

Discussion

The primary finding of this prospective study of community-dwelling older women at high risk of fracture was that changes in gait parameters over several years are associated with increased likelihood of recurrent falls. In particular, decreases in swing time and increases in double support phase over 2.8 years were associated with increased likelihood of recurrent falls in the subsequent 1.3 years.

Gait parameters, including gait speed and double support phase, measured at a single time point have been associated with falls in a number of studies [12, 20–23]. Gait symmetry and double support duration were associated with recurrent falls in the subsequent year in a study of 96 community-dwelling women aged at least 70 [22]. Slower gait speed was associated with increased risk of falls over 20 months, and additionally, poorer performance for swing and double support phases was associated with falls risk in almost 600 older adults [23]. Similar to our study, Callisaya and colleagues did not find a linear association between baseline gait parameters and 12-month risk of multiple falls in 400 older Australians but did report a significant quadratic trend for gait speed and cadence with risk of multiple falls [11]. We also observed a quadratic trend that approached significance (P = 0.072, data not shown) for cadence with recurrent falls between baseline and follow-up 1 (also around 12 months). These findings may reflect previous observations indicating a threshold effect in the protective benefit of gait speed, possibly attributable to an increased falls risk during performance of activities at higher gait speeds [10].

In conjunction with previous research, these data suggest that gait parameters measured at a single time point may predict recurrent falls risk over shorter follow-up periods, but possibly not over longer terms. Furthermore, given that we observed no associations with subsequent recurrent falls and changes in gait parameters to follow-up 1, it is possible that changes in gait parameters over 1 year are not adequately sensitive to predict recurrent falls over the subsequent 3 years.

It is likely that incident falls during the study period resulted in changes in gait. Indeed, fear of falling may increase as a result of a previous fall and is associated with deleterious changes in gait speed, stride length and double...
support time [8, 24], possibly reflecting attempts to improve stability during locomotion. To establish an understanding of the relationship, we specifically examined risk for recurrent falls occurring subsequent to changes in gait parameters. Importantly, we observed that changes in swing time and double support phase over 2.8 years were significantly associated with recurrent falls after this time point, and the association of change in step length with recurrent falls after follow-up 2 also approached significance. This suggests that declines in gait parameters over several years may be predictive of incident falls in older women, independent of previous fall occurrences.

Further research is required to determine whether multiple gait assessment guidelines can provide additional clinical benefit to current single measurement guidelines. Such guidelines may identify patients who have experienced significant declines in gait performance, but whose performance remains acceptable according to distribution-based cut points [12]. For example, an older woman whose gait speed decreases from 1.2 to 1.0 m/s over 3–4 years may not meet criteria for sarcopenia [25], yet our results indicate that this individual may have as much as 80% increased risk of recurrent falls. A barrier to the development of such guidelines is that requirement for multiple assessments and devices capable of measuring gait parameters such as double support phase (e.g. GAITRite) may be both time-consuming and expensive. However, feasibility of multiple gait assessments may increase with improvements in reliability and affordability of new technologies including wearable sensor systems, and in future could conceivably be used to regularly monitor gait in the everyday environment with data transmitted to clinicians [26].

The findings of this study are subject to limitations. The sample size was relatively small and observed associations may be generalised only to older women who may be at high risk of hip fracture. Furthermore, there was significant loss (27%) to follow-up which limits our ability to draw conclusions about those women in the poorest health in this population, although only one participant was lost to follow-up due to a fracture. We cannot rule out the possibility of residual confounding related to the participants’ involvement in a large RCT of high-dose vitamin D supplementation; nevertheless, there were no differences in the proportion of treated participants among non-fallers and recurrent fallers, and observed associations were significant after adjustment for serum 25OHD. Lastly, we did not examine measures of gait variability which may also be independent predictors of falls risk [8, 11, 27]. However, gait variability measures demonstrate lower reliability than gait parameters [1], and so it may not be ideal for repeated assessment in clinical settings.

In conclusion, changes in gait parameters over several years are significantly associated with increased likelihood of being a recurrent faller among community-dwelling older women at high risk of fracture. Further research is required to develop gait monitoring guidelines and gait parameter decline cut points that may be utilised by clinicians to identify older adults at risk of incident falls and sarcopenia.

Key points
- Baseline gait performance parameters were not associated with recurrent faller status in this cohort of 135 older women.
- Changes in gait performance parameters over several years were predictive of increased likelihood for being a recurrent faller.
- Further research is required to determine whether gait performance should be regularly monitored in clinical settings.

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Conflicts of interest
None declared.

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References

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