Gait impairment and falls in cognitively impaired older adults: an explanatory model of sensorimotor and neuropsychological mediators

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Abstract

Objectives: to explore the associations between spatiotemporal gait parameters and falls in cognitively impaired older people and to investigate whether sensorimotor and neuropsychological factors mediate the association between gait performance and falls.

Design: prospective cohort study with a 1 year follow-up.

Setting: community-dwelling sample.

Participants: sixty-four participants (62–96 years of age) with cognitive impairment.

Measurements: gait analysis and sensorimotor and neuropsychological functions were assessed in all participants. Falls were identified prospectively for 1 year.

Results: multiple fallers (≥2 falls) had significantly slower gait velocity, shorter stride length, greater double support time and increased step length variability in univariate analyses. Multivariate logistic regression indicated that the relationship between gait and falls was mediated primarily by sensorimotor function and to a lesser extent by neuropsychological performance.

Conclusion: the findings indicate that slow and variable gait patterns increase the risk of falls in cognitively impaired older adults. Further, the association between gait and falls seems to be mediated in large by reduced sensorimotor functioning. Further research is needed to investigate whether interventions aimed at improving gait and/or sensorimotor fall risk factors, such as strength and balance, can prevent falls in cognitively impaired older adults.

: accidental falls, aged, gait, dementia, elderly

Introduction

Dementia affects 5–8% of the population over 65 years of age [1] and up to 30% of people aged 85 years and above [2]. Approximately 60% of older people with cognitive impairment (CI) fall each year and many suffer major adverse outcomes such as fractures, institutionalisation and death [3]. Recent studies using computerised gait analysis have shown that gait dysfunction can predict cognitive decline and dementia in non-demented older adults [4, 5], and that gait dysfunction is prevalent in people with dementia [6–11]. However, only two studies have prospectively examined the relationship between gait patterns and falls in cognitively impaired older people [12, 13].

Gait disorders in dementia have been classified as ‘higher level’ [14], suggesting that basic sensorimotor functions remain intact and cerebral integration is impaired [14]. Impaired higher level processes may also adversely affect the ability to plan and react to changing demands, possibly increasing fall risk. However, no studies have directly contrasted
the contributions of sensorimotor and neuropsychological impairments to gait dysfunctions and falls in people with dementia.

The aims of this study were to: identify spatiotemporal gait risk factors for falls in community-dwelling cognitively impaired older people, examine the relationship between these gait measures and sensorimotor and neuropsychological functions, and elucidate the relationship between gait and falls by exploring potential sensorimotor and neuropsychological mediators.

Methods

Participants
Sixty-four cognitively impaired participants were recruited from health-service settings, community services and via advertisements. Participation was dependent on (i) being aged 60+ years, (ii) living in the community and (iii) having a ‘person responsible’ with 3.5+ h of face-to-face contact per week. CI was defined as a Mini-Mental State Examination (MMSE) score <24 [15], an Addenbrooke’s Cognitive Examination-Revised (ACE-R) <83 [16] or a specialist physician diagnosis of CI or dementia. Exclusion criteria included a stroke within 18 months, neurodegenerative disorders excluding dementia, insufficient English to complete the assessment or known end-stage illness. Power analysis was performed using the mean and standard deviation (SD) values for gait velocity from a previous study [13] (two-tailed test, 5% significance level, 80% power). This indicated that a sample size of 63 was required to detect a 10 cm/s difference in gait velocity between sub-groups. The study had Ethics Committee approval and consent was obtained from all participants and their person responsible prior to assessment.

Baseline assessment
Participants and their person responsible were interviewed at baseline in their homes to obtain information on demographics, medical and medication history and usual level of function.

Neuropsychological assessment
Neuropsychological assessment was undertaken using the ACE-R [16] which contains measures of attention and orientation, memory, verbal fluency, visuospatial and language skills. The MMSE is also contained within the ACE-R [16]. Verbal fluency (/14), contained within the ACE-R, included both phonemic and semantic fluency (each component/7). The 15-item Geriatric Depression Scale (GDS) was completed as an assessment of mood [17].

Sensorimotor assessment
Sensorimotor function was assessed with the Physiological Profile Assessment (PPA), a validated measure of fall risk involving tests of vision, simple reaction time, proprioception, knee extension strength and postural sway [18]. In previous studies, weighted contributions from these five variables provides a falls risk score that can predict those at risk of falling with 75% accuracy in cognitively intact community-dwelling older people [19–21].

Blood pressure
Blood pressure (BP) was measured after 5 min of quiet lying, and again after 1 and 3 min of standing. Orthostatic hypotension was defined as a ≥20 mmHg drop in systolic BP or a ≥10 mmHg drop in diastolic BP.

Gait assessment
Temporal and spatial parameters of gait were measured with a GAITRite® mat (CIR Systems Inc., Clifton, NJ, USA). The GAITRite® mat is a reliable measure of spatiotemporal gait variables [22]. Participants performed two trials walking with their usual indoor mobility aid at their preferred speed in a quiet environment (Neura gait laboratory). Participants started walking 1.5 m before the GAITRite mat and walked 1.5 m beyond it. Six gait variables were calculated; velocity (cm/s), stride length (cm), cadence (steps/min), double support time (DST) (s), coefficient of variation (CV) of stride time (%) and CV of step length (%). The CV is a measure of variability and is expressed as the percentage of the SD to the mean [5, 12, 13, 23]. Gait variables reported are the mean of the two trials.

Falls follow-up
Monthly falls calendars with reply paid envelopes were given to participants/person responsible. If a calendar was not returned within the first 2 weeks of the following month, a telephone call was made to the person responsible to obtain the falls information. A fall was defined as an unexpected event in which the participant comes to rest on the ground, floor or lower level [24]. Multiple fallers were defined as those people who fell two or more times in the 12-month follow-up period.

Statistical analysis
The data were analysed using SPSS 18.0 for Windows (SPSS, Inc., Chicago, IL, USA). The distribution of number of falls, DST, CV step length and CV stride time variables were normalised using log transformations and the normalised data were used in all analyses. Univariate logistic regression analyses were performed to investigate the relationship between neuropsychological, sensorimotor and gait variables and multiple fallers (≥2 falls). Multivariate logistic regression was performed using the enter method to assess the relationship between gait, falls and sensorimotor and neuropsychological functions.
Results

Demographic, medical, gait, sensorimotor and the neuropsychological measures for the multiple fallers, non-multiple fallers and total sample are presented in Table 1. Thirty-four (54%) participants reported falls, 22 (35%) reported ≥2. One participant was lost to follow-up. Compared with non-multiple fallers, multiple fallers had decreased gait velocity, decreased stride length, increased DST and increased step length variability. Multiple fallers also experienced more falls in the past, used more medications, had more heart problems, more diagnosed hypertension and performed significantly worse on the GDS, verbal fluency test and the PPA fall risk score.

Multivariate analysis of gait and falls

The multivariate logistic regression analyses showed that the associations between DST and step length variability and falls remained significant after adjusting for GDS and number of medications (Table 2, Model 1). Additional analyses (Table 2, Models 2 and 3) showed that when additionally adjusting for PPA and verbal fluency separately, PPA

Table 1. Univariate analysis of baseline demographics, medical characteristics, neuropsychological, gait and sensorimotor performance

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All, n = 64</th>
<th>Multiple fallers (≥2), n = 22</th>
<th>Non-multiple fallers (&lt;2), n = 41</th>
<th>OR (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
</table>

Demographics

| Age, mean ± SD                     | 81.3 ± 6.8  | 82.5 ± 6.9                    | 80.7 ± 6.7                        | 1.328       (0.770–2.291) | 0.307   |
| Female, n (%)                      | 30 (46.9)   | 10 (45.5)                     | 19 (46.3)                         | 0.965       (0.341–2.729) | 0.946   |
| Previous falls, n (%)              | 36 (56.3)   | 19 (86.4)                     | 16 (39.0)                         | 9.896       (2.515–38.037) | 0.001   |
| Use of walking aid, n (%)          | 15 (23.4)   | 6 (27.3)                      | 8 (19.5)                          | 0.646       (0.192–2.179) | 0.482   |
| Education, years, mean ± SD        | 10.1 ± 2.9  | 9.6 ± 2.4                     | 10.5 ± 3.1                        | 0.719       (0.402–1.286) | 0.266   |

Neuropsychological performance, mean ± SD

| Attention and orientation          | 15.3 ± 2.8  | 14.4 ± 3.6                    | 15.8 ± 2.2                        | 0.606       (0.354–1.039) | 0.068   |
| Memory                             | 14.3 ± 5.0  | 13.6 ± 5.3                    | 14.8 ± 4.9                        | 0.776       (0.460–1.309) | 0.341   |
| Verbal fluency                     | 6.6 ± 2.9   | 5.4 ± 3.7                     | 7.2 ± 2.2                         | 0.518       (0.293–0.913) | 0.023   |
| Language                           | 21.0 ± 3.4  | 20.8 ± 3.7                    | 21.0 ± 3.4                        | 0.933       (0.535–1.569) | 0.794   |
| Visuospatial                       | 13.0 ± 2.9  | 12.5 ± 2.2                    | 13.2 ± 3.2                        | 0.772       (0.458–1.299) | 0.329   |
| MMSE score                         | 24.1 ± 4.2  | 22.7 ± 5.1                    | 24.8 ± 3.6                        | 0.615       (0.361–1.046) | 0.073   |
| ACE-R score                        | 70.2 ± 12.0 | 66.4 ± 13.7                   | 72.1 ± 10.7                       | 0.624       (0.367–1.059) | 0.080   |
| GDS score                          | 2.86 ± 2.45 | 4.36 ± 2.75                   | 2.12 ± 1.86                       | 3.001       (1.457–6.180) | 0.003   |

Medications

| Arthritis                          | 38 (60.3)   | 14 (63.6)                     | 23 (57.5)                         | 1.293       (0.443–3.776) | 0.638   |
| Heart problems (any)               | 27 (42.2)   | 13 (59.1)                     | 13 (31.7)                         | 3.111       (1.062–9.113) | 0.038   |
| IHD                                | 15 (23.8)   | 6 (27.3)                      | 9 (22.0)                          | 1.333       (0.404–4.403) | 0.637   |
| Cardiac arrhythmia                 | 10 (15.9)   | 6 (27.3)                      | 4 (9.8)                           | 3.469       (0.860–13.989) | 0.080   |
| Other heart problems               | 5 (7.9)     | 3 (13.6)                      | 2 (4.9)                           | 3.079       (0.474–20.004) | 0.239   |
| Hypertension                       | 36 (56.3)   | 16 (72.7)                     | 19 (46.3)                         | 3.088       (0.994–7.195) | 0.049   |
| Diabetes                           | 12 (19)     | 6 (27.3)                      | 6 (15.0)                          | 2.125       (0.592–7.628) | 0.248   |
| Stroke                             | 6 (9.4)     | 3 (13.6)                      | 2 (4.9)                           | 3.079       (0.474–20.004) | 0.239   |

Postural BP

| Orthostatic hypotension            | 13 (22.8)   | 6 (31.6)                      | 7 (18.4)                          | 2.044       (0.575–7.265) | 0.269   |

Gait variables (mean ± SD)

| Gait velocity, cm/s               | 88.44 ± 26.72 | 78.96 ± 29.69 | 94.25 ± 23.60 | 0.546 (0.312–0.955) | 0.034 |
| Stride length, cm                 | 105.79 ± 24.42 | 97.05 ± 25.55 | 111.15 ± 22.53 | 0.543 (0.310–0.952) | 0.033 |
| Cadence, steps/min                | 90.27 ± 13.77 | 96.03 ± 15.74 | 101.30 ± 12.46 | 0.673 (0.391–1.157) | 0.152 |
| Stride time variability           | 2.83 ± 1.55   | 3.30 ± 1.50     | 2.59 ± 1.55    | 1.583 (0.936–2.677) | 0.087 |
| Step length variability           | 5.72 ± 3.08   | 7.32 ± 3.29     | 4.87 ± 2.67    | 2.354 (1.274–4.350) | 0.006 |

Sensorimotor performance (mean ± SD)

| PPA falls risk score              | 1.32 ± 1.41  | 2.13 ± 1.30      | 0.86 ± 1.27    | 2.801 (1.483–5.293) | 0.002 |

ACE-R, Addenbrooke’s Cognitive Examination-Revised, a score <83 indicates CI (range: 0–100); MMSE, Mini-Mental State Examination, a score <24 indicates CI (range: 0–30); Domains of ACE-R, higher scores are better, attention and orientation (range: 0–18), memory (range: 0–26), verbal fluency (range: 0–14), language (range: 0–26) and visuospatial (range: 0–16); GDS, Geriatric Depression Scale, a score of >5 indicates probable depression; IHD, Ischaemic heart disease; PPA, Physiological Profile Assessment, scores <1 indicate low falls risk; SD, standard deviation. Values in bold identify significant results.

1 Data missing for one participant.
2 Data missing for six participants.
Table 2. Multivariate logistic regression models assessing the relationship between gait variables and multiple falls controlling for covariates

<table>
<thead>
<tr>
<th>Gait variable</th>
<th>Model 1a</th>
<th>P-value</th>
<th>Model 2b</th>
<th>P-value</th>
<th>Model 3c</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td></td>
<td>OR (95% CI)</td>
<td></td>
<td>OR (95% CI)</td>
<td></td>
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<tr>
<td>Gait velocity</td>
<td>0.631 (0.339–1.176)</td>
<td>0.147</td>
<td>0.647 (0.358–1.266)</td>
<td>0.220</td>
<td>0.795 (0.409–1.546)</td>
<td>0.500</td>
</tr>
<tr>
<td>Stride length</td>
<td>0.607 (0.322–1.146)</td>
<td>0.124</td>
<td>0.646 (0.341–1.224)</td>
<td>0.180</td>
<td>0.782 (0.395–1.551)</td>
<td>0.482</td>
</tr>
<tr>
<td>DST</td>
<td>2.007 (1.061–3.794)</td>
<td>0.032</td>
<td>1.915 (0.999–3.709)</td>
<td>0.054</td>
<td>1.689 (0.895–3.187)</td>
<td>0.106</td>
</tr>
<tr>
<td>Step length variability</td>
<td>2.181 (1.167–4.076)</td>
<td>0.014</td>
<td>2.132 (1.091–4.167)</td>
<td>0.027</td>
<td>1.767 (0.888–3.513)</td>
<td>0.105</td>
</tr>
</tbody>
</table>

aModel 1 controlling for GDS and number of medications.
bModel 2 controlling for verbal fluency, GDS and number of medications.
cModel 3 controlling for overall PPA falls risk score, GDS and number of medications.

performance was the principal mediator (i.e. attenuated the associations between the gait measures and falls to a greater extent).

Discussion

The study findings indicate that cognitively impaired older adults who fell multiple times had significantly slower gait velocity and shorter stride length, as well as a longer DST and increased variability of step length compared with those who did not fall or fell only one time. The multiple fallers also scored worse on tests of mood and verbal fluency and had higher PPA fall risk scores when compared with the non-multiple fallers.

Of the spatiotemporal gait measures, step length variability discriminated best between multiple fallers and non-multiple fallers, a finding consistent with previous studies that have found variability measures discriminate between cognitively intact fallers and non-fallers [12, 23, 25, 26]. Two previous studies have examined the relationship between gait impairment and falls in older people with Alzheimer’s dementia in residential care. One found reduced cadence [13] and the second, increased stride length variability in fallers [12]. The differences between the current and previous studies may reflect differences in fall definitions and ascertainment methods, settings and populations studied.

The logistic regression analyses showed that the effect of poor gait performance on falls was strongly reduced when controlling for sensorimotor performance, but less so when adjusting for neuropsychological performance, indicating that impairments in basic sensorimotor functions primarily influence gait in older people with CI.

Notwithstanding, we found a significant relationship between verbal fluency, a measure of executive function, and gait indicating likely involvement of the frontal lobe [27]. Further, as our sample included only cognitively impaired older people, of whom most had some executive dysfunction (ACE-R verbal fluency mean score = 6.6 out of a possible 14) [16], it is possible that the relationship between verbal fluency and falls was attenuated due to a restriction in the range of verbal fluency scores.

We acknowledge that our study has certain limitations. The sample size is relatively small for a prospective falls study, though it had sufficient power to detect meaningful changes in gait parameters. Also, the inclusion of participants with previous falls in the sample is a design factor that prevents us from determining the impact of previous falls on gait characteristics and subsequent falls.

In summary, our findings show that gait dysfunction in cognitively impaired older adults predicts multiple falls and that this relationship is mostly mediated through sensorimotor function. By targeting sensorimotor impairments, it may be possible to improve gait performance and reduce fall rates in this high-risk population. Further research is needed to investigate whether dual-task performance is of any added benefit, and additionally, if employing dual-task training improves performance and reduces falls.

Key points

- Spatiotemporal gait measures predict falls in cognitively impaired older people.
- The relationship between gait and falls is mediated largely by sensorimotor function and to a lesser extent by neuropsychological function.
- The findings may assist in the design of fall prevention strategies for this group.

Conflicts of interest

The PPA (FallScreen) is commercially available through Neuroscience Research Australia.

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References


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