Gait variability in younger and older adult women is altered by overground walking protocol

SIR—Measures of gait variability are now commonly used to study age-related gait changes [1–7]. Some studies have shown that older adult fallers, and those identified with an increased falls risk, exhibit greater variability in basic spatiotemporal measures of gait when compared to both older adult non-fallers [2, 4, 5] and younger adults [4]. However, other work has reported no differences in measures of gait variability between healthy younger and older adults [6], healthy and frail older adults [7] and older adult fallers and non-fallers [1, 3].

A possible reason for the ambiguous findings of the previous studies may lie in the different walking protocols used to collect the gait data. Studies that have reported no effect of age on measures of gait variability commonly used repeated single over-ground walking protocols [1, 3, 6, 7]. Conversely, studies using continuous over-ground walking protocols have reported significant age effects [2, 4, 5, 8]. Repeated single trial walking protocols generally involve repetitive periods of waiting, gait initiation in response to an auditory command, steady-state walking for several strides, followed by gait termination at the end of a short walkway. In contrast, continuous walking protocols typically involve walking without interruption over longer distances. It is possible that the frequent disruptions to the temporal locomotor rhythm of gait experienced during repeated single walking protocols may affect gait variability and thereby contribute to the ambiguous findings reported by gait variability studies [9].

To our knowledge, no study has investigated the effect of repeated single and continuous over-ground walking protocols upon measures of gait variability. As such, little is known about the effect of these protocols upon measures commonly used to investigate gait changes associated with ageing. The aim of this study therefore was to determine whether gait variability data captured during repeated single over-ground walking differs from variability data captured during continuous over-ground walking in younger and older women.

Methods

Participants

Twenty-two younger female volunteers (age: 21.2 ± 2.5 years, height: 1.66 ± 0.08 m; mass: 62.6 ± 9.8 kg) and 32 older female volunteers (age 67.4 ± 6.3 years, height: 1.62 ± 0.07 m; mass: 65.1 ± 13.2 kg) participated in this study. The older adults were recruited through advertisements distributed to local senior social groups, whereas the younger adults were recruited through advertisements placed on University notice boards. The Human Research Ethics Committee at Australian Catholic University approved all procedures for this study.

Volunteers wore comfortable clothing and walking shoes with a heel height < 2.5 cm. On arrival, participants were screened using a previously published protocol [10] to ensure that they did not have any overt health problems impacting on balance and mobility. Written informed consent was obtained prior to testing.

Procedure

Participants completed two walking protocols presented in random order. The first protocol involved ten repeated single walking trials and the second protocol involved ten continuous laps of a walking circuit. Ten trials/laps were performed to ensure that representative gait data were collected [11]. The repeated single walking protocol required participants to walk at self-selected speed along a flat walkway containing an 8.1 m instrumented GAITRite mat (CIR Systems Inc., Havertown, PA, USA). The participant was asked to start walking in response to a ‘go’ signal and stop at a designated finish position. The start and finish positions were indicated by markers placed two body lengths before and after the mat so as to ensure steady-state walking across the GAITRite [12]. After completing the trial, the participant waited at the finish position whilst the data was processed, and then walked back to the start position in response to a ‘go’ command for the next trial. Data were recorded for each traversal of the walkway.

The continuous walking protocol consisted of a curvilinear circuit that incorporated two straight sections (3 m apart) that were of the same length as the repeated single walking condition. The GAITRite mat was positioned along one of the straight sections. On a ‘go’ command, participants completed 10 laps of the circuit at self-selected speed. The GAITRite system was re-set when each participant was on the opposite side of the circuit. A treadmill was not used to collect continuous gait variability data as past work has shown that parameters such as stride time variability are altered by treadmill walking [9].
Research letters

Table 1. Standard deviations, coefficients of variation and effect size of each variable for the repeated single and continuous walking protocols for younger participants

<table>
<thead>
<tr>
<th></th>
<th>SD</th>
<th>CV</th>
<th>P-value</th>
<th>Effect size</th>
<th>SD</th>
<th>CV</th>
<th>P-value</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity (cm/s)</td>
<td>6.0</td>
<td>4.6</td>
<td>0.01</td>
<td>0.79</td>
<td>3.9</td>
<td>3.2</td>
<td>0.02</td>
<td>0.63</td>
</tr>
<tr>
<td>Step length (cm)</td>
<td>2.5</td>
<td>2.2</td>
<td>0.04</td>
<td>0.46</td>
<td>3.1</td>
<td>2.9</td>
<td>0.07</td>
<td>0.34</td>
</tr>
<tr>
<td>Stride Length (cm)</td>
<td>4.2</td>
<td>3.7</td>
<td>0.05</td>
<td>0.43</td>
<td>2.7</td>
<td>2.4</td>
<td>0.07</td>
<td>0.33</td>
</tr>
<tr>
<td>Step width (cm)</td>
<td>1.8</td>
<td>1.9</td>
<td>0.43</td>
<td>0.05</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Step time (msec)</td>
<td>1.6</td>
<td>1.5</td>
<td>0.08</td>
<td>0.41</td>
<td>3.2</td>
<td>2.9</td>
<td>0.02</td>
<td>0.61</td>
</tr>
<tr>
<td>Stride time (msec)</td>
<td>2.2</td>
<td>1.9</td>
<td>0.02</td>
<td>0.67</td>
<td>2.2</td>
<td>1.8</td>
<td>0.01</td>
<td>0.78</td>
</tr>
</tbody>
</table>

NB: SD indicates standard deviations; CV indicates coefficient of variation; NA indicates not applicable.

Table 2. Standard deviations, coefficients of variation and effect size of each variable for the repeated single and continuous walking protocols for older participants

<table>
<thead>
<tr>
<th></th>
<th>SD</th>
<th>CV</th>
<th>P-value</th>
<th>Effect size</th>
<th>SD</th>
<th>CV</th>
<th>P-value</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity (cm/s)</td>
<td>5.0</td>
<td>3.8</td>
<td>&lt;0.01</td>
<td>0.58</td>
<td>3.8</td>
<td>2.9</td>
<td>&lt;0.01</td>
<td>0.51</td>
</tr>
<tr>
<td>Step length (cm)</td>
<td>2.5</td>
<td>2.2</td>
<td>&lt;0.01</td>
<td>0.46</td>
<td>3.6</td>
<td>3.3</td>
<td>&lt;0.01</td>
<td>0.34</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>3.7</td>
<td>3.2</td>
<td>&lt;0.01</td>
<td>0.48</td>
<td>2.8</td>
<td>2.4</td>
<td>&lt;0.01</td>
<td>0.40</td>
</tr>
<tr>
<td>Step width (cm)</td>
<td>2.2</td>
<td>2.5</td>
<td>0.05</td>
<td>0.34</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Step time (msec)</td>
<td>1.9</td>
<td>1.9</td>
<td>0.47</td>
<td>0.02</td>
<td>3.6</td>
<td>3.6</td>
<td>0.44</td>
<td>0.04</td>
</tr>
<tr>
<td>Stride time (msec)</td>
<td>2.6</td>
<td>2.4</td>
<td>0.14</td>
<td>0.24</td>
<td>2.6</td>
<td>2.3</td>
<td>0.09</td>
<td>0.31</td>
</tr>
</tbody>
</table>

NB: SD indicates standard deviations; CV indicates coefficient of variation; NA indicates not applicable.

Materials

For both walking protocols, gait data were collected by a GAITRite walkway system (length: 810 cm; width: 89 cm; height: 0.625 cm) that sampled at 80 Hz. Previous work has shown both protocols to be reliable when collecting spatiotemporal GAITRite data for younger and older women [13]. The GAITRite mat contained 27,648 sensors that were 1 cm square in size and were placed 1.27 cm apart. This system has been shown to provide a spatial accuracy of between 0.51 to 0.66 cm for measures of step and stride length, respectively [14].

Statistical analysis

Walking velocity, step and stride length, step and stride time and step width were collected by the GAITRite system and analysed with SPSS (Version 12). To quantify gait variability, standard deviation (SD) and coefficient of variation (CV) were calculated. It is recommended that CVs should only be calculated for ratio data [15]. Therefore, since step width is interval data, CVs were not calculated for this parameter.

Paired t-tests were used to compare variability measures across protocols. Bonferroni adjustments were not made because this study was interested in detecting differences in each individual gait parameter [16]. Instead, effect sizes (ESs) were calculated to determine the importance of statistical differences found between the protocols [17]. Based on Cohen’s [18] suggestions, a small ES was defined as 0.2, a medium effect as 0.5 and a large effect as 0.8.

Results

Variability data for each group and walking protocol are listed in Tables 1 and 2. For the younger adult group, significant differences between the single and continuous walking protocols were found for velocity (P = 0.01), step length (P = 0.04) and stride time (P = 0.02) SDs. Additionally, velocity (P = 0.02), step time (P = 0.02) and stride time (P = 0.01) CVs were also found to be significantly different between the repeated single and continuous walking protocols. Most of the ESs for these differences were medium to large, ranging from 0.46 to 0.79. For the older adults, significant differences between the repeated single and continuous walking protocols were found for velocity, step length and stride length SDs and CVs (P < 0.01). Medium ESs were observed for these differences, with values ranging from 0.34 to 0.58.

Discussion

This study investigated the effect of over-ground walking protocol on the gait variability of younger and older women. The repeated single walking protocol resulted in significantly higher SDs for velocity, step length and stride time, and significantly higher CVs for velocity, step time and stride time in the younger adult sample. For the older participants, the repeated single walking protocol resulted in significantly higher SDs and CVs for velocity, step length and stride length. Medium to large ESs were found for the majority of these increases in variability.
The higher gait variability found with repeated single walking may be due to the repeated stoppages in the protocol. Although recent work [19] suggests that this protocol might better reflect everyday walking, recording variability in this manner assumes that any given stride is unaffected by a previous stride [9]. This assumption is questionable since work has shown that a given stride is affected by previous strides, demonstrating dependence between consecutive gait cycles [9, 20, 21]. Hence, it is possible that any inter-relationship between strides during continuous walking may be perturbed by the repeated stoppages encountered in the single walking protocol. The presence of this perturbation may partly explain the higher gait variability exhibited by the participants in this protocol.

The significant increases found in the gait variability measures for the repeated single walking protocol may have important clinical implications. Previous work has shown that increased variability in the measures of stride length, stride time, stride width and walking velocity are associated with future falls in older adults and pathological populations [2, 5]. Consequently, many researchers and clinicians now use the presence of increased gait variability as a marker of gait malfunction or impairment. The results of this investigation, however, show that a repeated single walking protocol may increase gait variability. It would be of interest to investigate whether the increase in variability found during this protocol affects the capacity of clinicians and researchers to identify gait impairments or predict those older adults at risk of future falls.

A potential limitation of this study was the collection of gait data over a discrete section of the continuous walking circuit. Recording gait data in this manner may result in a series of gait trials that are similar to a repeated single walk protocol. This protocol, however, was chosen in order to reflect the increasing use of instrumented mats in clinical gait research [1, 7, 22]. Furthermore, strides analysed from discrete gait trials collected during continuous over-ground walking do not have the same spatial and temporal perturbations that result from the repeated stoppages during single walking protocols. This ensures dependence between gait cycles during a continuous walking protocol.

In conclusion, this study found that measures of gait variability are altered by the overground walking protocol adopted. In comparison to a continuous over-ground walking protocol, a repeated single over-ground walking protocol significantly increased the variability of several basic spatiotemporal measures of gait. Future work should consider walking protocol when investigating gait variability.

Key points

- In older adult populations, measures of gait variability are commonly used to evaluate ambulation and assess falls risk. Currently, the effect of walking protocol upon gait variability is unknown.
- This study shows that in comparison to a continuous over-ground walking protocol, a repeated single trial over-ground walking protocol significantly increases measures of gait variability.
- The repeated stoppages inherent in repeated single trial walking protocols may perturb the spatiotemporal rhythm of gait. This most likely increases gait variability.

Conflicts of interest

None.

KADE L. PATERSON1,∗, NOEL D. LITHGO2, KEITH D. HILL3,4

1 School of Exercise Science, Australian Catholic University Fitzroy, Victoria 3065, Australia
Email: kade.paterno@acu.edu.au

2Rehabilitation Sciences Research Centre, c/o Royal Talbot Rehabilitation Centre, Kew, Victoria 3101, Australia

3Musculoskeletal Research Centre, Faculty of Health Sciences La Trobe University and Northern Health Bundoora, Victoria 3086, Australia

4Preventive and Public Health Division, National Ageing Research Institute, 34–54 Poplar Rd, Parkville, Victoria 3052, Australia

∗To whom correspondence should be addressed

References


9. Dingwell JB, Cusumano JP, Cavanagh PR, Sternad D. Local dynamic stability versus kinematic variability of continuous...
Elderly patients undergoing revascularisation are more likely to present with complex lesions and associated co-morbid conditions [2]. Although the effects of cardiovascular therapies on morbidity and mortality have been reported [3–5], there is paucity of data on quality of life following percutaneous coronary revascularisation (PCR) in octogenarians. We recorded both clinical outcomes and quality of life in octogenarians at 6 and 12 months after PCR.

**Methods**

Seventy-four consecutive patients aged ≥80 years undergoing PCR were recruited over 18 months and prospectively studied. Local ethics committee approval was obtained.

No patients underwent more than two-vessel revascularisation, 28 patients underwent two-vessel revascularisation and the remainder underwent single vessel only.

**SF 36**

We obtained data for the eight scales and the physical and mental health summary scales [6, 7]. The summary scales were compared to normative data for the general population, age >75 years in the USA [7, 8]. The data from the eight individual scales were compared to the normative data from the UK population [9].

**Seattle angina questionnaire (SAQ)**

The SAQ is a validated, self-administered, disease-specific measure for patients with coronary artery disease [10, 11].

The physical limitation and angina frequency scores were classified as minimal (scores 75–100), mild (50–74), moderate (25–49) and severe (0–24). Severe angina reflects episodes several times per day, moderate angina several times per week to every day, mild angina reflects weekly occurrence and minimal angina occurs less than once a week or not at all. Angina stability scores were classified as much better (76–100), slightly better (51–75), unchanged (50), slightly worse (25–49) and much worse (0–24). Treatment satisfaction score was categorised as mostly to completely satisfied (75–100), somewhat to mostly satisfied (50–74) and somewhat dissatisfied to not satisfied at all (0–49). Quality-of-life scores were classified as excellent (75–100), good (50–74), fair (25–49) and poor (0–24) [12, 13].

**Analysis of time trends in outcome measures**

Both raw SF-36 and SAQ scores were analysed in the same way. Longitudinal analysis of each of the standard subscale scores served as the dependent variable in a hierarchical linear model incorporating indicators for the three time periods (baseline, 6 and 12 months) as well as a random effect for each patient. Because of the limited size of the data set, we did not adjust the model for any person specific covariates nor test for covariate effects.