Stepping reaction time and gait adaptability are significantly impaired in people with Parkinson’s disease: Implications for fall risk

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ABSTRACT

Background: Decline in the ability to take effective steps and to adapt gait, particularly under challenging conditions, may be important reasons why people with Parkinson’s disease (PD) have an increased risk of falling. This study aimed to determine the extent of stepping and gait adaptability impairments in PD individuals as well as their associations with PD symptoms, cognitive function and previous falls.

Methods: Thirty-three older people with PD and 33 controls were assessed in choice stepping reaction time, Stroop stepping and gait adaptability tests; measurements identified as fall risk factors in older adults.

Results: People with PD had similar mean choice stepping reaction times to healthy controls, but had significantly greater intra-individual variability. In the Stroop stepping test, the PD participants were more likely to make an error (48 vs 18%), took 715 ms longer to react (2312 vs 1517 ms) and had significantly greater response variability (536 vs 329 ms) than the healthy controls. People with PD also had more difficulties adapting their gait in response to targets (poorer stepping accuracy) and obstacles (increased number of steps) appearing at short notice on a walkway. Within the PD group, higher disease severity, reduced cognition and previous falls were associated with poorer stepping and gait adaptability performances.

Conclusions: People with PD have reduced ability to adapt gait to unexpected targets and obstacles and exhibit poorer stepping responses, particularly in a test condition involving conflict resolution. Such impaired stepping responses in Parkinson’s disease are associated with disease severity, cognitive impairment and falls.

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1. Introduction

Balance and gait impairments are disabling symptoms of Parkinson’s disease (PD) that adversely affect performance of daily activities, reduce independence and increase the risk of falls. Around 60% of people with PD fall at least once a year, with a large proportion (50–86%) falling recurrently [1]. Most falls occur when people with PD are walking and when their symptoms are controlled i.e. in the “on medication” status [2]. To avoid falls while performing daily activities, effective stepping responses and gait adjustments, appropriately scaled for speed, magnitude, direction and accuracy, are required. Declines in the ability to adapt stepping and gait behavior, particularly under challenging conditions, might contribute to trips; which is frequently reported as a cause of falls in people with PD [3].

It has been proposed that attentional control deficits may lead to less effective behavioral responses in people with PD [4]. Several studies using finger-tapping tasks indicate people with PD, compared with controls, become increasingly slow to respond to a stimulus as choice complexity increases [5]; are slower to respond to a target flanked by incongruent distractors [6] and make more errors in the incongruent trials of the Stroop task [7].

Although deficits in finger-task reaction time are well
documented and related to an increased risk of falling [8], little is
known about the effects of attention control on stepping in people
with PD - a task previously associated with an increased fall risk in
older people with and without mild cognitive impairment [9–11].
This is of interest as the stepping tasks capture both cognitive and
motor components of reaction time performance and thus may be
useful tools for effective fall prevention for people with PD. Like-
wise, measurements of the ability to adapt gait, particularly in
challenging environmental conditions, may also provide valuable
information about impaired behavioural responses in PD, as
attentional deficits are also related to gait impairments [12].

Previous research on attention control of stepping using a vir-
tual reality paradigm has shown that people with PD with freezing
gait have longer motor pauses when required to respond to a
conflicting stimulus (i.e. a red coloured stimulus to move the feet
while seated) compared with people with PD without freezing of
gait and non-PD controls [13]. PD patients with freezing of gait also
display inappropriate postural adjustments prior to step initiation
when required to respond to an attentional task (finger press in
response to an auditory stimulus) [14]. Similarly, people with PD in
their “off” medication state show a slower stepping reaction time
than controls in a task requiring stepping forward or backward as
soon as a coloured shape (i.e. cross or circle; yellow or blue) is
presented on a screen, with PD freezers being more affected [15].

There is also evidence that the ability to adapt gait in response to
upcoming environmental changes is impaired in PD. Previous
studies using obstacle avoidance paradigms have shown that peo-
ple with PD approach and step over a fixed obstacle slower and
with smaller steps than control participants [16]. They also exhibit
impaired foot clearance (shorter vertical foot-obstacle distance)
during obstacle crossing [17] and impaired foot placement accuracy
in a walking task involving fixed stepping targets [18].

Although these studies provide good insights into PD stepping
and gait behaviour, no studies have investigated attention control
of stepping in people with PD in their “on” medication state during
tasks requiring stepping with both legs in multiple directions
(forward, backward, right and left). Likewise, the ability to adapt
gait in response to unexpected hazards appearing on the pathway
[19] has not been investigated to date in PD. Such investigations
could provide new insights for effective fall prevention for people
with PD.

Thus, the aims of this study were to determine a) the extent of
stepping response and gait adaptability impairments in people
with PD, and b) the clinical and cognitive correlates of such deficits
within the PD group. We hypothesised that compared with healthy
controls, people with PD would demonstrate impaired stepping
and gait responses, and that such deficits would be associated with
poorer cognitive function, worse PD symptoms and previous falls.

2. Methods

The study was approved by the University of New South Wales
and the Sydney University Human Research Ethics Committees.
Participants provided written informed consent prior to
participation.

2.1. Participants

Participants were recruited from metropolitan Sydney, Australia
through the research team’s research volunteer databases and
through Parkinson’s NSW newsletters and support groups. PD
volunteers were recruited for a training study (ACTRN12613006887875) and their data were collected as part of the
baseline assessments. Participants were included if they were
65 years and older, living in the community, able to walk unaided
for ≥30 m and cognitively capable of following all instructions
(MOCA scores 20–30). Participants with PD were required to have
been on the same PD medication for at least two weeks. Volunteers
with and without PD were excluded if they had any medical condi-
tions which would preclude or interfere with the physical
assessment (e.g. physician diagnosed dementia, acute or terminal
illness, progressive neurodegenerative diseases (other than PD),
major psychiatric illnesses, colour-blindness or visual impairments
that could not be corrected).

Researchers experienced in working with people with PD and
trained in the Movement Disorders Society Unified Parkinson’s
Disease Rating Scale (MDS-UPDRS) administered section 3 of
the scale (motor examination) [20], the Hoehn and Yahr rating scale
(H&Y) [21] and The New Freezing of Gait Questionnaire [22] for the
PD participants. Table 1 presents the demographic, anthropometric
and cognitive (Montreal Cognitive Assessment (MoCA score [23]))
data for both groups, as well as clinical characteristics for the PD
participants.

2.2. Choice stepping reaction time (CSRT) and Stroop stepping tests

Stepping performance was measured with the CSRT [10] and
arrows (right, left, right front and back and left front and back) as
well as two central stance panels to indicate the position to initiate
steps and return to after completing them was used for both tests
(Fig. 1–F1 and F2). Participants were instructed to stand on the
central panels. For the CSRT test, the configuration of the step
panels was presented on a screen in front of the participants and
they were asked to make rapid step responses to the target arrows
in response to corresponding visual stimuli presented randomly
on the screen and return to the central panels. Six practice
trials and 18 test trials were administered. CSRT performance was
measured in milliseconds (ms) and subdivided into: 1) decision
time (i.e. stimulus presentation to foot lift-off), 2) movement time
(i.e. foot lift-off to step-down) and 3) total response time (i.e. sum of
the decision time and movement time). The average time per trial

<table>
<thead>
<tr>
<th>Variables</th>
<th>Parkinson’s disease</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>70 ± 4</td>
<td>71 ± 4</td>
</tr>
<tr>
<td>Number of women (%)</td>
<td>13 (39)</td>
<td>19 (58)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>76.3 ± 13.8</td>
<td>75.8 ± 14.6</td>
</tr>
<tr>
<td>Body height (cm)</td>
<td>170.7 ± 8.0</td>
<td>168.9 ± 10.4</td>
</tr>
<tr>
<td>Usual gait velocity (m/s)</td>
<td>1.26 ± 0.24</td>
<td>1.29 ± 0.15</td>
</tr>
<tr>
<td>Usual step length (m)</td>
<td>0.67 ± 0.11</td>
<td>0.69 ± 0.07</td>
</tr>
<tr>
<td>MoCA (score)</td>
<td>26.3 ± 2.8</td>
<td>27.2 ± 2.4</td>
</tr>
<tr>
<td>Previous falls (# of participants (%))</td>
<td>18 (54%)</td>
<td>10 (30)</td>
</tr>
<tr>
<td>MDS-UPDRS-III (score)</td>
<td>36.1 ± 12.2</td>
<td>n/a</td>
</tr>
<tr>
<td>Hoehn and Yahr stage</td>
<td>2.1 ± 0.4</td>
<td>n/a</td>
</tr>
<tr>
<td>Years since diagnosis</td>
<td>7.8 ± 3.8</td>
<td>n/a</td>
</tr>
<tr>
<td>Freezing of gait (# of participants (%))</td>
<td>10 (30)</td>
<td>n/a</td>
</tr>
</tbody>
</table>

*Significantly different between control and Parkinson’s disease groups (p < 0.05); | trend (p = 0.062).

a Montreal Cognitive Assessment (adjusted for years of education); score range
0–30, high scores indicate better cognitive performance.

b Number of participants who reported falling once or more in the previous 12 months.

c Movement Disorders Society version of the Unified Parkinson’s Disease Rating Scale, section 3 (motor examination); score range 0–132, high scores indicate increased disease severity.

d The New Freezing of Gait Questionnaire, number of participants that reported
freezing of gait.
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