

# Developing methods to evaluate how people with Parkinson's Disease turn 180°: an activity frequently associated with falls

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## Abstract

**Purpose:** To develop a test that identified fallers from their turning strategies, as people with Parkinson's Disease (PD) commonly fall turning.

**Method:** We compared (1) Turn Types demonstrated when turning 180° during the Timed Up and Go Test (TUG Test) by 19 non-fallers and 29 fallers (median age 71) and (2) Turn Types, Turning Steps, Heelstrike, Stability and the Use of Space and Support demonstrated when turning 180° during an everyday activity by 15 non-fallers and 26 fallers (median age 75). Turns were rated from video by observers blinded to group. Inter-observer agreement was tested.

**Results:** Similar proportions of fallers and non-fallers demonstrated multiple-step Turn Types during the TUG Test (69% v 58%;  $p = 0.433$ ) and the everyday activity (66% vs. 46%;  $p = 0.241$ ). When turning, similar proportions of each group lacked Heelstrike, lost Stability and used the available Space and Support ( $p > 0.7$ ); Turning Step counts were also similar ( $p = 0.891$ ). Inter-observer agreement proved acceptable except for Turn Type during everyday activity (Kappa = 0.46).

**Conclusions:** The anticipated differences between fallers and non-fallers were not identified, perhaps obscured by insufficiently or overly challenging protocols and/or the compensations deployed by fallers. Further methodological development is needed in the analysis of fall-related activities with high-risk groups.

## Introduction

Knowing what a faller was attempting to do when he or she fell can suggest why the fall occurred and how further falls might be avoided and people with Parkinson's Disease (PD) tend to experience postural instability in specific circumstances.<sup>1-4</sup> They are known to have

difficulty turning<sup>5-8</sup> and to fall turning.<sup>4, 8</sup> Falling during turning carries a high risk of hip fracture.<sup>1, 9, 10</sup> Though not a common cause of falls among elderly fallers in general<sup>11-12</sup> research suggests that a greater proportion of elderly fallers than non-fallers appear unsteady, hold on, stagger or stop when turning<sup>13-14</sup> and that fallers take more steps and longer to turn than non-fallers.<sup>15</sup> These findings prompt the question; do fallers and non-fallers with PD differ in the ways they turn?

The evaluation of turning while walking<sup>13, 16</sup> presents a methodological challenge in terms of defining the beginning and end of the turn, definitions which are essential in order to count turning steps and time the manoeuvre reliably. Prescribing where the turn should be made (marking a line or zone on the floor) restricts the subject's choice of how to complete the manoeuvre. 'On-the-spot' turns<sup>13-17</sup> have more clearly defined start-points and end-points than walking turns but are not without methodological weaknesses. The test is not especially balance-demanding as the head stays over the base throughout, the manoeuvre is not representative of an everyday activity and focuses the subject's attention on turning alone; for people with PD who are temporarily better able to move when attending to a single task and/or under the facilitation of external stimuli, the test is uninformative. Laboratory-based attempts to describe turning have produced findings of limited applicability to people with PD, having predominantly involved small samples of young healthy volunteers and been heavily dependent on the use of high-technology investigative tools during tightly controlled experimental set-ups.<sup>18-27</sup>

We conducted two studies in the course of developing a suitable method for evaluating the way in which people with PD perform the commonly fall-related activity of turning. Study One was laboratory-based and necessitated defining the Turn Types demonstrated

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during a walking 180° turn (i.e. the patterns of Turning Steps observed during a change from ambulation in one direction to continued ambulation in the opposite direction). Study Two evolved from Study One and was community-based with a broader focus. A 180° turn during an everyday activity (making a cup of tea) was observed; Turn Types plus five other features of turning were evaluated. The objectives of each study were:

- (1) To identify differences between the ways fallers and non-fallers with PD turn, and
- (2) To develop the methods for evaluating the turning strategies of people with PD.

## Methods and results

We recruited independently ambulant, community-dwelling people with PD via local GPs for both studies and gained their written consent. Potential participants were excluded if they were unable to walk without the assistance of another person, had any neurological diagnosis in addition to PD or failed a gross cognitive screening test, the Middlesex Elderly Assessment of Mental State.<sup>28</sup> PD severity was measured using the Hoehn and Yahr Grades.<sup>29</sup> At interview, participants were classified as a faller (having fallen in the previous 12 months) or a non-faller in Study One and as a repeat-faller (having fallen at least twice in the previous twelve months) or a non-repeat-faller in Study Two. So that the 180° turns demonstrated could later be rated by an observer blind to the participant's fall-history and PD severity, the turns were video-recorded (using a tripod-mounted camera). In an attempt to avoid the Halo Phenomenon,<sup>30</sup> the observers did not watch the entire video-recording of each participant but only the turn.

### STUDY ONE

#### Measurement tool

In collaboration with two experienced physiotherapists, we reviewed 40 videos of out-patients with PD walking up and down a corridor in a neurologist's clinic. From the 30 videos where a walking 180° turn could be seen clearly, we distinguished and defined six Turn Types (see table 1 and figure 1). Four Turn Types were characterized by their multiple Turning Steps and two were characterized by few Turning Steps.

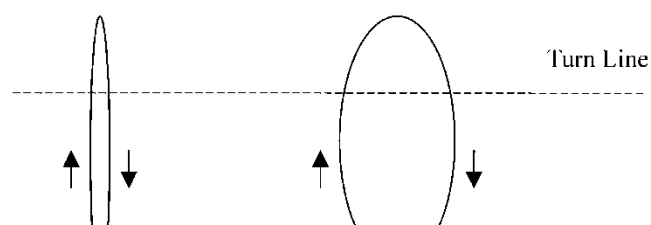
To evaluate the inter-rater reliability of the Turn Type definitions, 10 physiotherapists used them to rate 12

**Table 1** Turn types during walking 180° Turns

Group	Turn type	Definition
Multi-step	Festination Forward	Multiple, small, quick shuffling steps. Consistently moving forward, either in a U-shape or 'on-the-spot'.
	Wheeling	Series of steps in an arc round a central point, like stepping on spokes of a wheel.
	Backward	On completion of turn, taking full step backward before advancing in new direction.
Few steps	Twisting	Pivoting on one planted foot or on both planted feet.
	Sideways	Whilst turning, taking a sideways or backward step with one foot.

(a) 'On-the-Spot'

(b) 'U-shaped'



**Figure 1** Representation of the two sub-types of Forward Turn. During Forward Turns participants constantly steps forward, either approaching and returning from the turn along the same trajectory, turning tightly 'on-the-spot' (representation a), or approaching and returning from the turn along parallel trajectories, turning following a wide arc (representation b).

turns (four fallers with PD, four non-fallers with PD and four healthy elderly people) from video. A Kappa measurement of agreement was calculated<sup>31</sup> and interpreted following Landis and Koch,<sup>32</sup> i.e. 0.41–0.6 indicates moderate agreement, 0.61–0.8 good agreement and 0.81–1 very good agreement.

#### Procedure

We invited the 63 people with PD (median age 72 years, IQR 67–78 years; two at Hoehn and Yahr Grade I, 19 at Grade II, 32 at Grade III and 10 at Grade IV; 40 fallers) participating in a larger fall prediction study<sup>33</sup> to complete the Timed Up and Go Test [TUG Test<sup>34</sup>] in our gait laboratory (transport was provided). A video camera was set to record the test, in which participants rose (on the command 'Go'), walked 3 m to a line on the floor, turned 180°, walked back to the chair and sat down. These walking 180° turns were defined as the change from ambulation in one direction to continued

ambulation in the opposite direction. Data were collected by one researcher and the turns rated from video by another. Chi-square analyses were used to compare the Turn Types of (a) fallers and non-fallers, and (b) people with mild PD (Grades I–II) and those with more severe PD (Grades III–IV).

### Results

Of the 12 turns rated when testing inter-rater reliability, fewer than seven of 10 therapists (70%) agreed on the Turn Type definition for four turns, 70–80% agreed on three turns and 90–100% agreed on five turns: overall, reliability was only moderate (Kappa = 0.60). Forty-eight of the 63 potential participants (76%) attended the laboratory (median age 72 years, IQR 67–75 years). Two participants were at Hoehn and Yahr Grade I, 17 at Grade II, 26 at Grade III and three at Grade IV. Twenty-nine participants were fallers, seven (24%) at Hoehn and Yahr Grades I–II. The distribution of Turn Types among the participants is shown in table 2. Similar proportions of fallers and non-fallers demonstrated multiple-step Turn Types during the TUG Test (69% vs. 58%;  $p = 0.433$ ). Turn Types characterized by multiple Turning Steps were demonstrated by a significantly greater proportion of those with more severe PD than those with milder PD (76% vs. 47%, respectively);  $p = 0.004$ .

### STUDY TWO

#### Measurement tool

We recorded videos of seven people with PD and six without making a hot drink in their own kitchens and reviewed them in collaboration with three other therapy researchers. Focussing on the 180° turns that arose spontaneously during the task, we defined five features of turning (in addition to Turn Type) readily observable

from video: the number of Turning Steps (count of steps taken prior to walking), Heel-strike (decreased or not), Stability (apparently stable or unstable), Use of Space (did subject cross open space or not?) and Use of Support (did subject hold on to any fixed support?) while turning. To evaluate the inter-rater reliability of each feature, two observers compared their evaluations of the videos collected during the study. Kappa coefficients were estimated for the categorical data, as in Study One.

#### Procedure

One hundred and twenty-six people with PD were invited to take part in the study. A video camera was set up in the participants' kitchens to record their movement as they completed the everyday task of making a cup of tea. To enhance their safety and the normality of the situation, the researcher remained nearby and engaged in conversation. Data were collected by one researcher and the turns rated independently by two others who together reached a consensus rating. A 180° turn was defined as a 180° change in direction from a standing position that required stepping and rotation of the whole body around its vertical axis. A 180° turn was rated when a participant relocated from one side of the kitchen to the opposite side, e.g. from one work surface or the fridge or sink to another work surface or a cupboard. Chi-square analyses were used to compare the Turn Types, Heel-strike, Stability and Use of Space and Support of (a) repeat-fallers and non-repeat-fallers, and (b) people with milder PD (Grades II–III) and those with severe PD (Grade IV): Mann–Whitney Tests were used to compare the Turning Step counts.

#### Results

Inter-rater agreement on Turn Type was moderate (56%,  $K = 0.46$ ), on Stability and Heel-strike was good

**Table 2** Turn types by participant fall history and PD severity

Turn types		Fall history			PD severity			
		All (n = 48)	Fallers (n = 29)	vs.	Non-fallers (n = 19)	I–II (n = 19)	vs.	III–IV (n = 29)
Multiple steps	Festinant	2 (4%)	2 (7%)	vs.	0	1 (5%)	vs.	1 (3%)
	Forward	26 (54%)	16 (55%)	vs.	10 (53%)	8 (42%)	vs.	18 (62%)
	Wheeling	3 (6%)	2 (7%)	vs.	1 (5%)	0	vs.	3 (10%)
Few steps	Twisting	4 (8%)	2 (7%)	vs.	2 (11%)	2 (11%)	vs.	2 (7%)
	Sideways	13 (27%)	7 (24%)	vs.	6 (32%)	8 (42%)	vs.	5 (17%)

Distribution of grouped turn types: Fallers vs. Non-fallers,  $p = 0.433$ ; I–II vs. III–IV PD,  $p = 0.004$ .

(90%,  $K = 0.76$  and 93%,  $K = 0.73$ ) and on Use of Space and Support was very good (95%,  $K = 0.87$  and 98%,  $K = 0.91$ ). The mean difference for the Turning Step count was 0.06 ( $\pm 0.65$ ), 95% limits of agreement  $-1.4$ – $1.2$ .

Seventy-five of the 126 potential participants (60%) agreed to take part (median age 75 years, IQR 69–79 years; diagnosed a median seven years, IQR 4–14; median Hoehn and Yahr Grade III, range II–IV; 43 repeat-fallers) but 34 (45%) could not attempt the everyday activity we intended to observe. The distribution of turning strategies among the 41 remaining participants (median age 75 years, diagnosed a median six years, 12 at Grade IV, 26 repeat-fallers) is shown in table 3. Thirty-four participants (83%) lacked heelstrike when turning; 24 (59%) demonstrated multiple-step Turn Types (the median number of steps taken was 5, IQR 4–7); 13 (32%) appeared unstable; only seven (17%) used support and only four (of 36, 11%) avoided open spaces.

Repeat-fallers and non-repeat-fallers turned in similar ways: they demonstrated similar distributions of the grouped Turn Types ( $p = 0.241$ ), took similar numbers of Turning Steps ( $p = 0.891$ ) and similar proportions of both groups demonstrated Instability ( $p = 0.734$ ), decreased Heelstrike ( $p = 1.000$ ) and the use of Space ( $p = 1.000$ ) and Support ( $p = 1.000$ ) when turning. Those with milder and more severe PD demonstrated similar distributions of the grouped Turn Types ( $p = 0.296$ ) and similar proportions of both groups demonstrated decreased Heelstrike ( $p = 1.000$ ) and the

use of Space ( $p = 1.000$ ) and Support ( $p = 0.165$ ) when turning. However, those with milder PD took fewer Turning Steps than those with severe PD ( $p = 0.046$ ) and apparent Instability when turning was more common among those with severe PD than those with milder PD ( $p = 0.004$ ).

## Discussion

Berg *et al.* argued that the effective clinical assessment of elderly fallers relied upon an understanding of the activities during which falls arise:<sup>12</sup> both studies described here constitute steps toward developing a method of evaluating one of the most common fall-related activities that will allow unstable turners and those at risk of falling to be identified. Describing Turn Type during the TUG Test provides a fuller description of how an individual with PD turns than simply timing the overall performance. The challenges inherent to video-recording in the home (such as optimizing the field of view and light level and safely managing trailing leads) were successfully overcome and usable data was generated. There was only modest agreement between raters when the Turn Type definitions were tested in Study One and certain definitions were agreed upon more readily than others. For example, the definitions of Forward and Wheeling turns may have overlapped, although the former involves constant forward stepping and the latter a series of side-steps to change direction. The poor inter-rater agreement on Turn Type in Study Two probably stemmed from the definitions having been

**Table 3** Turning strategies during an everyday activity by participant fall-history and PD severity

Strategy	Fall history			PD severity		
	Non-RF (n = 15)	vs.	R-F (n = 26)	II–III (n = 29)	vs.	IV (n = 12)
<i>Turn type</i>						
Multiple steps						
Backward	3 (20%)	vs.	5 (19%)	4 (14%)	vs.	4 (33%)
Festinant	0	vs.	2 (8%)	2 (7%)	vs.	0
Forward	2 (13%)	vs.	9 (35%)	6 (21%)	vs.	5 (42%)
Wheel	2 (13%)	vs.	1 (4%)	3 (10%)	vs.	0
Few steps						
Twist	0	vs.	1 (4%)	1 (3%)	vs.	0
Sideways	8 (54%)	vs.	8 (31%)	13 (45%)	vs.	3 (25%)
Steps	Median [IQR]	vs.	5 [4–7]	4 [4–6.5]	vs.	6 [5–8.8] *
Instability	N (%)	vs.	4 (27%)	9 (35%)	vs.	5 (17%)
↓ Heelstrike	N (%)	vs.	4 (27%)	9 (35%)	vs.	8 (67%) *
Used space	N (%)	vs.	13 (87%)	21 (81%)	vs.	24 (83%)
		vs.	12 (92%)	20 (87%)	vs.	24 (89%)
			N = 13	N = 23		N = 27
Used support	N (%)	vs.	2 (13%)	5 (19%)	vs.	3 (10%)
					vs.	4 (33%)

Non-RF = Non repeat-fallers; R-F = Repeat fallers; IQR = Inter-quartile range. \* Differences non-significant ( $p > 0.1$ ) except between II–III and IV PD for steps ( $p = 0.046$ ) and Instability ( $p = 0.004$ ).

developed for walking turns and not being transferable to turns from a standing-start. In light of the demonstrated inter-rater reliability, one strength of both studies was that two raters reached a consensus decision on Turn Type, after repeated video playback and discussion. For future studies, turns from a standing-start require redefinition.

Study One informed Study Two, with particular respect to sample drop-outs, group characteristics and the extent to which turning was cued. The major weakness of Study One was that 70% of the potential participants with Grade IV PD were unwilling to travel to the laboratory, as their disability made travel almost impossible. The fallers who attended the laboratory were probably the more mobile of the fallers we identified and this may go some way towards explaining the similarities between the performances of our fallers and non-fallers (alternatively, the TUG Test may not have been sufficiently challenging to reveal difficulty turning in the group with a history of falls). Having conducted Study Two in the participants' homes, and negated the need for travel on their part, we were surprised at the number of people unable to make a cup of tea while we observed their movement. Again, it was people with severe PD who constituted the majority (59%) of the dropouts. In contrast to the laboratory protocol, the task we chose to investigate in the home may have been too challenging for many of the participants. The sample we were able to observe was small and probably consisted of only the most able individuals recruited. Researchers face the challenge of developing a testing situation that people with severe instability will be able to attempt but which will reveal the nature of their movement dysfunction. Other tasks that would be widely applicable yet challenging (perhaps heightened by time constraints or other demands) could be explored; reaching, carrying, rising from sitting and stepping backwards are all activities associated with falls in PD.<sup>4</sup>

In Study One, the distinction between the groups may have been blurred by 'unrepresentative' fallers and non-fallers, e.g. fully mobile individuals might have fallen once accidentally, whereas a once frequent faller may have avoided falls in the previous year by never mobilizing alone. In Study Two we defined our groups more tightly by including only those participants who had fallen at least twice in the 'repeat-faller' group. Even so, the groups were heterogeneous: the time since diagnosis varied considerably across the non-repeat fallers and approximately a quarter of the group was at Grade IV. Future studies should define participant groups even more tightly, with reference to previous and recent fall-

history. In the laboratory, turning was cued *visually*, by the line on the floor, and *cognitively*, by the TUG Test protocol. The cues may have temporarily enhanced the mobility of the participants, masking any difficulty turning. In Study Two, our protocol minimised cueing and encouraged the performance of a more natural, spontaneous turn (i.e. mimicking a 'real life situation', as advocated by Yekutieli):<sup>2</sup> participants were not asked to turn but to make a cup of tea, i.e. they were not instructed to turn at all. Participants in Study One were told when to begin the TUG Test and where to turn but those in Study Two were only asked to allow us to record the way in which they moved about their kitchens. The turns that we observed arose when the participants needed to cross from one side of their kitchens to the other, i.e. the participants were double-tasking, turning spontaneously while pursuing another objective. However, the activity that we chose to study still constrained the participants to some extent: turning away from a work surface, they were compelled to step backwards or sideways. This environmental constraint may explain why so many participants (83%) were observed to lack heelstrike when turning: heelstrike is unlikely when stepping backwards.

Because the participants' kitchens differed, (a) the turns that we evaluated occurred at different points in the course of the task (i.e. some turned with hands free, others carrying objects such as kettles and mugs) and (b) five participants did not have any spaces to cross between work surfaces (hence the reduced numbers in the analysis of the item Use of Space). Evaluating naturally occurring turns is in many ways more satisfactory than evaluating standardized test procedures but the drawback is that the participants have the scope to tackle the task in widely differing ways. There is clearly a need for a test that draws on the advantages of both methods, i.e. a standard protocol and evaluation procedure for a turn that represents a manoeuvre that is challenging in real life; we are currently developing a test that we believe meets the requirements, the Standing Start 180° Turn Test.<sup>35</sup>

In light of these methodological challenges, it is not surprising that the anticipated differences in the ways fallers and non-fallers with PD turn were not elucidated. The finding that similar proportions of both groups appeared unstable during turning, however, brings into question the validity of the functional task as a test for distinguishing fallers and adds weight to the argument that a new type of turn test is needed.<sup>35</sup> Researchers who have demonstrated differences between the turns of elderly fallers and non-fallers have used unsubstantiated concepts of 'normality' or methods not

appropriate to people with PD. As Yekutieli demonstrated, people with PD can be 'acutely sensitive to context', making their performance during testing an unrepresentative reflection of their everyday ability.<sup>2</sup>

Although unlikely, it may be that the fallers recruited had no difficulty turning (and had hitherto always fallen during other activities) or had found ways of coping with their movement difficulties (as only a third appeared unstable). Potentially useful fall-preventive strategies such as avoiding crossing open spaces and holding on when turning round were demonstrated by very few of the participants: only 13% of the repeat-fallers remained within grabbing distance of an external support when turning and just one in five held on. Perhaps the finding that so few fallers and so few people with severe PD deployed compensatory strategies when turning is the key finding to come from this work. Strategies such as these and taking multiple Turning Steps could be usefully encouraged in those with a history of instability when turning. Therapeutically, promoting adaptive turning might be more appropriate than attempting to 'normalize' the performance of this challenging activity.

Whilst neither test was performed differently by fallers and non-fallers, both tests revealed differences between the groups divided by PD severity: three-quarters of the participants in the more severe PD groups demonstrated Turn Types characterized by multiple Turning Steps. Patla *et al.* described walking turns as 'a challenging task for the locomotor system':<sup>19</sup> multiple Turning Steps (each of reduced magnitude) might compensate for the postural instability and/or limitation of axial rotation often evident in advanced PD. It is not surprising that two-thirds of the severe PD group appeared unstable while turning, as the later stages of the disease are defined to some extent by evidence of postural instability.<sup>29</sup> Thigpen *et al.* have suggested that (among the elderly population, in general) Turn Type is modified in response to 'subtle changes in balance':<sup>16</sup> longitudinal studies are required to document the changes in the ability to turn that accompany the progression of PD.

## Conclusions

The anticipated differences between fallers and non-fallers were not apparent using the methods deployed, perhaps obscured by insufficiently-, or overly-, challenging protocols and/or the compensations deployed by fallers. Avoiding turning in open spaces, using external support and taking multiple small steps may be useful compensatory strategies for potentially unstable turners. Further methodological development is needed in the

analysis of fall-related activities with high-risk groups. A compromise between standardized testing in a controlled setting and functional testing in a familiar setting must be developed.

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