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Spin turns in advanced Parkinson's disease: A new clinical gait sign?

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ABSTRACT

Objective: Two strategies are known for turning while walking: step turns (the direction change is performed with 3 steps or more) and spin turns (turning on one/both feet simultaneously). It is unknown which strategy patients with Parkinson's disease (PD) choose and if L-dopa and STN-DBS are influencing this strategy.
Methods: Video-recordings of 171 PD patients that completed 180° turns were analyzed by two blinded raters before surgery, both off and on L-dopa, and one year after STN-DBS-implantation. The strategies were classified: 1) spin 2) step and 3) mixed (spin plus step) strategy. The characteristics of the patients with different strategies were compared.
Results: Interrater reliability for classification of turning strategy showed high agreement ($\kappa = 0.894$). The distribution of the preferred strategy differed significantly between treatment conditions (untreated, treated with L-dopa, L-dopa plus stimulation; $X^2(4) = 67.2$, $p < 0.0001$). The spin turn was found in 10.5% of patients OFF-drug, 23.5% ON-drug and in 38.8% ON-drug/ON-stim condition. In the three treatment conditions patients with spin turns had significantly lower UPDRS III scores compared to people with step turns ($p = 0.017$, $p = 0.001$, $p = 0.006$, respectively); step turn patients had poorer postural instability and gait disorders (PIGD) scores ($p = 0.04$, $p = 0.002$, $p = 0.04$, respectively).
Conclusion: The turn strategy can be reliably identified in clinical settings and is a simple motor sign. The spin turn is associated with better motor performance. Since improvements in motor score in patients with fluctuations are also related to behavioral changes, we cannot exclude that the turn strategy also represents a feature of psycho-motor interaction.

1. Introduction

Turning while walking is a fundamental element of locomotion and essential for functional independence. It is a complex movement that requires deceleration, body rotation and stepping out toward the new direction while keeping balance [1,2]. Turning is associated with fall risk, and in elderly adults, the fractures during turning are estimated to occur eight times more common than during straight walking [3].

Two main turning strategies during human walking are physiologically distinguishable [4]: the spin turn strategy, defined as a change in direction opposite to the pivot foot, for example to turn to the right subject alters direction by spinning the body around the left foot with one or both feet simultaneously (Fig. 1, video 1) and the step turn strategy, characterized by an initial weight shift to the left leg to turn right, followed by the right hip is rotated externally, then weight is shifted onto the right leg, until the left leg steps in the new direction (Fig. 1, video 1). The stepping strategy is safer because the base of support is wider while changing direction [4,5]. Young adults prefer to change the course of their travel path by making a step turn [1] and surprisingly older adults prefer spin turns but only until the turn exceeds 90° indicating an adaptive strategy to ensure safety while making a larger turn [5].

Supplementary video related to this article can be found at https://doi.org/10.1016/j.parkreldis.2019.10.011.

Difficulty in changing direction is an early feature of Parkinson's disease (PD) [6]. With disease progression turning performance becomes particularly impaired being related to freezing of gait (FOG) [7] with falls and increased risk of hip fractures [2]. People with PD with FOG show slower turning performance with increased cadence and number of steps compared to people without FOG [8]. Small studies investigating the influence of dopaminergic medication on turning are conflicting. Patients with PD had a shorter turn duration in the "ON" vs.

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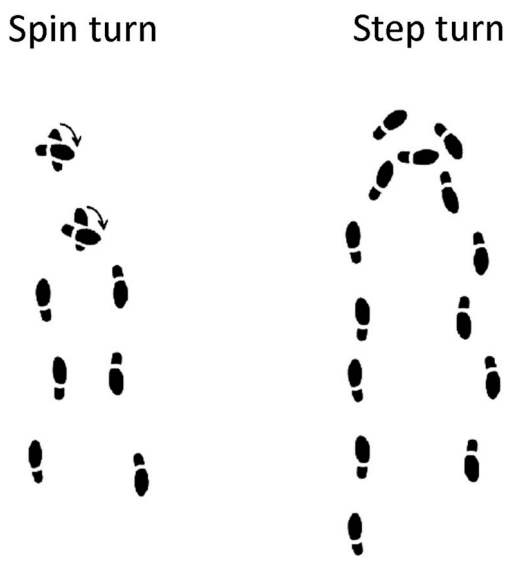

Fig. 1. Turning strategies while changing direction at 180°.

"OFF" medication state [9], and only PD patients without FOG performed better [10]. One recent study has shown that dopaminergic medication in PD can influence turning by altering the strategy [11]. However, overall turning strategies have rarely been studied in PD, although this might be particularly dangerous with regard to falls [2].

This study has two aims: (1) to investigate turning strategies in people with PD and to characterize patients using different strategies; (2) to analyze the effect of L-Dopa and STN-DBS on turning strategies.

2. Methods and patients

2.1. Patients

Of the 324 PD patients that received STN-DBS in our center until January 2017, 171 had medical records and a complete set of videotaped walking tasks under all three conditions: baseline prior to surgery in the OFF- and ON-drug state, and first follow-up in the ON-drug/ON-stim condition up to 1 year after the surgery. The walking task that included two 180° turns was rated at baseline in the OFF-drug condition, requiring that L-dopa should be discontinued for 12 h and the dopamine agonists for 72 h and the ON-drug condition, evaluated 60 min after taking 1.5 times of the regular L-dopa equivalence dosage. The follow-up assessment was held 3–12 months after the surgery in the ON-drug/ON-stim condition, that represents the usual state of the patient. All patients were assessed as in-patients at both baseline and follow-up visits prior to video recordings.

2.2. Turning strategy

Patients were not specifically instructed to perform one or the other turning strategy. It was not recommended which direction to turn. According to the instructions of the UPDRS scale, the patients were only asked to walk a given walk-way [12].The turning strategies in this study were classified into three categories [13]:

1) pivot/spin turn strategy: turning on one foot or both feet simultaneously, the direction change is performed in 1 movement, 2) step turn strategy: the direction change at 180 is achieved with 3 steps or more, no pivoting occurs and 3) mixed strategy (spin plus step): the turn is accomplished with 1–3 steps and a pivot. The identification of the preferred strategy was based on video recordings that were analyzed by two blinded raters who were unaware of the treatment condition, but the patient identity and sometimes also the pre- or postoperative status could not be hidden because the patient's hair was not covered (perioperative hair cut), and the patients did not wear a scarf (cable sometimes identifiable). Only the 180° turns were rated. Therefore, raters noted the turning direction (right or left).

2.3. Statistical analysis

All statistical analyses were calculated using SPSS software. Interrater reliability was determined by calculating Cohen's kappa coefficient (κ). A Chi-Square test was calculated comparing the frequency of turning strategies in different treatment conditions. Descriptive statistic and test for normality (Shapiro-Wilk) were performed for all variables. Differences of the three patients' groups (spinners, mixed, steppers) were analyzed with the Kruskal-Wallis test. Also, the patients which changed the strategy (step to spin) and those who used the same (step) strategy were compared with the Mann-Whitney test or independent as appropriate.

3. Results

A total of 171 patients had videos of all three conditions and fulfilled the other inclusion criteria. They were analyzed in this study. Clinical characteristics are shown in Table 1. In evaluating the video-based turning strategy, two independent raters (OG, AA) had an excellent agreement (k = 0.894).

The strategy preference was significantly different between the treatment conditions (OFF-drug vs ON-drug vs ON-drug/ON-stim), $X^2(4) = 67.2$, p = 0.0001 (Fig. 2).

Table 1
Demographic characteristics and outcome parameters at baseline in OFF-, ON-drug and at follow-up ON-drug/ON-stim conditions.

	OFF-drug baseline				ON-drug baseline				ON-drug/ON-stim follow-up			
	spinners	mixed	steppers	P[a]	spinners	mixed	steppers	P[a]	spinners	mixed	steppers	P[a]
Number of patients*	18	4	149	< 0.0001	40	27	103	0.0001	66	24	80	0.0001
Age	59.1 ± 8.4	59.7 ± 9.3	60.6 ± 8.1	0.83	58.5 ± 7.7	60.8 ± 6.9	61 ± 8.5	0.22	60.1 ± 6.9	61.8 ± 6.6	60.5 ± 9.3	0.46
Disease duration	10.2 ± 5.1	12.0 ± 1.7	13.5 ± 5.4	0.2	12.6 ± 4.7	13.4 ± 5.5	13.4 ± 5.5	0.89	12.3 ± 5.5	12.5 ± 4.4	14.3 ± 5.5	0.06
Sex, female: male*	3:15	0:4	50:99	–	8:32	8:19	37:66	–	17:49	9:15	27:53	–
UPDRS III	31.8 ± 8.9	45.7 ± 5.2	39.3 ± 11.8	**0.006**[b]	14.4 ± 6.4	17.7 ± 8.9	20.7 ± 9.6	**0.002**[b]	12.1 ± 6.1	14.0 ± 6.3	16.9 ± 9.8	**0.009**[b]
PIGD score	3.4 ± 2.1	5.2 ± 2.2	6.6 ± 3.1	< **0.0001**[b]	2.0 ± 1.7	2.9 ± 2.85	3.2 ± 2.4	**0.01**[b]	2.0 ± 1.6	3.0 ± 2.4	3.1 ± 2.9	**0.02**[b]

The data is presented as mean ± SD for all except those noted with *, which are presented as frequencies. The P values are presented for comparisons of spinners, mixed and steppers regarding demographic and clinical outcome parameters. UPDRS III, Unified Parkinson's Disease Rating score-motor impairment; PIGD, Postural instability Gait Disorder score, composed as a sum of UPDRS items 13 (falling), 14 (freezing), 15 (walking), 29 (gait) and 30 (postural instability).

[a] Kruskal-Wallis test was used to analyze differences of demographic parameters and clinical outcomes between the groups; a Chi-square was used to compare the number of patient's frequencies.

[b] Significant differences in bold for spinners versus steppers.

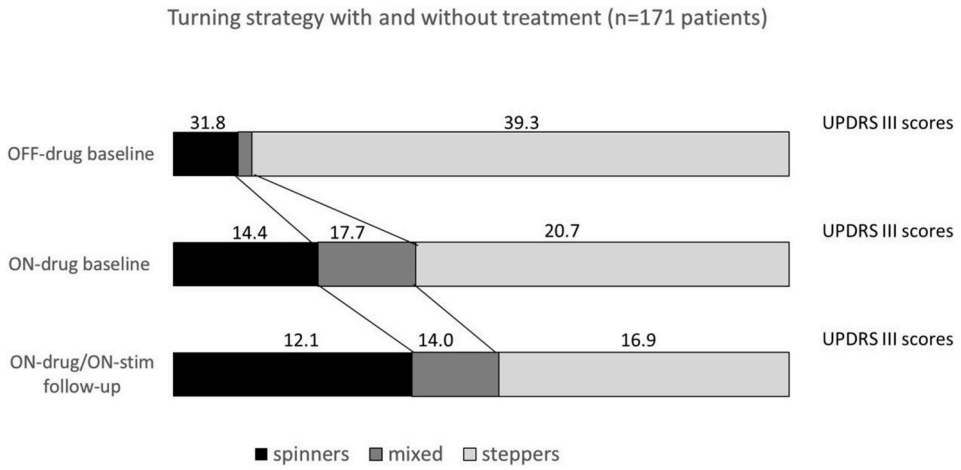

Fig. 2. Turning strategy with and without treatment at baseline in OFF-, ON-drug and at follow-up ON-drug/ON-stim conditions in 171 patients. The numbers show the mean UPDRS III scores for each group.

In the OFF-drug state 18 patients (10.5%) used a spin strategy, 149 a step (87.1%) and 4 (2.3%) a mixed strategy. In the ON-drug condition, 40 (23.5%) preferred a spin strategy, 103 (66%) a step and n = 27 (15.9%) a mixed strategy. In the combined treatment condition (ON-drug/ON-stim) the spin strategy was observed in 66 (38.8%) of the patients, the step strategy in 80 (47.1%) and the mixed strategy in 24 (14.1%).

We looked for differences of the UPDRS III between the patient groups (Fig. 2). In all three conditions (OFF-drug, ON-drug, ON-drug/ON-stim) patients with spin turns have significantly lower UPDRS III score compared to step turn patients (p = 0.017, p = 0.001, p = 0.006, respectively); and patients with a step turn have poorer postural and gait control (PIGD) scores (p = 0.04, p = 0.002, p = 0.04, respectively) compared to patients with a spin turn (Table 1). For patients with a mixed step strategy, there are no significant differences neither to spinners nor to steppers. The OFF-drug condition was not analyzed because of small numbers in the mixed group (n = 4). There were 3 patients who changed from spin to step at baseline (OFF-drug to ON-drug) and 8 patients changed from spin to step at follow-up (ON-drug to ON-drug/ON-stim). Due to the small numbers statistical analysis was not performed.

Patients who maintained step strategy were compared to those who change from step to spin strategy. Between the OFF- and ON-drug conditions changers from step to spin strategy (n = 26) compared to those who maintained the step strategy (n = 99) have a significantly lower UPDRS III (15.5 ± 6.8 vs 19 ± 14 points, p = 0.04) but from the ON-drug to ON-drug/ON-stim the patients that maintain step strategy (n = 62) do not differ from patients who change from step to spin strategy (n = 27). No differences were found for the PIGD-score (Table 2).

The freezing of gait item from the UPDRS rating scale (number 14, UPDRS II) is significantly different between spinners and steppers only at baseline in OFF-drug condition (data not shown), which means that both spinners and steppers experience freezing of gait episodes in daily life.

4. Discussion

Gait has been studied extensively in Parkinson's disease, including the assessment of continuous (e.g., step length, gait variability, gait asymmetry) and episodic (FOG) gait disorders. To the best of our knowledge, the turning behavior was studied so far with respect to the inability to coordinate the body segments during turning, resulting in a simultaneous rotation of the head, trunk and pelvis producing an “en-bloc” turn [14], reduced speed and increased turning duration [2], reduced stride length and step width [15]. However, the turning strategy has not yet been addressed in detail. Just counting the number of steps during the step strategy with multiple steps and the absence of pivoting while turning [13,16] were mentioned in some studies. The physiologically well-described step or turn strategy [4] has so far escaped attention, although it represents an easy to observe and a meaningful sign of the motor status of people with PD. We have studied this behavior during different interventions which show that turning strategy changes within one individual depending on the motor state.

The patterns are easy and reliable to identify with the naked eye during routine walking tests in the office. The two extremes of spin and step turns are straightforward. Their relation to the motor status is obvious from this study, as for every treatment condition, the spinners had a better overall UPDRS motor score and PIGD-score than the steppers. As the spin turns come with a higher demand on adaptive changes of the body segments and are associated with a higher risk for destabilization and ultimately falls [17] it is plausible that a better

Table 2
Demographic characteristics and outcome parameters of patients that maintain the step strategy and the patients that switch from step to spin strategy from OFF- to ON- drug (baseline change) and from ON-drug to ON-drug/ON-stim (follow-up change).

	Baseline change (OFF-drug to ON-drug)			Follow-up change (ON-drug to ON-drug/ON-stim)		
	Maintain the step strategy	Change from step to spin strategy	P[a]	Maintain the step strategy	Change from step to spin strategy	P[a]
Number of patients*	99	26	–	62	27	–
Age	60.8 ± 8.6	59.6 ± 7.0	0.4	60.7 ± 9.4	60.6 ± 6.8	0.6
Disease duration	13.7 ± 5.5	12.7 ± 5.2	0.7	14.3 ± 5.2	12.6 ± 6.4	0.2
UPDRS III	20.8 ± 9.8	15.9 ± 6.6	**0.04**	17.9 ± 10.5	13.5 ± 7.5	0.07
PIGD score	3.3 ± 2.4	2.4 ± 1.8	0.08	3.2 ± 2.8	2.3 ± 1.9	0.2

The data is presented as mean ± SD for all except those noted with *, which are presented as frequencies.
[a] Mann-Whitney test was used to analyze differences of demographic parameters and clinical outcomes between the two patient groups.

motor condition is associated with more spin turns.

The mixed strategy patients were not different from either the spinners and the steppers which may indicate that this is a transitional state between the spinners and the steppers. For clinical purposes, this small group of patients with 'mixed strategy' may be classified as undetermined. Spinners compared to steppers also had better PIGD scores for all three conditions. This may explain that patients running the higher risk of spin turns can afford this higher challenge. But interestingly the general motor (UPDRS III) and PIGD scores do not significantly differ between the patients that maintain the step strategy and those who change their turning pattern from a step to a spin turn between the preoperative ON-drug baseline condition and postoperative ON-drug/ON-stim follow-up condition. Also, the absolute score of the UPDRS III or PIGD does not solely explain the difference between turning patterns as patients with step turns had a much better UPDRS III in the ON-drug/ON-stim than the patients with spin turns in the OFF-drug condition at baseline. Therefore, we expect that the choice of the turning strategy also depends on other factors than mobility. Indeed, the higher demand for motor behavior of the spinning strategy [5] may also reflect a difference regarding to the cognitive and/or the emotional status of the patients. Unfortunately, we cannot test this in our patient group as we have not consistently used a behavioral score during the routine assessments.

Another interesting finding is the freezing of gait status. Previous studies postulate that freezers do more steps on turning [8,16], we discovered that both spinners and steppers do experience freezing of gait episodes, meaning that if a patient turns with just one step (spin) can also be a freezer, which is essential for both, clinical assessment and further research, where the turning strategy should be reported.

This study had limitations as it was not prospectively planned. However, the analysis is based on blindly evaluated video-sequences, which are part of a standardized database enhancing the reliability of the results. The database did not include consistent behavioral and cognitive data for the whole group, and therefore, the relation to such parameters was not studied.

The results of this study show that the turning strategy is easy and reliable to identify and associated with the current motor state in people with PD. The turning strategy certainly cannot replace the full assessment of gait functions but may be a useful overall or additional parameter for mobility. There are several questions which should be studied. For example, if falling is related to turning strategy which could also prompt specific physiotherapeutic training and recommendations for patients. Another interesting area would be to look for the relation of behavior and in particular risk-seeking behaviors and turning strategy. This was not done in the current cohort, but we wanted to present the finding to the community also to foster more research in this simple and easy to obtain motor feature.

Documentation of author roles

OG, AA and GD: 1A, B, C; 2B, C; 3A

SP, DB: 1A, B; 2C; 3B

CS: 1A, B 2 A, C; 3B

1. Research project: A. Conception, B. Organization, C. Execution;

2. Statistical Analysis: A. Design, B. Execution, C. Review and Critique;

3. Manuscript Preparation: A. Writing of the first draft, B. Review and Critique;

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