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Impaired step-length setting prior to turning in Parkinson's disease patients with freezing of gait

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Impaired stride-length setting is implicated in the development of freezing of gait (FOG) in PD, with reduced mean step-length superimposed on a successively reduced step-length (sequence effect) leading to freezing episodes.¹ The majority of PD patients note FOG during gait initiation and/or turning.² While the first three steps on gait initiation were shorter in FOG subjects,³ successively reduced step-length prior to turning has not been directly demonstrated. Our goal was to determine if prior to a turn, step-length setting was differentially affected in PD FOG patients.

100 subjects (26 healthy controls (HC), 36 no-FOG and 38 FOG) were recruited from the Movement Disorders Clinic at UAMS, after institutional approval (supplementary table). Subjects with probable or definite FOG were included⁴, while those with >1 fall/day, MoCA score <10, and anti-dopaminergic medication use in the prior year were excluded.

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Author roles

Lakshmi Pillai, Aliyah Glover and Shannon Doerhoff were involved in research project execution and manuscript review and critique. David Williams was involved in statistical analysis review and critique as well as manuscript review and critique. Linda Larson-Prior and Edgar Garcia-Rill were involved in research project organization and manuscript review and critique. Tuhin Virmani was involved in research project conception, organization and execution, statistical design and execution, and writing of the manuscript.

Other: All authors have agreed to conditions noted on the Authorship and Contributorship Form. This work has not been accepted for prior publication. The authors take full responsibility for the data, the analyses and interpretation, and the conduct of the research. The corresponding author guarantees the accuracy of the references. The corresponding author had full access to all the data and has the right to publish any and all data.

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Subjects walked at their comfortable pace, ON-medications, eight lengths of a 20×4' pressure-sensor impregnated mat (Zeno Walkway, ProtoKinetics, Havertown, PA), either turning 180° OFF the mat (to calculate continuous gait), or ON the mat in their “normal” turning pattern (Figure 1A). Turn onset was identified by a change in foot angle or visualization on videos. Normalized mean step-length (NSL) and coefficient-of-variability (CV) were calculated to exclude baseline group differences in step-length⁵.

$$\text{Normalized mean step length "step N"} = \frac{\text{mean step length "step N"}}{\text{mean step length "continuous gait"}}$$

$$\text{CV step length "step N"} = \frac{\text{standard deviation step length "step N"}}{\text{mean step length "continuous gait"}}$$

The decline in step-to-step mean and CV in step-length was calculated using the slope of change over the three pre-turn steps. Statistical analysis was performed using SPSS version 24 (IBM).

There was a successive decrease in NSL prior to turning in all groups (Figure 1B) and a significantly greater decline in NSL, but not CV, in the FOG group (Figure 1C, E). The decrease in absolute step-length (step3-step1) was also approaching statistical significance (HC: 3.7±2.5cm [95%CI 2.6–4.7], no-FOG: 4.0±2.4cm [95%CI 3.2–4.8], FOG: 5.2±2.9cm [95%CI 4.2–6.2]; Group p=0.053 ANOVA). 12/38 FOG subjects with witnessed freezing (by T.V.) during turning, had a shorter mean continuous gait step-length (49.3±10.3 vs. 56.7±10.1 cm; p=0.046, ANOVA) and a greater decline in pre-turn NSL compared to those without witnessed freezing (−0.063±0.027 vs. −0.041±0.022; p=0.016, ANOVA). Taken together, these findings support a role for the “sequence effect” contributing to turn freezing.

The strengths of this work include the number of subjects and the evaluation of subjects’ “normal” turns. While all three groups were not perfectly matched, we normalized each subjects’ step-length prior to turning with their mean continuous step-length, to reduce group differences in disease severity. A prior study noted no difference in the average step-length of two pre-turn steps and freezing occurring predominantly at 160/180° of turns around a cone.⁶ However, freezers walking around an obstacle turn with a wider arc,⁷ and narrower turns elicit more freezing.⁴ Our subjects froze in the middle 1/3 of their turns (71%), when making the sharpest angular changes with the shortest steps, and we assessed the decline in pre-turn step-length, which could account for these differences.

Training patients to increase their step-length prior to turning could help reduce the “sequence effect”, thereby reducing the impact of turning freezing on patients’ mobility and fall risk.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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REFERENCES

1. Chee R, Murphy A, Danoudis M, Georgiou-Karistianis N, Iansek R. Gait freezing in Parkinson's disease and the stride length sequence effect interaction. *Brain* 2009;132(Pt 8):2151–2160. [PubMed: 19433440]
2. Schaafsma JD, Balash Y, Gurevich T, Bartels AL, Hausdorff JM, Giladi N. Characterization of freezing of gait subtypes and the response of each to levodopa in Parkinson's disease. *Eur J Neurol* 2003;10(4):391–398. [PubMed: 12823491]
3. Okada Y, Fukumoto T, Takatori K, Nagino K, Hiraoka K. Abnormalities of the first three steps of gait initiation in patients with Parkinson's disease with freezing of gait. *Parkinsons Dis* 2011;2011:202937. [PubMed: 21785691]
4. Snijders AH, Haaxma CA, Hagen YJ, Munneke M, Bloem BR. Freezer or non-freezer: clinical assessment of freezing of gait. *Parkinsonism Relat Disord* 2012;18(2):149–154. [PubMed: 21968033]
5. Shah J, Pillai L, Williams DK, et al. Increased foot strike variability in Parkinson's disease patients with freezing of gait. *Parkinsonism Relat Disord* 2018.

6. Spildooren J, Vercruysse S, Heremans E, et al. Head-pelvis coupling is increased during turning in patients with Parkinson's disease and freezing of gait. *Mov Disord* 2013;28(5):619–625. [PubMed: 23408374]
7. Willems AM, Nieuwboer A, Chavret F, et al. Turning in Parkinson's disease patients and controls: the effect of auditory cues. *Mov Disord* 2007;22(13):1871–1878. [PubMed: 17595036]

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Fig 1.

(A) Experimental paradigm: subjects walked 8 full lengths of a pressure sensor mat walking off at both ends (left panel) or turning on the mat at a defined point set by two traffic cones placed off the mat (right panel). (B) Normalized step-length of the three successive steps prior to turn onset. (C) Slope of decline in mean normalized step-length of successive pre-turn steps. (D) %CV in step-length of the three successive steps prior to turn onset. (E) Slope of increase in %CV of successive pre-turn steps.