# Effect of vibrotactile stimulation with cueing on falls in Parkinson's disease: case study

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## Abstract

Introduction: Parkinson's Disease (PD) is a progressive neurodegenerative disorder which presents with a myriad of motor, non-motor and psychiatric symptoms. Symptoms which are typically more difficult to treat, such as gait abnormality, postural instability and freezing of gait, increase the risk of falls in this vulnerable population, which has a negative impact on health outcomes and a considerable economic impact. Novel technologies utilising non-invasive neuromodulation may help ameliorate some of these symptoms and reduce the risk and burden of falls. This paper reports a case of a PD patient utilising a wearable device delivering vibrotactile stimulation and cueing to aid mobility and reduce risk and number of falls.

Case Presentation: The 75-year-old male, with a 15-year history of PD, presented with postural instability, frequent falls, freeze of gait and deteriorating coordination. The patient required assistance from his primary caregiver to ambulate and apomorphine injections were utilised by the patient upon severe freezing for symptom relief. Utilising a wearable device delivering vibrotactile stimulation and cueing over a 14-week period reduced falls by 83%, the FES-1 score by 15.5% and his MDS-UPDRS Part III motor score by 20 points.

Discussion: Long-term use of the novel vibrotactile stimulation device, which delivers rhythmic kinesthetic stimuli on the sternum, significantly reduced the frequency of falls in this patient with PD. This finding may be due to improvements in postural stability and freeze of gait, as reflected in MDS-UPDRS assessment scores, and patient self reporting. Further larger-scale studies are needed to confirm and validate these findings.

KEYWORDS: CUEING; FREEZING OF GAIT; PARKINSON'S DISEASE; POSTURAL INSTABILITY; VIBROTACTILE STIMULATION

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GO, XST, and FP made contributions to the acquisition, analysis and interpretation of data, and wrote the manuscript. ADP made contributions to acquisition of data. All authors read and approved the final manuscript.

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Written informed consent was obtained from the patient for publication of this case report and any accompanying images. A copy of the written consent is available for review by the Editor of this journal.

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## Background

Parkinson's disease (PD) is a progressive brain disorder that manifests in a myriad of symptoms including rigidity, bradykinesia, tremor, freezing of gait, and difficulties in coordination and balance.[1] PD patients with postural instability and walking difficulties experience many challenges that increase the risk of falls such as rigidity, poor posture, as well as irregular changes in their stride and speed.[2] A 6-month study on falls showed that 50.8% of PD patients fell at least once and 25.4% fell multiple times.[3] A report also found that patients with PD have a higher predisposition for hip fractures, constituting 4.3% of all PD patient emergency admissions.[4] 45.8% of the patients evaluated for falls have also expressed their fear of future falls, further contributing to a poorer quality of life.[4]

External auditory, visual and tactile rhythmic cognitive stimuli, also known as cueing, have been shown to exert lasting mitigating effects on most PD patients' gait symptoms. Furthermore, the beneficial effects would extend to more patients if the cueing settings can be tailored towards the individual's movement.[5] A small feasibility study on cueing for falls management showed that 73% report fewer falls and 61% report better self-management in the event of freezing.[6] Vibratory stimulation applied on insoles resulted in more regular strides, faster walking speed, bigger stride length, and better cadence[7] while somatosensory training also increases patients' awareness of their body position and movement.[8]

In this case study, we present a patient with Hoehn-Yahr (HY) stage 4 PD with a history of recurrent falls. The patient exhibited a notable decrease in fall episodes and fear of falling with the aid of a wearable device delivering vibrotactile stimulation and cueing.

### *Case Presentation*

## Background

A 75-year-old man with a 15-year history of PD, at Hoehn-Yahr stage 4, reported deteriorating coordination, postural instability, freeze of gait and a history of frequent falls. He has a past medical history of hypotension and sigmoid volvulus. He has no other neurological history to note. The patient relies on apomorphine injections upon severe freezing and to provide relief for his symptoms. He is prescribed levodopa/benserazide 100mg/25mg twice a day, 12mg of ropinirole once a day, carbidopa/levodopa 25mg/100mg five times a day. He was unable to ambulate without assistance from his wife, his primary caregiver. The patient was given a novel vibrotactile stimulation device on the 21 April 2021 to use daily over a period of 14 weeks. The patient was free to use the device whenever needed, with no limit on daily use.

## Methods

The intervention is a wearable device that delivers rhythmic kinesthetic stimuli through a specialised frequency and pattern known as the CUE1. It is attached to the sternum via medical adhesive patches and operated with the push of a button. The pattern of stimulation can be modified by the user using an accompanying application.

During the initial visit, an MDS-UPDRS assessment was performed to establish a baseline severity of his symptoms. The MDS-UPDRS assessment was repeated again with the device turned on, after 45 minutes of uninterrupted device usage. The MDS-UPDRS was performed remotely, rigidity and postural stability were therefore omitted. An International Falls Efficacy Scale (FES-I) was also conducted to establish his baseline concerns of fear of falling. The patient was asked to keep a falls count diary.

The patient and his caregiver were followed-up after the 14-week period to reassess his fear of falling and to discuss his experience with the device on in relation to his symptoms.

### *Results*

### *Frequency of falls*

Prior to device use, the patient would fall an average of 1.3 times a week, equivalent to 18 falls in 14 weeks. During the 14-week testing period of using the device, the patient had fallen 3 times.

### *FES-1*

There was a 9 point improvement in his FES-1 score, reflecting improvement in 50% of the questions detailed in FES-1. Full FES-I results in the appendix.

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### *MDS-UPDRS*

The patient exhibited a 20 point reduction in his UPDRS assessment score, from a score of 37 to 17 after using the device for approximately 45 minutes, with drastic improvement in posture, gait and freezing-of-gait.

| Assesment | Before device use | After 45 mins device use | Percentage improvement |
|---|---|---|---|
| Frequency of falls | 1.3/week | 0.2/week | 83% |
| FES-1 | 58 | 49 | 15.5% |
| MDS-UPDRS total | 33 | 15 | 54.1% |

### *MDS-UPDRS Part III motor examination individual test scores*

| Part | Test | Stimulation off | Stimulation on | Difference |
|---|---|---|---|---|
| 3.1 | Speech | 1 | 0 | -1 |
| 3.2 | Facial expression | 4 | 3 | -1 |
| 3.4a | Finger Tapping - R | 0 | 0 | 0 |
| 3.4b | Finger Tapping - L | 1 | 0 | -1 |
| 3.5a | Hand Movements - R | 2 | 1 | -1 |
| 3.5b | Hand Movements - L | 1 | 0 | -1 |
| 3.6a | Pron-Sup - R | 1 | 1 | 0 |
| 3.6b | Pron-Sup - L | 1 | 1 | 0 |
| 3.7a | Toe Tapping - R | 1 | 0 | -1 |
| 3.7b | Toe Tapping - L | 1 | 0 | -1 |
| 3.8a | Leg Ability - R | 0 | 1 | 1 |
| 3.8b | Leg Ability - L | 0 | 0 | 0 |
| 3.9 | Arising from Chair | 4 | 0 | -4 |
| 3.10 | Gait | 4 | 1 | -3 |
| 3.11 | Freezing of Gait | 4 | 1 | -3 |
| 3.13 | Posture | 3 | 1 | -2 |
| 3.14 | Global Spontaneity | 1 | 1 | 0 |
| 3.15a | Postural Tremor - R | 1 | 0 | -1 |
| 3.15b | Postural Tremor - L | 0 | 0 | 0 |
| 3.16a | Kinetic Tremor - R | 1 | 1 | 0 |
| 3.16b | Kinetic Tremor - L | 2 | 0 | -2 |
| 3.17a | Rest Tremor - RUE | 0 | 0 | 0 |
| 3.17b | Rest Tremor - LUE | 0 | 0 | 0 |
| 3.17c | Rest Tremor - RLE | 0 | 1 | 1 |
| 3.17d | Rest Tremor - LLE | 0 | 0 | 0 |
| 3.17e | Rest Tremor - Lip/jaw | 0 | 0 | 0 |
| 3.17f | Constancy of Rest tremor | 0 | 2 | 2 |

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***Interview/ qualitative feedback***

The patient reported improvement in overall confidence with device use. He would normally have the device in close proximity, and would use the device when needed. When using the device, he was able to ambulate without assistance from his caregiver. He was able to confidently rely on the device to provide symptomatic relief on his gait. The 3 falls he experienced during the 14-week period were less traumatic than his usual falls. This was attributed to him being able to fall with greater control, hence reducing the risk of injury. Both the patient and his caregiver also reported a notable decrease in the frequency of freezing.

The patient reported drastic improvement in his daily living. He was finally able to perform activities which he normally would have had to rely on his caregiver, such as washing the dishes. His caregiver felt more confident leaving him alone in the house while she was out performing errands. Having had to rely on apomorphine injections to provide symptomatic relief during the day, he was able to reduce it from twice a day to once every other day.

## Discussion and Conclusion

We have previously reported that the short-term use of a novel vibrotactile stimulation device has helped to improve freezing-of-gait in two patients through focused vibrotactile stimulation and cueing.[9] In this case study, we have highlighted the long-term benefit of using the device which has helped to reduce the frequency of falls in one patient.

The novel non-invasive, wearable device which delivers rhythmic kinesthetic stimuli of a specialised frequency on the sternum has shown to significantly reduce the frequency of falls in this patient with PD. Over the 14-week testing period of regular device use, the patient has fallen over three times, compared to an average of 18 falls over the same period before using the device. The patient showed a significant reduction in this FES-1 score, reflecting an improvement in his fear of falling over the period of testing. Having had to rely on his wife, his caregiver, to mobilise and for his day-to-day activities, he has now regained his independence. This had a positive impact on his wife's mental health, given the huge burden towards caregivers of PD patients experiencing frequent falls.[10] The improvement is also reflected by a drastic 20-point improvement in the MDS-UPDRS assessment score.

In addition to age-related risk factors associated with falls, there are a multitude of PD-specific risk factors which contribute to recurrent falls in patients with PD.[11] We hypothesise that the drastic reduction in the frequency of falls in this patient is attributed to an enhancement in proprioceptive feedback, leading to improvement in postural stability, freezing-of-gait (FOG) and gait.

Postural instability (PI) is one of the cardinal features of PD, typically presenting at the later stages of disease.[12] Characterised by a disruption of the body's ability to maintain equilibrium during movement and at rest, PI often leads to recurrent falls, loss of independence and decreased quality of life. [13],[14],[15] The pathophysiology behind PI is complex and not well-understood. Since PI is refractory to dopaminergic drugs, it is believed that a non-dopaminergic pathway is involved.[16] Anticipatory postural adjustments and reactive postural control are involved in achieving balance during dynamic movements, requiring the integration and processing of both sensory and motor systems.[17] Both control mechanisms have been affected in PD, and is believed to be caused by an impairment in proprioceptive-motor integration.[18],[19], [20] Similarly to PI, FOG tends to manifest at advanced stages of the disease and is resistant to dopaminergic drugs.[21] Focused vibrotactile stimulation, introduced in this case study, delivers proprioceptive input to the brain via type IA afferent nerve fibres.[22] This proprioceptive feedback provides enhanced information on limb position and movement which may restore the control mechanisms affected in PI and FOG.[22],[23]

Gait disturbances in patients with PD classically present with a shuffling gait due to an increase in step to step variability of the gait cycle, often contributing to falls.[24] The pulsatile stimulation of the vibrotactile stimulation device produces a tactile cueing effect, a phenomenon often utilised for gait and posture rehabilitation in patients with PD.[25] It is believed that cueing bypasses the internal rhythm deficit of the basal ganglia using alternative circuitry.[26]

This case study demonstrates that long term use of a wearable device combining focused vibrotactile stimulation and cueing can help reduce falls in patients with PD through improvements in postural stability, FOG and gait in the home setting. A larger scale study would be required to validate this.

## Abbreviations

PD: Parkinson's disease; DBS: deep brain stimulation; TUG: Timed Up and Go

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# Appendix

***FES-I individual test scores***

FES-I is a questionnaire to evaluate the fear of falling in patients. Increasing levels of concern are assigned points from 1 to 4 which are totaled at the end of the questionnaire. Not at all concerned (1), Somewhat concerned (2), Fairly concerned (3), Very concerned (4). Low concern, moderate concern and high concern are totals ranging from 16-19, 20-27, 28-64, respectively.

| Part | Test | Stimulation off | Stimulation on | Difference |
|---|---|---|---|---|
| 1 | Cleaning the house (e.g. sweep, vacuum or dust) | 4 | 3 | -1 |
| 2 | Getting dressed or undressed | 3 | 2 | -1 |
| 3 | Preparing simple meals | 4 | 4 | 0 |
| 4 | Taking a bath or shower | 3 | 2 | -1 |
| 5 | Going to the shop | 4 | 4 | 0 |
| 6 | Getting in or out of a chair | 3 | 2 | -1 |
| 7 | Going up or down stairs | 3 | 2 | -1 |
| 8 | Walking around in the neighbourhood | 4 | 4 | 0 |
| 9 | Reaching for something above your head or on the ground | 3 | 2 | -1 |
| 10 | Going to answer the telephone before it stops ringing | 4 | 3 | -1 |
| 11 | Walking on a slippery surface (e.g. wet or icy) | 4 | 4 | 0 |
| 12 | Visiting a friend or relative | 4 | 3 | -1 |
| 13 | Walking in a place with crowds | 4 | 4 | 0 |
| 14 | Walking on an uneven surface (e.g. rocky ground, poorly maintained pavement) | 4 | 4 | 0 |
| 15 | Walking up or down a slope | 4 | 4 | 0 |
| 16 | Going out to a social event (e.g. religious service, family gathering or club meeting) | 3 | 2 | -1 |
| Total | FES-I Score | 58 | 49 | -9 |

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***Figures***

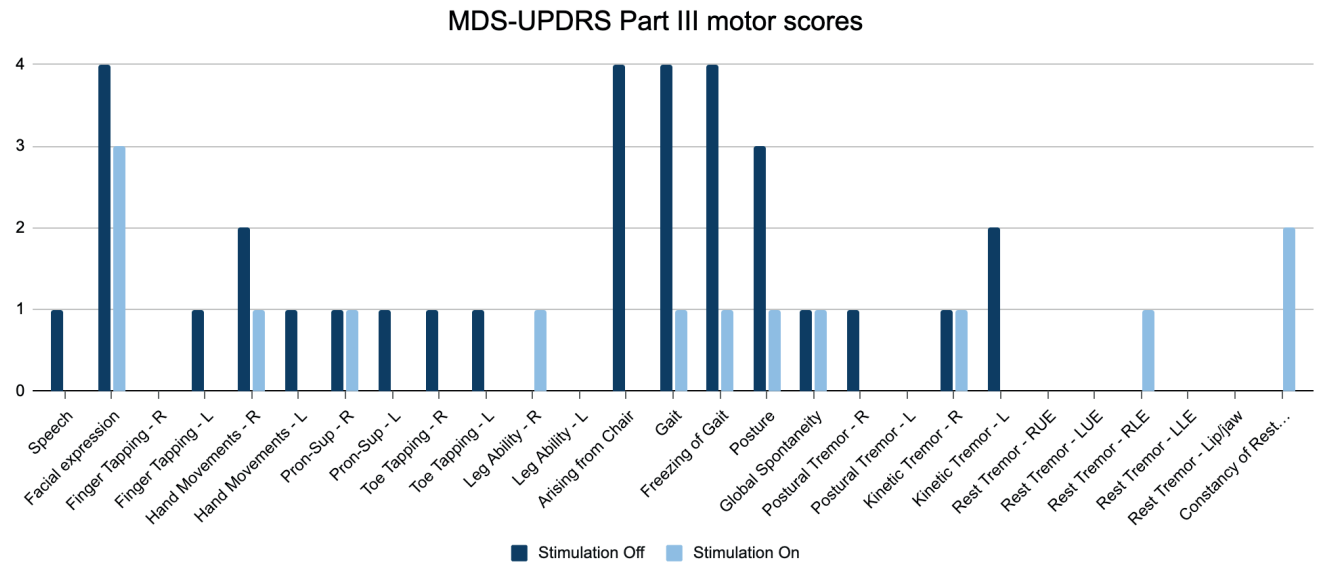


**Fig 1. MDS-UPDRS scores of each component of the remote part III motor examination before using the device and after using the device for 45 minutes.**

***Qualitative Questionnaire- Falls***

| | |
|---|---|
| **General Impressions** | **1.** Do you feel your confidence is greater, lesser or unchanged when walking with the device?<br>**2.** How do you feel when not having the device on?<br>**3.** Have you experienced a traumatic fall/sustained lasting injuries from a fall?<br>**4.** Do you remember what had caused it/what situation you were in? |
| **Stride, Balance & Posture** | **1.** Has your stride been affected/remained unchanged while using the device?<br>**a.** If affected, how was it before and how has it changed?<br>**2.** Has your balance and posture been affected/remained unchanged while using the device?<br>**a.** If affected, how was it before and how has it changed?<br>**3.** Did you use walking aids before/while using the device?<br>**a.** Has the use of walking aids changed throughout the use of the device? |
| **Gait** | **1.** Do you experience freeze of gait?<br>**2.** Has your freeze of gait been affected/remained unchanged while using CUE1?<br>**a.** If affected, how was it before and how has it changed?<br>**b.** Have the length of the episodes changed/remain unchanged with the device?<br>**c.** To what extent do you think freezing episodes influence your falls?<br>**3.** Do you experience festinating gait?<br>**4.** Has your festinating gait been affected/remained unchanged while using CUE1?<br>**a.** If affected, how was it before and how has it changed?<br>**5.** In what situations do you experience festinating gait?<br>**6.** To what extent do you think festinating gait influences your falls? |
| **Falls** | **1.** Has the severity of falls changed/remained unchanged while using CUE1?<br>**2.** Were there any symptoms that you experienced that might have caused your falls?<br>**3.** Were there any symptoms that the device has helped to decrease your falls? |

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## References


1. Jankovic, J. Parkinson's disease: clinical features and diagnosis. J. Neurol. Neurosurg. Psychiatry 79, 368–376 (2008).

2. Pelicioni, P. H. S., Menant, J. C., Latt, M. D. & Lord, S. R. Falls in Parkinson's Disease Subtypes: Risk Factors, Locations and Circumstances. Int. J. Environ. Res. Public. Health 16, 2216 (2019).

3. Bloem, B. R., Grimbergen, Y. A., Cramer, M., Willemsen, M. & Zwinderman, A. H. Prospective assessment of falls in Parkinson's disease. J. Neurol. 248, 950–958 (2001).

4. Lisk, R., Watters, H. & Yeong, K. Hip fracture outcomes in patients with Parkinson's disease. Clin. Med. 17, s20 (2017).

5. Nieuwboer, A. Cueing effects in Parkinson's disease: Benefits and drawbacks. Ann. Phys. Rehabil. Med. 58, e70–e71 (2015).

6. Martin, T., Weatherall, M., Anderson, T. J. & MacAskill, M. R. A Randomized Controlled Feasibility Trial of a Specific Cueing Program for Falls Management in Persons With Parkinson Disease and Freezing of Gait. J. Neurol. Phys. Ther. 39, 179–184 (2015).

7. Novak, P. & Novak, V. Effect of step-synchronized vibration stimulation of soles on gait in Parkinson's disease: a pilot study. J. NeuroEngineering Rehabil. 3, 9 (2006).

8. Elangovan, N., Tuite, P. J. & Konczak, J. Somatosensory Training Improves Proprioception and Untrained Motor Function in Parkinson's Disease. Front. Neurol. 9, 1053 (2018).

9. Tan, X. S., Pierres, F., Dallman-Porter, A., Hardie-Brown, W. & Kwon, K.-Y. Focused vibrotactile stimulation and cueing effects on freezing of gait in Parkinson's disease: Two case reports. J. Mov. Disord. In press.

10. Davey, C., Wiles, R., Ashburn, A. & Murphy, C. Falling in Parkinson's disease: the impact on informal caregivers. Disabil. Rehabil. 26, 1360–1366 (2004).

11. Marck, M. A. van der et al. Consensus-based clinical practice recommendations for the examination and management of falls in patients with Parkinson's disease. Parkinsonism Relat. Disord. 20, 360–369 (2014).

12. Palakurthi, B. & Burugupally, S. P. Postural Instability in Parkinson's Disease: A Review. Brain Sci. 9, 239 (2019).

13. Jankovic, J. Parkinson's disease: clinical features and diagnosis. J. Neurol. Neurosurg. Psychiatry 79, 368–376 (2008).

14. Crouse, J. J., Phillips, J. R., Jahanshahi, M. & Moustafa, A. A. Postural instability and falls in Parkinson's disease. Rev. Neurosci. 27, 549–555 (2016).

15. Kerr, G. K. et al. Predictors of future falls in Parkinson disease. Neurology 75, 116–124 (2010).

16. Grimbergen, Y. A. M., Langston, J. W., Roos, R. A. C. & Bloem, B. R. Postural instability in Parkinson's disease: the adrenergic hypothesis and the locus coeruleus. Expert Rev. Neurother. 9, 279–290 (2009).

17. Papa, E. V., Garg, H. & Dibble, L. E. Acute Effects of Muscle Fatigue on Anticipatory and Reactive Postural Control in Older Individuals: A Systematic Review of the Evidence. J. Geriatr. Phys. Ther. 38, 40–48 (2015).

18. Kim, S. D., Allen, N. E., Canning, C. G. & Fung, V. S. C. Postural Instability in Patients with Parkinson's Disease. CNS Drugs 27, 97–112 (2013).

19. Gandolfi, M. et al. Postural Control in Individuals with Parkinson's Disease. Different Areas of Physiotherapy (IntechOpen, 2018). doi:10.5772/intechopen.81098.

20. Konczak, J. et al. Proprioception and motor control in Parkinson's disease. J. Mot. Behav. 41, 543–552 (2009).

21. Nutt, J. G. et al. Freezing of gait: moving forward on a mysterious clinical phenomenon. Lancet Neurol. 10, 734–744 (2011).

22. Kröger, S. & Watkins, B. Muscle spindle function in healthy and diseased muscle. Skeletal Muscle 11, 1-13 (2021)


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23. Steyvers, M. et al. Corticospinal excitability changes following prolonged muscle tendon vibration. Neuroreport. 14, 1901–1905 (2003)

24. Mirelman, A. et al. Gait impairments in Parkinson's disease. Lancet Neurol. 18, 697–708 (2019).

25. Muthukrishnan, N., Abbas, J. J., Shill, H. A. & Krishnamurthi, N. Cueing Paradigms to Improve Gait and Posture in Parkinson's Disease: A Narrative Review. Sensors 19, 5468 (2019).

26. Engel, A. K. & Fries, P. Beta-band oscillations—signalling the status quo? Curr. Opin. Neurobiol. 20, 156–165 (2010).

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