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The efficacy of functional electrical stimulation may reduce bradykinesia in Parkinson's Disease (PD) - A meta-analysis

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Abstract

Objectives

Functional Electrical Stimulation (FES) is an effective, non-invasive therapeutic tool for managing Parkinson's disease symptoms, particularly for improving gait, reducing Freezing of Gait (FOG), and enhancing tremor control. FES induces movement in muscles, providing improvements in speed and stride length. It also demonstrates a "training effect," where benefits are sustained even after the device is removed.

Parkinson's disease is a degenerative disease of Central Nervous System that was first described in 1817 by James Parkinson [1], and is now recognized as the second most common neurodegenerative disease, second only to Alzheimer's disease. PD is rare before the age of 50 but the prevalence increases with age, affecting approximately 1% of the population over 60 years [2]. According to the Global Declaration for Parkinson's disease [3], 6.3 million people are affected by Parkinson's worldwide, with no differences between all races and cultures, with slightly more men than women affected. Possibly the disease prevalence will increase in the future, because of the general population ageing.

This present study, we investigated the effect of combined upper and lower limb Functional Electrical Stimulation (FES) to reduce bradykinesia in Parkinson's disease.

Methods

Eight people with Parkinson's disease and Using Hoehn and Yahir scores 2-3 used Functional electrical stimulation to assis dorsiflexion and hand opening movement for 3 weeks. Outcome measure were in nine-Hole Peg Test (9 HPT), Box and Block Test (BBT), 10 m walking test, Tinetti balance scale, modified Parkinson's disease quality of life questionnaire, SPES /SCOPA scale and compliance. All tests were carried out without functional electrical stimulation. Comparisons were tested using the student paired t-test.

All participants receive eight sessions along with their assigned electrical stimulation treatment and conservative treatment.

Participants: Eligibility and recruitment.

Inclusion criteria: Parkinson's disease ≥ 65 years of age.

Exclusion criteria: Other neurological diseases, surgery in the pelvic region in the last year.

Results: Two participants dropped due to difficulty in applying the equipment. Mean walking speed increased by 0.29 ms^{-1} (p=0.002), step-length by 0.09 m (p=0.007) and cadence by 19.8 steps min^{-1} (p = 0.045). Tinetti balance score increased by 2.9 ((p=0.006). Furthermore, there was an increase in the box and block test of 5.1 (p=0.025). The PD symptoms score of the Parkinson's disease quality of life questionnaire improved by 4.9 (p=0.013), and a reduction in SPEC/SCOPA score of 5.7 (p=0.005), indicated a reduced impact of Parkinson's disease.

Conclusion: Functional electrical stimulation helps tackle the gait challenges, such as small steps and freezing, that limit the independence of individuals with Parkinson's disease.

Introduction

Parkinson's disease is one of the fastest growing neurodegenerative movement disorders, is chronic progressive of the central nervous system. It is the most common disorder of the Basal Ganglia (BG) and the second most common neurodegenerative disorders after Alzheimer's disease. The condition was first described as "shaking palsy" by Dr. James Parkinson in 1817. Parkinson's disease mostly presents in later life (older than 60 years old), in a small proportion, the disease starts between the age group 20 and 40 years old (juvenile Parkinsonism. In India, the average age group of onsets is around 50 years, which is a decade younger than in other parts of the world [4]. It is estimated that PD affects 1% of the population over the age of 60 years [5,6]. PD comprises a variety of motor symptoms and a wide range of Non-Motor Symptoms (NMS), including several autonomic dysfunctions.

Materials and methods

Etiology and epidemiology: The prevalence of Parkinson's disease has doubled in the past 25 years. Global estimates in 2019 showed more than 8.5 million individuals with PD (WHO 2020). The median onset of the disease is 60 years. Males are two or three times more commonly affected than females. The etiology of PD is unknown, called idiopathic. There is no known single, universal causative factor that has yet been identified. However, a considerable amount of research suggests that PD results from a variety of pathological processes in addition to influencing factors, such as environment, aging process, and genetic factors (commonly associated genes- LRRK2, PINK1, PARK1).

Parkinson's disease predominantly a disorder of Basal Ganglia (BG). The BG is a group of nuclei (caudate, putamen, and globus pallidus) embedded deep in the cerebral hemisphere, whereas related nuclei are subthalamic nucleus, substantia nigra pedunculopontine nucleus (Figure 1).

Pathophysiology: The main area of the dysfunction is the loss dopaminergic neurons in the substantia nigra of BG in (Figure 2).

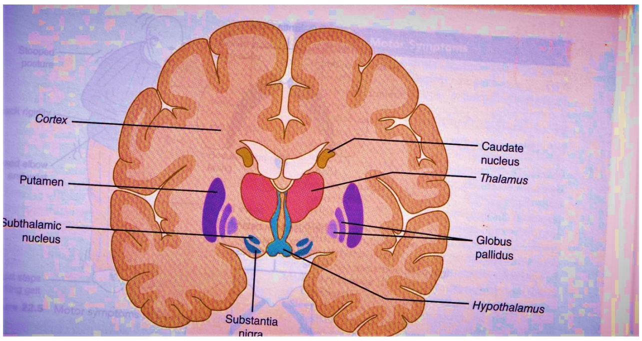

Figure 1: Nuclei of basal ganglia and related structures.

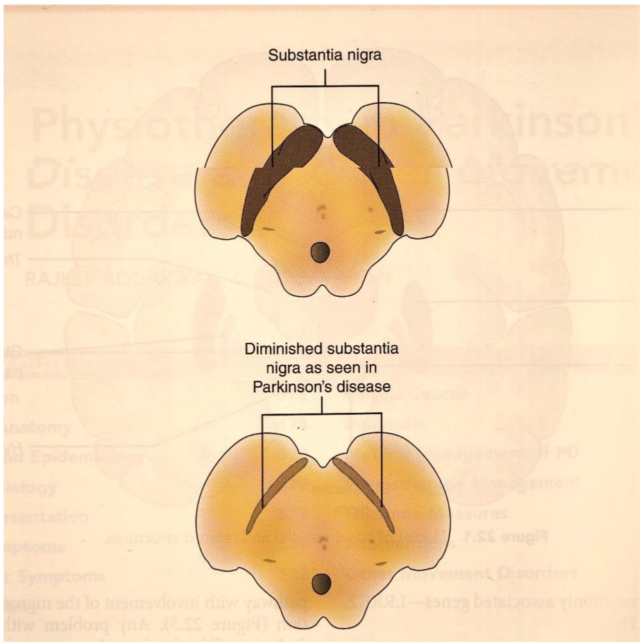

Figure 2: Pathological changes in Parkinson's Disease (PD).

Clinical presentation: The motor symptoms of (Figure 3), in Parkinson's disease usually start from one side and gradually progress to the other side within a few years. Bradykinesia and rigidity followed by tremor are often the first symptoms of the Parkinson's disease, and postural instability is usually seen later in the disease and these are the cardinal symptoms of PD. People with Parkinson's disease (PWD) may present with secondary motor symptoms along with cardinal motor symptoms (Table 1).

On the other hand, non-motor symptoms in (Table 2). Such as constipation, rapid eye movement, depression, autonomic dysfunction and cognitive dysfunction often predate the motors symptoms and hence this phase in which clinical signs are not present but the neurodegeneration has started is known as prodromal Parkinson's disease.

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Table 1: Motor symptoms in Parkinson's Disease (PD).

Primary motor symptoms or cardinal signs	Secondary motor symptoms	Tone
Tremor (resting tremor) Rigidity (cogwheel or lead pipe) Bradykinesia (slowness of movement) Postural instability (loss of postural reflexes)	Gait: Freezing of gait Shuffling gait Festination Reduced arm swing Speech and swallowing difficulty Dysarthria (motor speech disorder) Dysphagia (difficulty swallowing) Sialorrhea (excessive secretion of saliva)	Dystonia (involuntary muscle contraction) Hypokinesia (decreased bodily movement) Micrographic (small handwriting) Hypomimia (reduced facial expression /masked face)

Table 2: Non-motor symptoms.

Cognitive disorders	Mood disorders	Psychotic disorders	Autonomic dysfunction	Sleep disorders	Sensory disorders
Dementia Impaired judgment Confusion	Depression Anxiety Apathy Abulia	Hallucination Delusion	Orthostatic hypotension Sexual dysfunction Seborrhea (excessive sweating) Urinary bladder disorder Constipation	Restless –leg syndrome Rapid eye movement (REM) Insomnia Excessive daytime somnolence	Pain Parenthesis Fatigue

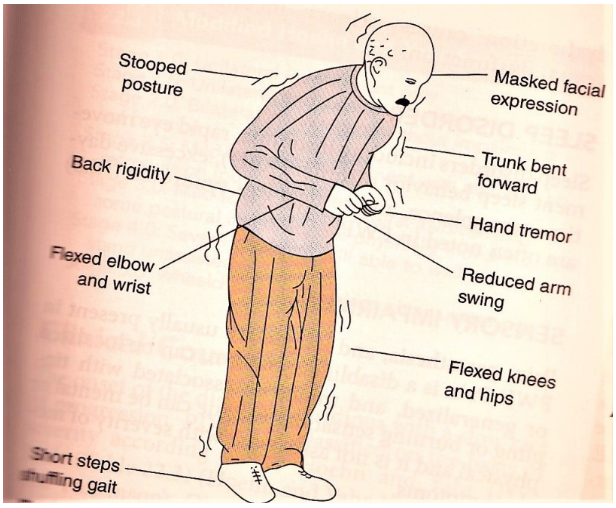

Figure 3: Motor symptoms of Parkinson's Disease (PD).

Tremor and posture: Resting tremor is most commonly seen in the hand, and it can be assessed by observing or simply by the history given by the patient. Postural tremor can be seen in a position against gravity. To test postural tremor of the upper extremity, the patient should be asked to fully extend the elbow with 90-degree arm flexion and hold the arm in that position. Hence, rapid alternating movement is used to assess kinetic tremor that can be seen in goal directed movements such as writing and drinking coffee.

A stooped or bent posture is a notable manifestation commonly observed in PWP, which the posture tends to become increasingly flexed over time. Further, alterations in posture might encompass rounded shoulders, diminished curvature of the lower back and a forward inclination of the head or entire body. In PWP, muscle strength in the lower limb, particularly in the knee and hip extensors, has been reported to be reduced as compared with that in the healthy individual. Trunk muscle stiffness limits the trunk rotation and muscular extensor activity. However, trunk stiffness affects counter –rotation ability of the thorax on the pelvic until they rotate in the same direction. Clinical examination of static posture is made by inspection; the onset of flexion is often insidious, leaving people unaware that it is occurring. Some varied postural changes are shown in (Figure 4).

Patient taking Synodical CR 125 mg tablet containing Levodopa (100 mg) and Carbidopa (25 mg) primarily used to treat symptoms of Parkinson's disease, including tremors, muscle stiffness and slow movement. It replenishes dopamine in the brain to improve motor control, daily functioning, and quality of life. 'CR' (controlled release) formulation, it provides a slow release of medicine to offer consistent control over symptoms.

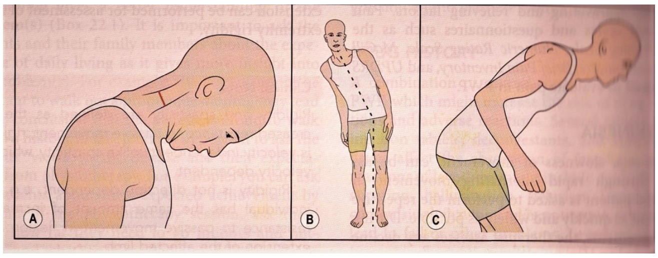

Figure 4: Varied postural changes common in people with Parkinson's disease. **(A)** Antecollis **(B)** Pisa syndrome, and **(C)** Camptocormia, Antecollis- forward flexion of the head and neck [7].

Pisa syndrome- reversible lateral bending of the trunk [8], Camptocormia- abnormal flexion of trunk and that appears when standing and disappears in the supine position [9].

Parkinsonian gait is characterized by bradykinesia, hypokinesia, and akinesia. This can severely restrict mobility and increase the risk of falls. Mann et al., hypothesized that FES, when used to produce dorsiflexion may be a useful intervention to assist the initiation of stepping [10], overcoming freezing in gait. In a feasibility study, six people in Parkinson's disease who exhibited freezing in gait used an FES device for a period of two months. The participants chosen for the study did not have dropped foot, therefore allowing the effect on freezing to be studied independently. The study showed that FES use was associated with reduced episodes of freezing, increased gait speed, increase stride length and reduced incidence of trips and falls. Further, it was found that there was a training effect, demonstrated by improved gait parameters, 6 weeks after FES was withdrawn.

However, Popa et al., has demonstrated to exploit the effect of bradykinesia and hypokinesia seen in the Lower Limb (LL) to improve dexterity and speed of movement in the upper limb [11,12]. Electrical stimulation was used to train the finger, thumb and wrist extensors for 30 minutes per day for 15 days on the most affected upper limb. Improvements were seen in the nine-hole peg test (9-HPT) in (Figure 5), and in the Finger Tapping Test (FTT) in (Figure 6). Demonstrating that dexterity was bilaterally improved, hence this may be due to an interhemispheric transfer as cross education [11-13]. Initial experience with Upper limb stimulation has used stimulation to open the hand. Furthermore, this was done because hand opening is required at the initiation of movement sequence when acquiring an object. However, we have observed that people with Parkinson's disease often have difficulty in producing in fine movements of the hand involved in a palmar grasp where the tips of the index and middle fingers are brought together with the thumb. This movement can be produced by stimulation of the median nerve at the wrist and of the ulnar nerve supplying the lumbricals on the dorsal face of the hand.

The evidence to date indicates that people with Parkinson's disease may benefit from both upper and lower limb stimulation but to our knowledge, there are no reports of both interventions being used in combination.

Figure 5: 9 hole finger tapping test for Parkinson's disease patient offers a significant diagnostic and monitoring benefits by objectively assessing bradykinesia, amplitude (size) and rhythm as part of (UPDRS).

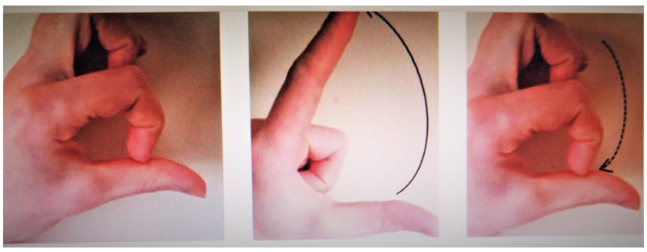

Figure 6: Finger Tapping Test (FTT) sequence with and without dexterity device for Parkinson's disease patient. The Parkinson's disease patient being assessed begins with the tip of their index finger at the distal crease of their thumb **(A)**, they then raise the index finger as high as possible **(B)** and then return to the start position **(C)**. Thus, this is repeated a number of times and as quickly as possible.

Figure 7: A-75-years old (M) with Parkinson's disease has been taking physiotherapy treatment with BP checking and pain in left arm biceps tendonitis to relieve pain, ultra sound therapy treatment is used mild to moderate pattern intensity.

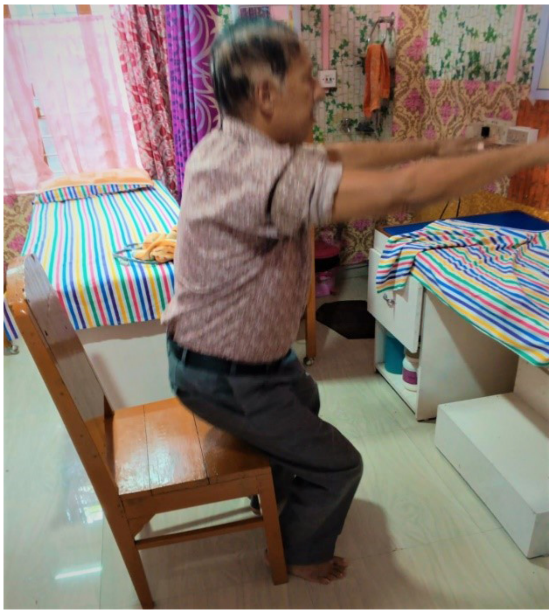

Figure 8: A 75 years old (M) patient with Parkinson's disease - Stand up from a seated position is essential to maintaining quality of life. Stand strong. Sit with control. These movements matter more than you think.

10-meter walking speed of each participant. In contrast to the upper limb, lower limb electrical stimulation was applied synchronized to the gait cycle and therefore in direct association with the function it was intended to improve. Lower limb stimulation had a direct orthotic effect assisting gait by increasing dorsiflexion and stabilizing the ankle in early stance. The mean stimulation time was also greater than received in the upper limb. A possible confounding effect in understanding the mechanism behind the reported gait changes may be the increased amount of walking that was reported by some participants in the study period, compared to their normal levels of activity. The protocol required that the time spent walking was increased through the intervention period. However, it is possible that functional electrical stimulation uses also enabled greater activity. Furthermore, several studies have investigated the use of physiotherapy interventions aimed at increasing activity and walking speed changes have been reported [14-18]. A weighted mean gain in walking speed in these studies was calculated to be 0.11 ms^{-1}, less than half the gain reported in this study, suggesting that functional electrical stimulation may have an additional effect.

Discussion/Conclusion

In this study modest improvement in upper limb function were recorded. In the earlier study [11], electrical stimulation was used for longer each day, 30 minutes, while in this study compliance with upper limb stimulation was less than expected, averaging 21 minutes a day. It is possible that combination of upper limb, functional electrical stimulation with walking may be affected upper limb treatment compliance.

Appendix I

Hoehn and Yahr stages

Stage 1.0 - Unilateral involvement only.

Stage 1.5 - Unilateral and axial involvement.

Stage 2.0- Bilateral involvement without impairment of balance.

Stage 2.5 - Mild bilateral involvement with recovery on retropulsion (pull) test.

Stage 3.0- Mild to moderate bilateral involvement, some postural instability but physically independent.

Stage 4.0- Severe disability, still able to walk and to stand unassisted.

Stage 5.0- Wheelchair bound or bedridden unless aided.

Declarations

Funding: All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Compliance with ethics requirements: The authors declare no conflict of interest regarding this article. Informed consent was obtained from all the concerned patients included in the study.

Informed consent statement: Not applicable.

Conflicts of interest: The author declares that there is no conflict of interest regarding the publication of this manuscript.

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