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Effects of Focal Muscle Vibration on Gait and Balance in Parkinson Patients: Preliminary Results

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Abstract: Background: Postural instability has a major impact on the mobility and daily life activities of Parkinson's disease (PD) patients as it often leads to reduced mobility, insecure stance and falls. The aim of this study was to evaluate the effect of focal vibration on the static and dynamic balance of a group of Parkinson's disease patients. Methods: Twenty-three idiopathic PD patients (14 M; 9 F), Hoehn and Yahr (HeY) stage II–III, underwent three weeks of focal muscle vibration applied to the quadriceps, soles of the feet and trapezius muscles bilaterally in addition to conventional physiotherapy. The static and dynamic balance was assessed at baseline (T0), after 3 weeks of treatment (T1) and after 1 month from the last treatment (T2) with the Tinetti scale and stabilometry evaluations. Results: There was a statistically significant improvement in the mean Tinetti score at T1, and in the Romberg area (CE/OE) of oscillation and oscillation velocity on the x-axis with the eyes closed at T2. Conclusions: Focal muscle vibration in conjunction with physiotherapy is a useful tool in the rehabilitation of gait and balance disorders of patients with Parkinson's disease HeY stage II–III.

Keywords: Parkinson's disease; focal muscle vibration; postural instability; gait and balance disorders

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1. Introduction

Parkinson's disease (PD) is a chronic, highly disabling neurodegenerative disorder characterized by bradykinesia, resting tremor, rigidity and postural instability [1]. Postural instability has been shown to have a major impact on the autonomy, mobility and quality of life of these patients as it often leads to insecure stance and falls [2].

Balance control is a complex system involving the integration of vestibular, visual and proprioceptive sensory information. Somatosensory information is derived from a variety of sources, most notably the cutaneous mechanoreceptors in the skin and the muscle spindles [3]. It is well known that a decline in skin sensitivity and proprioceptive input naturally occurs with aging. Moreover, kinesthetic sensory deficits may occur due to systemic and neurologic disorders (e.g., diabetes, stroke etc.) [3].

Previous studies have demonstrated that the integration of sensory information is abnormal in PD patients with strong repercussions on motor function, posture, static and dynamic balance and greater reliance on visual input for postural control [4–8].

The effectiveness of current treatments on postural instability and kinesthetic deficits in PD is controversial. Bartolic et al. [2] observed improvement in postural control after treating rigidity with apomorphine. Wright and colleagues [6] suggest that axial kinesthetic sensitivity worsens with levodopa. Furthermore, important side effects and loss of therapeutic efficacy after years of use of dopaminergic agonists represent a major clinical challenge [9].

Muscle vibration is a safe, non-invasive rehabilitation technique that holds promise for improving mobility and balance in moderate to severe PD patients. It consists of local vibrations applied on selected muscles or tendons by means of a mechanical device. Stimulation of Ia afferent fibers from muscle spindles and cutaneous receptors strongly increases the exteroceptive and proprioceptive input to the central nervous system (CNS). This has been shown to induce a plastic modulation of the primary sensory motor cortex and spinal reflexes, with long lasting positive effects on muscle tone and motor control [10–12].

Despite good results obtained in several other neurological conditions, such as post-stroke spatial heminattention, spastic hypertonia and motor control impairment [11], only a few studies exist on the use of focal vibratory energy for posture and gait disorders in Parkinson's disease. Most of the existing experiments in the literature are about whole-body vibration (WBV) which has shown limited efficacy on stability and movement control [13]. In contrast, focal vibration applied over the cervical and soleus muscles [14], and on quadriceps and paraspinal muscles [15], in conjunction with conventional physiotherapy, has shown positive effects on the patient's balance, risk of falling and quality of gait.

Despite a consistent body of literature on the use of muscle vibration in rehabilitation, there is currently insufficient evidence regarding its application in patients with Parkinson's disease, including muscle targets, duration and frequency of the treatment and technical parameters. Based on these premises, we aimed to evaluate the effects of focal vibration on static and dynamic balance of patients with Parkinson's disease.

2. Materials and Methods

This is a prospective, observational, pilot study. Twenty-three chronic patients with idiopathic Parkinson's disease (14 males and 9 females; mean age 67.00 ± 9.01 years) were recruited from the Physical and Rehabilitation ward of the Agostino Gemelli Foundation University Hospital of Rome.

The inclusion criteria were a diagnosis of Parkinson's disease according to the criteria of the Brain Bank of London; Hoehn and Yahr stage II-III; absence of cognitive impairment (MMSE > 24/30); effective pharmacological control of the pathology; being part of the PD group-rehabilitation program of our ward for at least one year; acceptance and signature of informed consent.

Exclusion criteria comprised: a diagnosis of atypical Parkinsonism; poor pharmacological compensation of the disease; diagnosis of other neurological diseases; diagnosis of neuromuscular diseases; diagnosis of osteo-articular pathologies; cognitive impairment (MMSE < 24); visual impairment; vestibular disorders; not being part of our PD group-rehabilitation for at least one year; denial of informed consent. The clinical and demographic characteristics of the patients are summarized in Table 1.

Table 1. Clinical and demographic characteristics of the patients.

Variables	PD (N = 23) (Mean ± Standard Deviation)
Sex (male; female)	14 M; 9 F
Age (years)	67.00 ± 9.01 (min 52; max 84)
BMI (kg/m^2)	25.14 ± 2.91 (min 20.6; max 35.9)
Length of Disease (years)	4.84 ± 26,4 (min 1.33; max 9.33)
UPDRS score	22 ± 9.62 (min 9; max 42)
MMS score	27.77 ± 3.41 (min 15; max 30)
LEDD (mg/day)	608.85 (min 400; max 850)

Abbreviations: BMI—body mass index; UPDRS—Unified Parkinson's Disease Rating Scale; MMS—mini mental status; LEDD—levodopa equivalent daily dose.

2.1. Intervention

Each patient underwent focal muscle vibration in association with conventional physiotherapy three times a week, for three weeks, for a total of nine sessions. The vibration was applied via a pneumatic vibration device (EVM, Endomedica, Rome, Italy) at a frequency of 100 Hz and an amplitude of 0.2 mm. Each session consisted of three stimulation trains of 10 min each, interspersed with 1 min of rest. The stimulus was applied at the level of the upper and lower trapezius, quadriceps femoris and sole of the foot bilaterally with the patient in sitting position [14,15]. The choice of this last target was based on our clinical judgment and recent literature evidence. The feet provide a direct interface between the body and the environment and represent an important sensory structure in the mechanism of postural control [3]. Plantar skin mechanoreceptors transmit crucial information about pressure variations on the sole of the feet which determine reflex postural reactions through activation of antigravitary muscles [3]. A recent literature review by Viseux et al. emphasizes how interventions aimed at stimulating the muscle spindles of the intrinsic muscles of the foot can improve standing balance, both in elderly individuals and patients with disrupted peripheral signal processing [3].

2.2. Group Rehabilitation

Group rehabilitation was carried out after each focal muscle vibration session. Each group consisted of 5 individuals coordinated by an experienced physiotherapist (DR). The physiotherapy program included several exercises according to the literature [16]:

- Exercises for the head and trunk control;
- Strengthening and stabilization of lower limbs and antigravity muscles;
- Stretching of the posterior kinetic chain muscles;
- Exercises aimed at recovering and maintaining a correct posture;
- Coordination and balance exercises;
- Gait training with and without obstacles.

2.3. Stabilometric Evaluation

Static balance was assessed through a standardized stabilometry exam performed on a "Prokin PK 254 P" device produced by TecnoBody S.r.l. (Dalmine (BG), Italy). The device consists of a static platform (47 cm of circumference) with four piezoelectric sensors positioned at the extremity of the four cardinal points. The temporal resolution was 0.01 s, and the sampling frequency was set at 20 Hz. The patients were asked to stand on the platform for 60 s in a neutral position with the feet forming a 30-degree angle. The test was performed 30″ with the eyes open and 30″ with the eyes closed. All data were analyzed by the ProKin 36 software in order to calculate the center of pressure (CoP) sway on the X (anterior-posterior) and Y (medio-lateral) axes (mm), the center of pressure (CoP) velocity on the X (anterior-posterior) (AP-vel) and Y (medio-lateral) (ML-Vel) axes (mm/s), the sway path (Perimeter, total length of CoP trajectory (mm) and the area of the ellipse (mm^2). Lower values reflect greater control in maintaining the static balance. We considered as a primary outcome the reduction of the length of adaptive movements in terms of perimeter and sway area as they represent parameters of global stability of the CoP.

2.4. Outcome Measure

The patients were evaluated at (T0), after 3 weeks of treatment (T1) and after one month from the last treatment session (T2). A Tinetti scale was used to assess the gait and dynamic balance while consecutive stabilometric examinations were performed to assess the static balance. All patients were tested during the "on phase", 45–90 min after the morning dose of levodopa.

The Tinetti scale, also known as performance-oriented mobility assessment (POMA), is a standardized screening modality for gait and balance disorders. It is applied to screen different patient populations including elderly patients and patients with Parkinson's disease. The test assesses a patient's balance and gait using a standardized scoring system comprising 16 items with a maximal score of 28. A score $\leq$ 18, a score between 19–24 and a score $\geq$ 25 reflect an overall high, medium and low risk of falls, respectively [17].

The study was carried out in accordance with the Declaration of Helsinki and the protocol was approved by the Ethics Committee of Policlinico Gemelli Foundation (prot. N

0016285/22, 11.05.2022, ID 4935). All patients provided written informed consent prior to inclusion in the study.

2.5. Statistical Analysis

Descriptive analysis was performed using standard procedures for the calculation of frequencies, measure of average position (arithmetic mean) and dispersion indicators. The differences between pretreatment and post-treatment measures at each timing were analyzed with Student's *t*-test for paired samples. A *p*-value < 0.05 for two side test was considered statistically significant. Data analysis was conducted with the software SPSS 1.4.

3. Results

Twenty-three chronic patients with idiopathic Parkinson's disease (14 males and 9 females; mean age 67.00 ± 9.01 years) affected by PD were enrolled in the study. The group showed an average Unified Parkinson's Disease Rating Scale (UPDRS) score of 22 ± 9.62 (min 9; max 42) and an average disease duration of 4.84 years (min 1.33; max 9.33).

Significant results were observed throughout the protocol in both dynamic and static balance tests. Significant improvements were observed in the Tinetti scale between T0 and T1) (p = 0.00), in the stabilometric values of closed-eyes mean medio-lateral oscillation velocity (Velocity x axis CE) between T1 and T2 (p level = 0.006), in the area of ellipse CE (p level = 0.006) and Romberg area (CE/OE) between T1 and T2 (p = 0.05) as described in Table 2.

Table 2. Tinetti score and significant stabilometric scores.

(Mean and SD)	T0	T1	T2	p Value
Tinetti	23.00 ± 1.84	**24.19 ± 1.74 ***	24.60 ± 2.18	0.000
Velocity x axis CE (mm/s)	26.03 ± 12.1	27.05 ± 17.80	**22.10± 14.01 ***	0.006
Area of ellipse CE (mm^2)	563.36 ± 340.02	509.15 ± 428.10	**428.57± 342.64 ***	0.006
Romberg Area CE/OE (mm^2)	319.04 ± 179.72	303.89 ± 187.02	**224.68± 124.09 ***	0.05

* p level ≤ 0.05 was considered statistically significant with Student's-test for paired samples.

4. Discussion

Sensory impairment is a great contributor to movement disfunction and postural instability in Parkinson's disease. While healthy subjects mainly rely on somatosensory information to maintain an upright posture, these individuals show an increased reliance on visual cues [18].

A study of Paolucci et al. [8] demonstrated that PD patients experience significantly greater variations in center of pressure (CoP) while performing stabilometric analyses with the eyes closed. Our results are in agreement with the study of Paolucci as the results showed a greater postural instability during static tests performed with closed eyes.

After application of focal vibration, a progressive reduction of the oscillation velocity on the x-axis, oscillation area with closed eyes and Romberg ratio were observed between T0 and T2. Moreover, a slight improvement of the Tinetti score was observed from T0 to T2 with a statistically significant difference at T1. This seems to suggest a beneficial role of focal vibration on proprioception and a decreased need of reliance on visual cues both during free stance and during motion associated with usual exercises.

Focal muscle vibration works by conveying repetitive proprioceptive and exteroceptive stimuli from peripheral musculocutaneous mechanoreceptors up to the ventral posterolateral nucleus of the thalamus and to the primary somesthetic areas of the cerebral cortex [10]. Studies on brain excitability performed under positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) have shown significant activation of the motor cortex during muscle vibration [11,12]. Moreover, experiments performed with transcranial magnetic stimulation (TMS) have demonstrated a facilitation of the muscular electrical response (MEP) and a modulation of intracortical inhibition, proving that pure sensory stimulation is able to influence the motor response [12].

In recent years, several studies have tested a novel proprioceptive focal vibration device (Equistasi®) consisting of a self-wearable patch, applied over the cervical spine that produces a 300 Hz vibration from body heat. This system has proven to be effective at improving posture, stability and quality of gait in moderate Parkinson's patients [7,9,18,19]. Compared to these studies, our protocol differs as it used a pneumatic vibration device (EVM, Endomedica, Rome, Italy) applied to the upper back and lower limb muscles. The choice of the vibration targets was based on our clinical judgment while the frequency and amplitude parameters were chosen according to the most commonly applied parameters in literature [11].

Despite the differences in site of application and frequency between the studies, in both cases, focal vibration has shown to work effectively in postural control and gait disorders in PD patients. A common criticism toward the use of focal vibration is that it is not clear how long the effects last after a treatment; some authors suggest that the effect is quickly lost as soon as the treatment is withdrawn while others reported visible effects even after weeks from the last application [12]. In our study, a statistically significant improvement of the Tinetti score and stabilometric parameters were noted also after one month from the last application. This result reflects a long-lasting functional improvement in balance and gait with a reduction of the risk of falls even in chronic patients and may provide a practical and safe alternative for cases were pharmacological therapies exhausted their full efficacy after years of treatment.

Limitations

This pilot study has several limitations that should be noted. In particular, the small sample, the concomitance with the physiotherapy treatment and the lack of a control group limit our understanding of the role of focal muscle vibration in the treatment of gait and balance disorders in Parkinson's disease. However, the selection of patients with chronic PD with at least one year of regular participation to our PD physiotherapy program ensures a relatively stable clinical picture, allowing us, with reasonable probability, to attribute the clinical improvement observed during the follow up period to the introduction of this novel treatment. Further studies should compare the effects of this technique in comparison with a control group performing only physiotherapy or pharmacological therapy. Moreover, as the course of PD is not linear, with variable and more rapid rates of deterioration in the early phase of the disease [1], further experiments should be conducted at different stages of the disease to define which subpopulation most benefit from this treatment.

5. Conclusions

Our preliminary results suggest that focal muscle vibration, applied bilaterally to the trapezius and quadriceps muscle and sole of the feet, in conjunction with physiotherapy, is a useful tool in the rehabilitation of gait and balance disorders of patients with moderate to advanced Parkinson's disease. Specifically, in the preliminary data, improvement in static and dynamic balance were observed after one month from the last treatment session. The focal muscle vibration could be a useful instrument for the rehabilitation of patients with Parkinson's disease in association with conventional physiotherapy. Exercise interventions probably reduce the rate of falls and slightly reduce the number of people falling in patients affected by mild to moderate Parkinson's disease, as showed in a recent Cochrane systematic review [20]. Further works are needed to increase the certainty of the effects of focal vibration alone or in combination with exercise. A comprehensive approach and multidisciplinary collaborations are desirable to obtain a better rehabilitative outcome.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data will be available on SPSS database if requested.

Conflicts of Interest: The authors declare no conflict of interest.

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