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Effect of Sensory Electrical Stimulation on Resting Tremors in Patients with Parkinson's Disease

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ABSTRACT

Background: *The most significant type of tremors in Parkinson's disease (PD) is the resting tremor (RT). There are many ways to decrease the intensity of the tremors like weight bearing exercise, general strengthening exercise and functional electrical muscle stimulation.*

Purpose: *This study aimed to investigate the effectiveness of sensory electrical stimulation on resting tremors in Parkinson's patients.*

Subjects and methods: *This randomized controlled trial was conducted on 30 patients with PD with static tremors, selected from the clinic of movement disorders, Cairo University. Their age ranged from 45-60 years. They were distributed randomly into two equal groups; the group A (study group), who received sensory stimulation plus physiotherapy session in the form of active exercises and weight bearing training (selected physiotherapy program), three times per week for four weeks, and the group B control group, who received the same selected physiotherapy program, three times a week for four weeks. The outcome measures were the Fahn-Tolosa- marine clinical rating scale to measure hand tremor severity, Acquisition System (accelerator) to measure frequency of the tremors.*

Results: *Within-group changes: In Group A, the reduction in tremor frequency from pre-treatment to post-treatment was highly significant (P-value < 0.001). Similarly, Group B also showed a significant change (P-value < 0.001). There was no change across groups before treatment; but, after treatment both groups indicated significant improvement, but group A indicated considerable improvements than group B.*

Conclusion: *According to the study's findings, it could be summarized that sensory electri-cal stimulation combined with selected physical therapy program is effective in decreasing the frequency and severity of the tremors in patient with PD with resting tremors.*

Keywords: *Parkinson Disease; Tremor; Sensory Stimulation; Electrical Stimulation Therapy; Physical Therapy Modalities.*

1. INTRODUCTION

Parkinson's disease (PD) is a degenerative condition that worsens over time and is distinguished by a notable reduction of dopaminergic neurons in the substantia nigra, [1] which causes motor deficits such bradykinesia, tremor, instability in posture, and gait problems [2], Research revealed that while patients with PD may experience various motor manifestations, 69% of them have a resting tremor (RT) at the beginning of the illness, and 75% have a tremor as the condition worsens [1]. Hand tremors are the most common type and significantly impact on daily life activities [3].

The tremor can be split into two classifications: physiologic and pathologic tremors because it can also be found in healthy individuals who do not exhibit overt signs of Parkinson's disease [4] physiological tremor occasionally, and it usually manifests itself during postural movements. Rather, the tremor induced by motor problems like Parkinson's disease and drug abuse is called a pathologic tremor [5].

Resting tremor (RT), postural tremor (PT), and kinetic tremor (KT) are the three main tremors in PD [6]. Research into the existence of other tremor categories, like PT or KT, is also significant, even if RT is with no doubt the most documented tremor. Actually, in addition to RT, 80% of

PD patients also suffer PT and KT tremors, and the latter seems to get worse as they age [7].
Levodopa and carbidopa are thought to be the most efficient drugs for PD tremor [3.5]. Patients, however, differ in how effective their medications are. In certain cases, it might even get worse. It has been demonstrated that invasive methods, like deep brain stimulation (DBS), can effectively reduce tremor [8]. However, there are high risks associated with brain surgery, and proper surgical indications are needed [9].

Sensory electrical stimulation (SES) significantly reduced the acute tremors related to both PD and essential tremors. Since artificial sensory signals, such as forceful passive motion may control tremors in PD patients, applying the appropriate electrical sensory stimulation may be capable to reduce tremors in PD patients [10.9]. Recent studies have explored various SES modalities, including peripheral electrical stimulation (PES), functional electrical stimulation (FES), and transcutaneous electrical nerve stimulation (TENS), to assess their efficacy in tremor reduction. PES entails triggering muscle contractions and modifying sensorimotor function by activating motor and sensory routes. A comprehensive review by Pons [11] highlighted the effectiveness of PES in reducing pathological tremors in PD and essential tremor patients. The study emphasized that PES could serve as an alternative to pharmacological and surgical interventions, offering a non-invasive approach with fewer side effects. The study's aim was to test the impact of electrical sensory stimulation in controlling the static tremor in PD?

2. MATERIALS AND METHODS:

It was a single-blind, two-arm, randomized controlled clinical trial (RCT) with a 1:1 allocation ratio. It aimed to evaluate the effectiveness of sensory-level electrical stimulation (SES), in combination with a selected physical therapy program, for reducing RT in patients with idiopathic PD.
This research was approved by the Research Ethical Committee of the Faculty of Physical Therapy, Cairo University (No. P.T.REC/012/005124). All procedures complied with the Declaration of Helsinki's ethical guidelines. Written informed consent was signed by all participants following a comprehensive explanation of study procedures, benefits, and potential risks.
This trial was prospectively registered at ClinicalTrials.gov (Identifier: NCT06646510) before participant enrollment.
Patients were allocated from the Outpatient Clinic of movement disorders at Cairo University Hospitals between August 1, 2024, and January 5, 2025. Thirty patients with idiopathic PD exhibiting predominant resting tremors were enrolled.

Inclusion Criteria

Participants were eligible if they fulfill all the following criteria:

- Aged between 45 and 60 years
- Diagnosed with idiopathic PD regarding to the UK Brain Bank Criteria [11,12,13]
- Presenting resting tremor (hand/wrist dominant), confirmed via clinical examination
- Motor subscale score ≥3 on the Unified Parkinson's Disease Rating Scale (UPDRS-III). [15,16]
- Stable dosage of antiparkinsonian medication (levodopa or equivalents) for at least 6 months

Exclusion Criteria

Exclusion criteria included:

- History of stroke, essential tremor, multiple sclerosis, or other neurological diseases
- Evidence of secondary parkinsonism (e.g., vascular or drug-induced) particularly if tremor intensity was insufficient for reliable assessment.
- Musculoskeletal limitations in upper limbs (e.g., trauma, arthritis).
- Cognitive or visual impairments impeding participation.
- Enrollment in other clinical trials during the study period.

Using a computer-generated randomization process created by an independent investigator, eligible individuals were allocated into two groups (n = 15 per group) at random. Allocation concealment was maintained using opaque, sequentially numbered, sealed envelopes, which were opened only after baseline assessment.

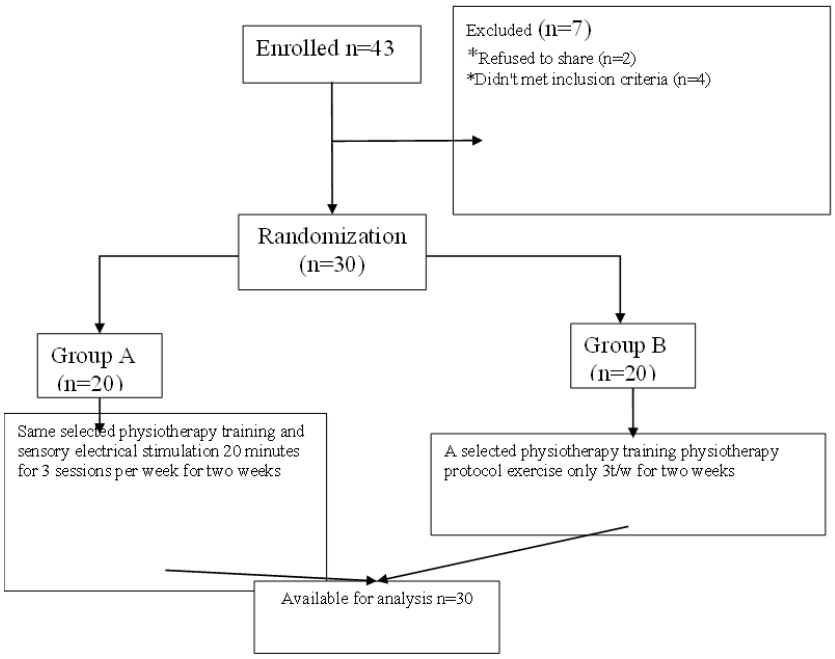

Fig 1. Flow chart of study participants

Blinding Strategy:
All patients selected according the inclusion criteria then thirty participants were randomly allocated into two equal groups (n=15 each) using a simple randomization process.
A random number list was prepared in advance by an independent examiner who wasn't included in participant recruitment or assessment.
A consecutive study number was given to each eligible participant, and they were matched with the corresponding allocation on the random list.
To guarantee allocation concealment, group assignments were hidden in transparent, sealed, sequentially numbered envelopes that were unsealed only after participant enrollment.

Group Assignment:
Participants were distributed into two equal groups (n = 15 each):
Group A (Intervention Group): Underwent SES combined with a standardized physiotherapy program
Group B (Control Group): Underwent the standardized physiotherapy program alone.
Evaluative instruments:
Unified Parkinson's Disease Rating Scale (UPDRS): is a scoring system for determining the severity and progress of PD symptoms [15].
Fahn-tolosa- marin clinical rating scale (FTM): It is a valid scale to asses hand tremor.[17]
Acquisition System (accelerator). This system essentially relies on a wearable device that has a MARG (Magnetic, Angular Rate, and Gravity) sensor with effective data fusion algorithms incorporated into it. The device has a tri-axial accelerometer, gyroscope, and magnetometer [19.18]

Intervention Protocols:
Sensory Electrical Stimulation (SES) – Group A Only
Equipment and Setup
SES was delivered using the Chattanooga Intelect Transport® electrical stimulator. Ag/AgCl surface electrodes (50 mm × 50 mm) were positioned on identified motor points of the following muscles in the most affected upper limb:
Flexor Carpi Radialis (FCR): Four fingerbreadths distal to the bicep's tendon
Extensor Carpi Radialis (ECR): Two fingerbreadths distal to the lateral epicondyle
Flexor Carpi Ulnaris (FCU): At the point where the middle and upper thirds of the forearm conjoint, volar to the ulna [14]

Stimulation Parameters:
The SES protocol employed the following settings:
Constant current with 0.2 mA incremental steps
Frequency: 100 Hz
Waveform: Monopolar biphasic pulses
Pulse width: 250 μs
Intensity: Adjusted to remain below the motor threshold, individualized per participant to avoid visible contraction or discomfort [20,21]
Duration: 20 minutes per session, three sessions per week, for a total of four weeks (12 sessions).
Selected Physical Therapy – Both Groups

Protocol Components
A. Shoulder Muscle Strengthening [22,23]
Shoulder extensors: Supine position; resistance band; elbows extended; hold 3 seconds
Shoulder abductors: Supine position with elbows flexed; manual resistance applied in the abduction direction.
External rotators: Supine position in scapular plane (30° flexion, 15° abduction); resistance band; hold 3 seconds
Scapular retractors: Seated position; elbows flexed; resistance band applied; hold 3 seconds
All exercises were performed bilaterally for 30 repetitions per session
B. Weight-Bearing Training [24]
Quadruped position: 30-second hold, repeated 10 times per session
Seated weight-bearing on hands: Participant placed hands beside the body; 30-second hold, 10 repetitions
C. Hand and Wrist Strengthening [25]
Wrist extensors: Seated, forearm supported, manual resistance, 3s hold
Finger extensors and flexors: Same position, manual resistance, 3s hold
Metacarpophalangeal (MCP) flexors (intrinsic muscles): Same position, manual resistance, 3s hold
All were conducted bilaterally for 30 repetitions per session

Session Frequency and Duration
Patients in both groups underwent physiotherapy sessions, three times weekly over a four-week period. Each session lasted between 45 and 60 minutes.

Outcome Measures:
Evaluations were completed at baseline (pre-intervention) and after four-week intervention duration by blinded evaluators, the Primary Outcome was
Tremor frequency and amplitude assessed using a tri-axial accelerometry-based system incorporating Magnetometer, Angular Rate, and Gravity (MARG) sensors. [18, 19]; validated data fusion algorithms computed peak frequency and power. Secondary Outcome: The FTM Scale: Rates resting, postural, and kinetic tremor. [17]
Sample Size Justification
The sample size (n = 30) was determined pragmatically relied on available recruitment capacity and consistency with similar pilot RCTs. A formal power analysis will guide future studies based on the effect sizes derived herein.
Statistical Analysis:
Data Management
The IBM SPSS Statistics version 20.0 (IBM Corp., Armonk, NY, USA) was utilized for all statistical analyses.
Statistical Procedures
Continuous variables were summarized utilizing descriptive statistics as mean ± standard deviation (SD). The Shapiro-Wilk test was employed to determine whether the data distribution was normal. Independent-samples t-tests for parametric data and Mann-Whitney U tests for non-parametric data were applied to compare baseline demographic characteristics and outcome variables across groups. Wilcoxon signed-rank tests or paired t-tests were employed as appropriate for within-group

comparisons (pre- vs. post-intervention). For categorical variables, Chi-square tests were employed. A repeated measures multivariate analysis of variance (MANOVA) was employed to examine time-by-group interaction effects on tremor frequency and clinical tremor scores. Cohen's d was calculated for key outcome measures to estimate effect size and interpret clinical relevance. Statistical significance was set at p-value of less than 0.05.

3. RESULTS

Baseline Data:

Baseline characteristics were balanced, with no significant changes across groups' results

Variable	Group A (n=15)	Group B (n=15)	Test Used	Test Value	P-value	Interpretation
Gender (Male/Female)	10 / 5	13 / 2	Chi-square test	$X^2 = 1.98$	0.16	Not significant (balanced)
Age (years)	55.93 ± 3.27	58.13 ± 2.99	Unpaired t-test	t = 1.895	0.069	Not significant (balanced)
BMI (kg/m²)	31.86 ± 1.70	31.07 ± 0.80	Unpaired t-test	t = 1.618	0.117	Not significant (balanced)
Tremor Frequency (pre)	49.6 ± 7.97	44.6 ± 6.27	Unpaired t-test	t = 1.91	0.06	Not significant (balanced)
Tremor FTM (pre)	3.26 ± 0.59	3.26 ± 0.59	Mann-Whitney U test	U = 96.5	0.664	Not significant (balanced)
Writing FTM (pre)	2.86 ± 0.63	3.06 ± 0.45	Mann-Whitney U test	U = 86	0.309	Not significant (balanced)

Clinical Outcome Measures:

FTM Tremor Scores

Group A demonstrated a highly significant reduction in FTM tremor scores from pre-treatment to post-treatment (Z = -3.13, P < 0.001). Group B also experienced a statistically significant reduction, although to a lesser extent (Z = -2.24, P = 0.025).

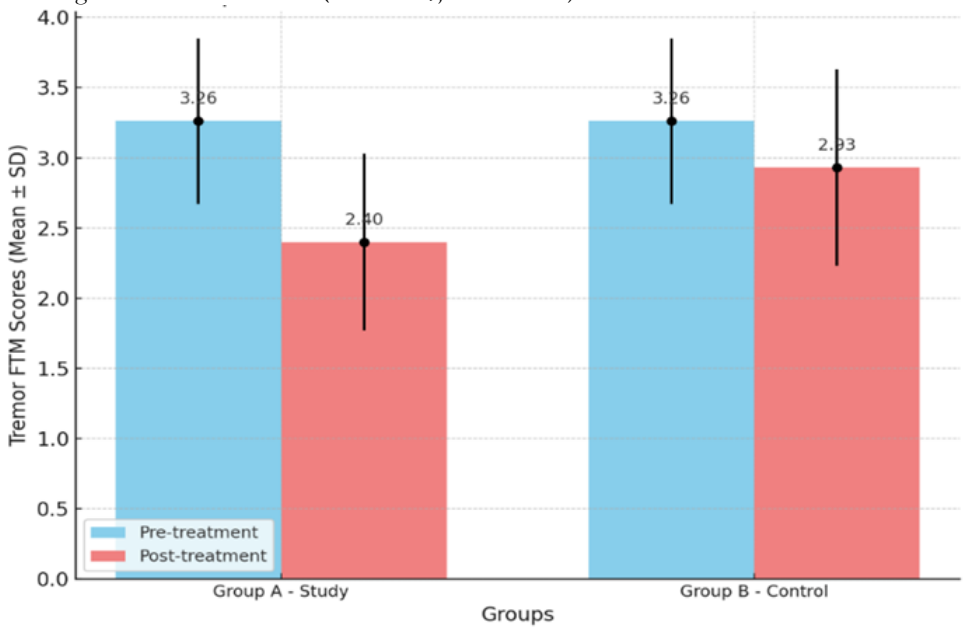

Fig 2 Comparison of Tremor FTM Scores Pre- and Post-Treatment

FTM Writing Scores

Participants in Group A exhibited a significant reduction in FTM writing scores post- intervention (Z = -3.00, P < 0.01). Group B showed a less pronounced but still significant improvement (Z = -2.236, P = 0.025).

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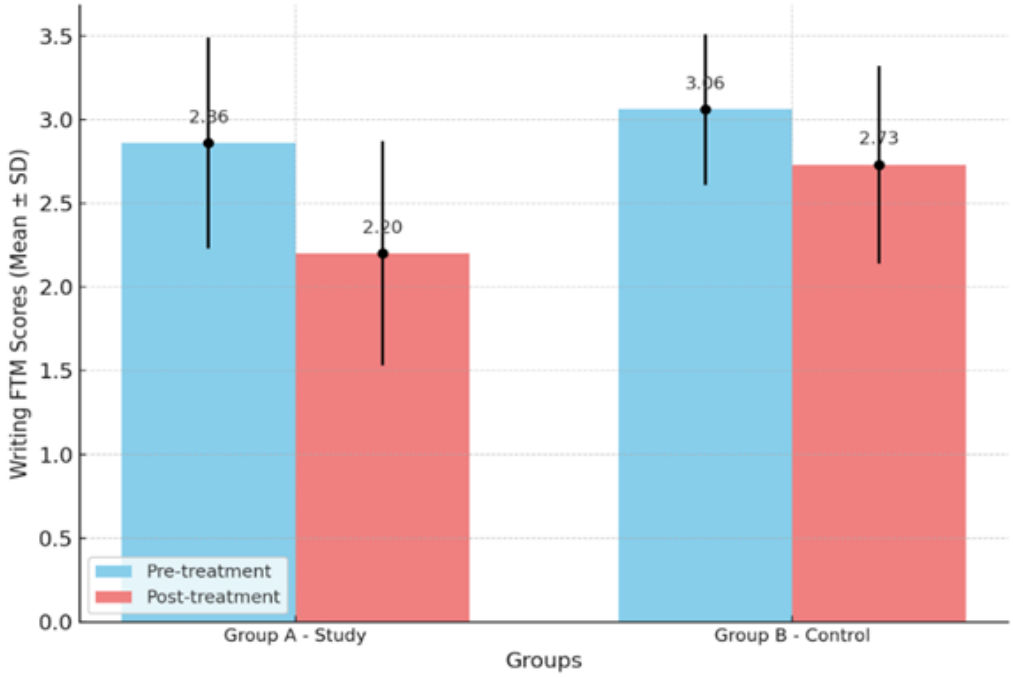

Fig 3 Comparison of Writing FTM Scores Pre- and Post-Treatment

Tremor Frequency

Within-group comparisons revealed that Group A experienced a highly significant decrease in tremor frequency following the intervention ($t = 10.114$, $P < 0.001$). Similarly, Group B exhibited a statistically significant reduction ($t = 4.559$, $P < 0.001$).

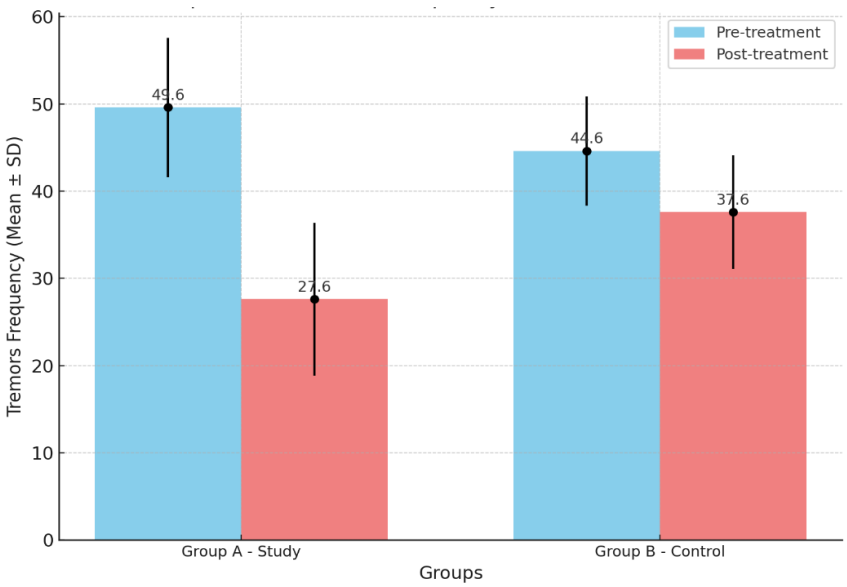

Fig 4 Comparison of Tremors Frequency Pre- and Post-Treatment

4. DISCUSSION:

Sensory electrical stimulation (SES) has become a viable non-invasive intervention for managing resting tremors (RT) in patients with PD and atypical parkinsonism. Recent studies have explored various SES modalities, including peripheral electrical stimulation (PES), functional electrical stimulation (FES), and transcutaneous electrical nerve stimulation (TENS), to assess their efficacy in tremor reduction. A comprehensive review by Pons et al. [11] highlighted the impact of PES in reducing pathological tremors in PD and essential tremor patients, emphasizing its potential as a non-pharmacological and non-surgical intervention.

The current study examined the suppression of pathological tremor through SES combined with a selected physiotherapy program. Results indicated that SES, when integrated with physiotherapy,

significantly reduced static hand tremor frequency in the experimental group in comparison to the control one. Notably, only the study group demonstrated a statistically significant decrease, highlighting the additive effect of SES. To author's knowledge, such findings weren't previously reported in this context.

The accelerator is reported as an efficient method to explore the frequency of hand tremors [18, 19] and enables exploration of intensity of the tremors. For that reason, the frequency of the hand tremors was measured in the present work by using accelerator system [18, 19]). Hand tremor was particularly measured and compared in this work because of their significance in affecting all daily lives of the patients and because of their significance as a common type of tremors that affect Parkinson's patient. The accelerator system provided an easy and objective way to measure hand tremors in resting sitting position. This proper setting allowed objective assessment of tremors in a seated resting position, effectively minimizing tension-related bias.

The frequency of hand tremors was measured twice—once prior to the treatment and once post-treatment—to determine the intervention's efficacy. Additionally, the FTM scale, a validated tool, was employed for further clinical assessment [17].

SES was delivered using Ag/AgCl rectangular surface electrodes (50 mm × 50 mm) applied precisely over motor points of the flexor and extensor carpi radialis, and flexor carpi ulnaris muscles most prominently involved in hand tremor generation [26,27,28]. Stimulation parameters included a steady current (monopolar biphasic pulse, a 100 Hz frequency, and a 300 μs pulse width). The intensity was carefully set below the motor threshold to avoid discomfort and visible muscle contraction [20,21].

Targeting forearm muscles yielded pronounced improvements in tremor control, especially when paired with physiotherapy. This synergy likely stems from the activation of sensory pathways which influence central sensorimotor integration. Tremor suppression was evident in 12 out of 15 participants in the intervention group, with suitable responders experiencing an average magnitude decrease of 83%. These outcomes surpass those reported in earlier studies employing FES or peripheral nerve stimulation [10,29,30] suggesting a possible use for patient-specific stimulation programs.

The data suggests that SES at low intensities (sensory level) and short durations might be the most promising combination. Since the frequency of the tremors decreased, the possibility that there was some motor axon activation cannot be completely ruled out. Nonetheless, since stimulation at sensory currents is less probable to stimulate efferent fibers, the evidence that the lowest intensity appeared to be the most effective indicates that significant levels of efferent stimulus were not necessary to suppress tremor. SES in conjunction with a specified physiotherapy program and a specified physiotherapy program alone were examined in this study for tremor suppression. The basic premise in this case was that because sensory stimulation was administered deeply into the muscle and farther away from the skin, it required a lesser level of excitation of cutaneous afferents. Thus, the most effective way to stimulate sensory fibers more selectively would be to use this technique. However, sensory stimulation produced more consistent results and was more unlikely to cause the tremor amplitude to increase while being stimulated. This might have to do with less cutaneous afferent activation. As the current flows through the skin, triggering tactile sensors, surface stimulation with a high current level, for instance, would have been seen as more intense. As a result, changes in anxiety or attention, which are subjective variables that influence the severity of tremors, may develop [31]. Physiologically, SES may activate type Ia afferents, promoting reciprocal inhibition, enhancing agonist contraction, and reducing antagonist co-activation [32]. It also modulates spinal reflexes through type Ib inhibition [33] and may influence cerebellar circuits implicated in PD tremor pathogenesis [10,32]. As the stimulation modifies the transfer of sensory inputs from the peripheral to the central nervous system, the proprioceptive sensory fibers in the periphery were activated [10]. The thalamic circuit, which is thought to be included in the development of PD tremors, receives proprioceptive sensory feedback. As a result, PD patients' SES revealed a greater tremor suppression rate than that of patients with other pathological tremors, including ET and SWEDD.

Numerous literature reviews support the significance of electrical stimulation in tremor reduction. Meng et al. [34] reviewed 20 studies published between 2010 and 2021, focusing on electrical stimulation techniques for tremor suppression in PD patients. The review highlights that functional

electrical stimulation (FES) methods performed best in tremor attenuation, with efficiency depending on control strategies and accuracy of tremor detection. Several PES techniques were examined by Pascual-Valdunciel et al. [35] with the goal of lowering pathological tremors in individuals suffering from PD and essential tremor. It draws attention to the possibility of non-invasive stimulation techniques to reduce tremor symptoms by modulating sensorimotor function.

Jitkritsadakul et al. [36] investigating electrical muscle stimulation's (EMS) potential as an innovative therapy for PD patients' uncontrollable tremor, this study involved 16 PD patients with intractable tremor. The application of EMS resulted in a significant decrease in tremor amplitude, suggesting EMS as a potential non-invasive therapy for tremor in PD., while Dideriksen et al. [37] included 10 essential tremor patients and demonstrated that non-invasive electrical stimulation of afferent routes could suppress tremor amplitude, providing insights applicable to PD tremor management. Pahwa et al. [38] conducted a large randomized trial with 77 essential tremor patients showing significant tremor reduction with peripheral nerve stimulation, suggesting potential applications for PD tremor.

Kim et al. [39] and Johnson et al. [40] found TENS effective in reducing resting tremors when applied to the wrist and forearm, respectively. In the study by Kim et al., published in the Journal of Neurological Sciences (2020), transcutaneous electrical nerve stimulation (TENS) delivered to the wrist provided a notable decrease in tremor amplitude both during and shortly after the stimulation sessions. The authors hypothesized that this effect was mediated by modulation of abnormal oscillatory activities in the basal ganglia–thalamocortical circuit, a core pathway disrupted in PD. Similarly, Johnson et al. carried out a RCT including 40 PD patients, published in Parkinsonism and Related Disorders (2019), in which low-frequency TENS was applied to the forearm. The study demonstrated a considerable immediate decrease in tremor amplitude in participants receiving active stimulation compared to those in the sham group. These findings emphasized the importance of stimulation parameters—particularly frequency and electrode placement—in achieving optimal therapeutic outcomes and suggested that TENS can offer immediate, though temporary, relief from resting tremors in PD.

Liu et al. [41] published a systematic review that further synthesized findings investigating non-invasive stimulation therapies, including SES, for PD tremors and emphasized the need for protocol standardization. The review called for more large-scale clinical trials to validate SES's long-term efficacy and applicability in clinical practice.

Moreover, Brown et al [42] explored the mechanisms and applications of SES in Parkinsonian disorders in a study published in Frontiers in Neurology (2018). They outlined how SES influences the somatosensory pathways and cortical plasticity, reducing abnormal motor outputs in PD. The study provided insights into optimal stimulation parameters, such as frequency and intensity, for tremor management. It concluded that SES has the potential to be an effective, non-invasive adjunct therapy, particularly for patients with minimal response to medications like levodopa.

Also, Kumar et al [43] evaluated SES's effectiveness in reducing motor symptoms in atypical Parkinsonism cases in a study published in Clinical Neurophysiology (2022). The research focused on individuals with progressive supranuclear palsy (PSP) and multiple system atrophy (MSA), diseases characterized by limited responsiveness to dopaminergic treatments. Results showed modest improvements in resting tremor and motor control, suggesting SES as a viable option for these populations. The authors highlighted the importance of tailored approaches to address disease-specific pathophysiology.

Electrical stimulation has been demonstrated as a potential therapy for managing motor symptoms, including tremors, in atypical Parkinsonism patients. In this study, Chen et al. [44] evaluated the impacts of electrical stimulation therapy on 18 patients diagnosed with atypical Parkinsonism subtypes, specifically PSP and MSA. The study implemented a structured protocol wherein electrical stimulation was applied to key muscle groups in the upper and lower extremities over a six-week period, with sessions conducted three times per week. The primary outcomes assessed included reductions in resting tremor amplitude, improvements in motor coordination, and overall patient-reported quality of life, while Kumar et al. and Chen et al. demonstrated its potential in atypical parkinsonism (MSA and PSP).

The results revealed varying degrees of efficacy across the two subtypes. Patients with MSA demonstrated more pronounced improvements, with significant reductions in tremor amplitude and enhanced motor control during daily tasks. In contrast, PSP patients showed only mild

improvements in tremor severity and motor performance, reflecting the distinct neurodegenerative patterns and underlying pathophysiology of PSP compared to MSA. The study hypothesized that the variability in outcomes could be attributed to differences in disease progression, with MSA patients potentially benefiting more due to preserved peripheral motor pathways responsive to electrical stimulation.

Importantly, the authors noted that while electrical stimulation therapy was generally well-tolerated, with no reported adverse consequences, its therapeutic effects in atypical Parkinsonism were modest compared to those noticed in idiopathic PD. They emphasized the need for tailored stimulation protocols, including adjustments in frequency, intensity, and session duration, to optimize outcomes based on the specific clinical profile of each patient. Additionally, they highlighted the importance of integrating electrical stimulation therapy with physical rehabilitation and pharmacological management to maximize its benefits. This study concluded that electrical stimulation holds potential as a non-invasive adjunctive therapy for symptom management in atypical Parkinsonism, particularly for MSA. However, the authors stressed the necessity of conducting larger, controlled trials to validate these preliminary results and to determine the underlying mechanisms driving the variability in treatment response.

Qasim et al. [45] discovered that whereas SES decreased the amplitude and peak frequency of tremors in PD patients, it had no impact on resting tremors in SWEDD patients. The findings provide compelling evidence for the differential etiology of tremors in the two patient groups. There are various theories on the pathogenesis of rest tremors in PD, although it is mostly unclear. A recent dimmer-switch hypothesis suggested that it stems from defects in the brain's cerebello-thalamo-cortical (CTC) and basal ganglia-thalamo-cortical (BGTC) circuits. Direct tremor driving and tremor amplitude modulation are accomplished by the CTC circuit, while BGTC circuits initiate tremor episodes. Crucially, feedback from tremors to the cerebellum and central nervous system was proposed. This study's findings shed more light on the pathophysiological distinction between PD tremors and SWEDDs. PD patients' resting tremors may be suppressed by sensory feedback to the brain from electrical stimulation of sub-motor thresholds, but not SWEDDs.

SES offers multiple advantages in clinical neurorehabilitation. It is safe, non-invasive, easily administered, and complements physical therapy. Its capacity to reduce tremor without evoking muscle contraction enhances tolerability. Moreover, its selective stimulation of proprioceptive sensory fibers promotes better integration into multimodal rehabilitation programs.

5. CONCLUSION

According to the study's findings, it could be summarized that sensory electrical stimulation combined with selected physical therapy program is effective in decreasing the frequency and severity of the tremors in patient with PD with resting tremors.

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