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Physiotherapy for managing tremors in patients with Parkinson's disease – a systematic review

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ABSTRACT: Primary Parkinsonism is one of the most prevalent movement disorders characterized by hypokinesia, rigidity, and tremor. The number of Parkinson disease (PD) cases is anticipated to rise globally, making finding effective and affordable interventions crucial. Physiotherapy interventions have shown promise in managing tremors, but high-quality systematic reviews are limited. This systematic review aims to evaluate the benefits of physiotherapy treatments in managing tremors in PD. The study followed the Centre for Reviews and Dissemination, and PRISMA guidelines. A comprehensive search was conducted using multiple databases, including PubMed, EMBASE, AMED, and PsycINFO. Keywords related to PD, physiotherapy, and tremors were used. The eligibility of studies was assessed independently by two reviewers, and the quality of included studies was evaluated using the JBI risk of bias tool. Data extraction focused on study characteristics, participant demographics, intervention details, and outcome measures. A total of seven studies met the inclusion criteria. The sample sizes ranged from 10 to 79 participants, and the interventions varied from standard exercises to technological interventions. The findings from the included studies demonstrated positive effects of physiotherapy interventions on tremor reduction and motor function improvement. However, due to the heterogeneity among the studies in terms of the classification of PD, outcomes measured, and intervention duration, it was challenging to draw definitive conclusions. In conclusion, while limited evidence exists, physiotherapy interventions have shown temporary benefits in reducing tremors and improving motor function in patients with PD.

Keywords: Exercises, Parkinson's, Physiotherapy, Rehabilitation, Tremor

1.0 INTRODUCTION

Parkinson's disease (PD) is a disease that is complex in presentation and is progressive. The cardinal signs of the disease are tremor, rigidity, and bradykinesia, often leading to postural instability in later stages (Kouli et al., 2018). The primary clinical characteristics linked to PD include motor symptoms: tremors, rigidity, and bradykinesia. Additionally, as the condition advances,

postural instability may become apparent. Furthermore, non-motor symptoms can manifest, potentially occurring before the onset of motor symptoms (Postuma et al., 2012). Motor and non-motor symptoms collectively play a substantial role in determining the level of disability and result in a diminished quality of life. Moreover, they can serve as predictive indicators of future dependency, necessitating supportive care (Kouli et al., 2018).

One study suggested that the onset of tremors, imbalance, fatigue, depression, constipation, and urinary tract dysfunctions may occur a few years before diagnosis (Kouli et al., 2018). Additionally, it has been reported that those who were presented with tremors or constipation have a higher risk of developing PD (Kouli et al., 2018). PD is heterogeneous in presentation, and two classifications have been suggested: tremor-dominant and non-tremor-dominant PD. However, these subtypes have not been met with a consensus. Individuals with tremors-dominant PD often lack other motor symptoms and may be more responsive to dopamine replacement therapy (Kouli et al., 2018).

Although dopamine replacement therapy using dopamine receptors is the first line of management, this method has several established side effects. These include major risks like cardiovascular risks, psychosis, depression, hepatic and renal insufficiency, and minor risks like nausea, vomiting, dizziness, and digestive problems. This family of drugs can significantly decrease the quality of life of PD patients (Borovac, 2016).

“Tremor is an involuntary, unintended, periodic movement of the muscles of one or more parts of the body that affects predominantly the hands” (Dineshkumar et al., 2022). Tremors in PD can be detected in the hand muscles (Delrobaei et al., 2018; Xu et al., 2016). Tremors in the hand have a frequency range where the number of oscillations per time can be noted (Umesh et al., 2015; Vial et al., 2019). There are several methods to measure tremors, including a gyroscope (Vial et al., 2019), accelerator (McKay et al., 2019) electromyograph (Xu et al., 2016).

Oral medications are the first line of treatment for tremor. However, patients often discontinue medications due to the negative side effects (Lees et al., 2010). It has been estimated that the number of patients who discontinue first-line medications is as high as 53%, resulting in a cascading increase in symptoms (Louis et al., 2010). Similarly, a large number of patients (33-80%) discontinued second-line medications, indicating that there were many side effects (Diaz & Louis, 2010). Other methods include deep brain stimulation and, surgery, which are beset by high costs, lack of accessibility, and secondary complications (Bronstein et al., 2011; Hariz, et al., 2008a; Hariz et al., 2008b).

These factors suggest the need to identify meaningful and effective methods that do not have the side effects and are economical. Moreover, it is established that physiotherapy is an integral part of management even when optimal medical and surgical care is given Keus et al., 2009). A systematic review by O’Connor and Kini (2011) identified neuromuscular physiotherapy, strength training, and functional electrical stimulation for controlling tremors, while other physiotherapy methods like weighted orthotics, limb cooling, and vibration therapy may have limited application. However, the authors cautioned that the evidence base was scanty and further research was necessary (O'Connor & Kini, 2011).

The number of PD patients in India is estimated at 0.58 million, with the numbers expected to increase exponentially in the next decade (GBD 2016 Parkinson's Disease Collaborators, 2018; Rajan et al., 2020). It is imperative to find meaningful interventions to address these patients' difficulties. The annual incidence of PD is around 1.5 to 2 per 10,000 people, and its cost burden is significant, with treatments like deep brain stimulation and tremor gloves being prohibitively expensive for many patients (Dhiman et al., 2021). The economic burden of PD in India is significant, with patients spending a median of INR 27,315 per year on direct out-of-pocket (OOP) health costs, and INR 18,712.8 on medications alone. The cost escalates as the disease progresses, with patients in advanced stages (3 and 4) spending over a third of their income on drugs.

Additionally, indirect costs, such as income loss due to job cessation, amount to a median of INR 60,000 per year, further intensifying the financial strain on patients and their families (Ola et al., 2022). The prevalence of PD is similarly expected to increase in other countries as well and state-of-the-art interventions like deep brain stimulation (DBS) and tremor gloves may be inaccessible to many these sufferers. Hence, it is necessary to find affordable, evidence-based interventions, and physiotherapy methods are one such area. Though there are studies on the efficacy of physiotherapy interventions to minimize tremors, high-quality systematic reviews are scarce.

2.0 METHODOLOGY

2.1 Research question

What is the role of physiotherapy in reducing tremors and improving motor function in patients with Parkinson's disease?

2.2 Study design

This systematic review is conducted in adherence to the Centre for Reviews and Dissemination (Booth et al., 2010) and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021).

2.3 Databases and information sources

A comprehensive literature search was conducted on electronic databases using a predeveloped comprehensive search strategy. The databases used for the systematic review were Medline (Ovid), Excerpta Medica Database (EMBASE), Allied and Complementary Medicine Database (AMED), and PsycINFO. Additionally, a citation search and a hand search were performed. The bibliography of the included articles was also searched to identify any potential articles.

2.4 Search strategy

The keywords were determined through various approaches. The search strategy is given in Table S1.

2.5 Study selection

A single reviewer conducted a literature search across various databases, and the resulting citations were exported to reference management software (Mendeley). The eligibility of the trials was assessed independently by two reviewers. Any discrepancies that arose were resolved through discussion until a consensus was reached. A third reviewer was available for consultation in the event of unresolved disagreements.

2.6 Eligibility criteria

This study encompassed primary research studies, specifically randomized controlled trials (RCTs), quasi-experimental studies, and controlled before-after studies. The target population consisted of individuals diagnosed with PD, irrespective of age, gender, or severity of disease. The intervention focused on physiotherapy approaches to reduce tremors and enhance motor function, delivered by qualified physiotherapists. The detailed eligibility criteria are given in Table S2.

2.7 Assessment of methodological quality

The Joanna Briggs Institute (JBI) risk of bias tool was used as the quality appraisal tool (Barker et al., 2023).

2.8 Data extraction

Two reviewers autonomously extracted pertinent data from the studies included in the study. A predefined data extraction form was used to collect key information. Any discrepancies or disagreements in the extracted data were sorted in a reviewer meeting.

3.0 RESULTS

3.1 Study selection

The process of study selection is outlined in **Figure 1**.

3.2 Characteristics of studies

The inclusion process yielded 7 published studies which were published within the last decade. Participants' ages were distributed 62 (n=147) to 68 (n=91) years intervention and control groups respectively.

3.3 Assessment of bias

As seen from **Table 1**, the methodological quality of articles was moderate to good when overall scores were considered. There were differences between articles on individual constructs. The descriptions of PD by various authors varied (**Table 2**). Four of the seven articles were from Asia, and the others were from North America and Europe. Except for the study from the USA, the sample sizes of other studies were moderate to adequate. Most studies reported positive outcomes in all interventions (**Table 3**) with small effect sizes. Moreover, the effects were temporary in most of the interventions (**Table 4**).

4.0 DISCUSSION

This systematic review explores the role of physiotherapeutic interventions in tremors associated with PD, uses standard methods to identify articles, and follows stringent quality appraisal and data extraction. The JBI tools for quality appraisal are commonly used due to their versatility and the availability of tools for various types of study designs (Barker et al., 2023).

Although PD is a commonly researched subject, as evident from the initial search results of over 800 articles, most were not included in this systematic review due to various factors, such as the study design not being specific to tremors and pharmacological agents being studied. The fact that only seven articles met the criteria for inclusion suggests that this is an area that requires further research.

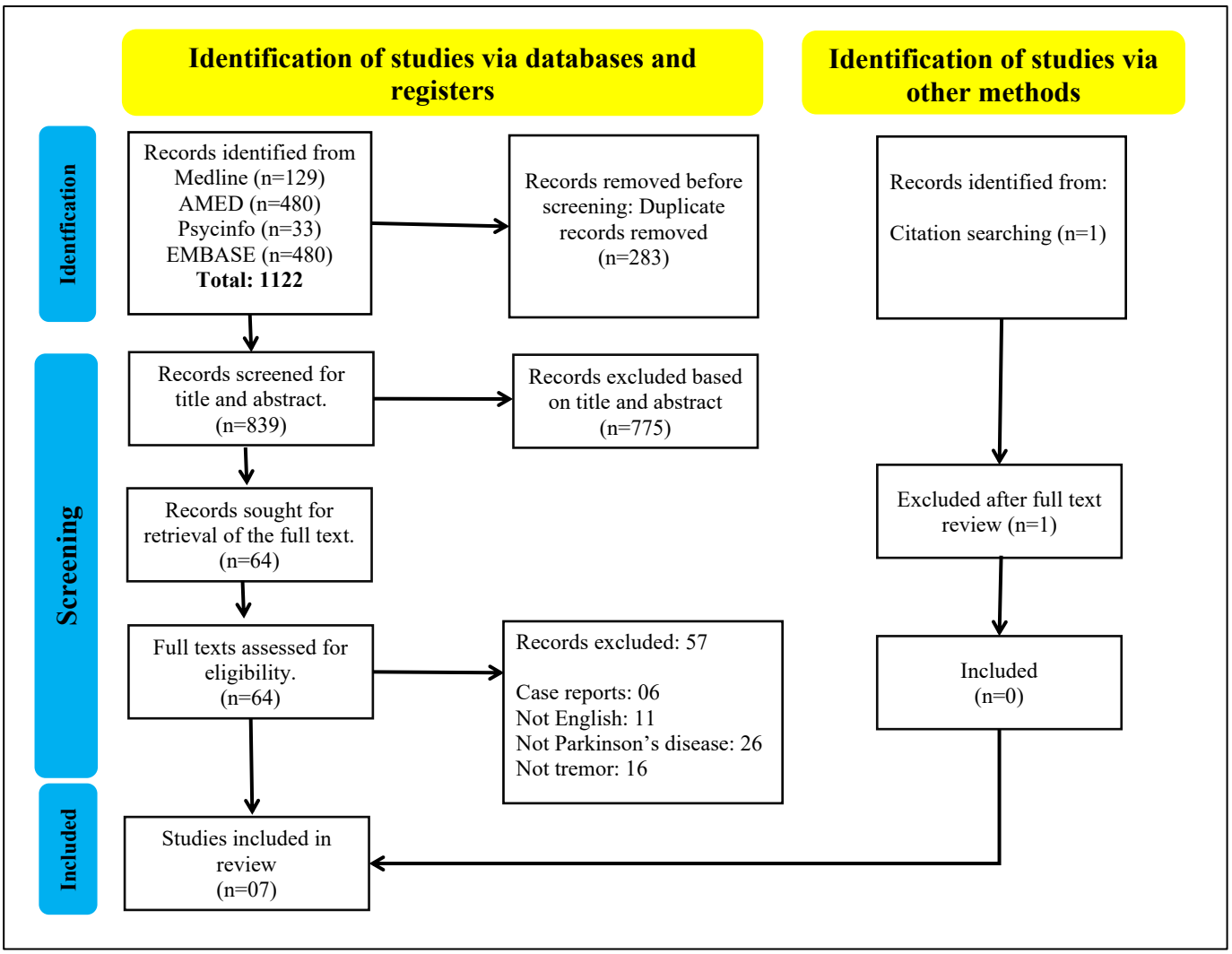

Figure 1: The study selection process

Table 1: Risk of bias appraisal

Author and year	Risk of bias appraisal item										Overall appraisal
	1	2	3	4	5	6	7	8	9	10	
Kashif et al., 2022	+	+	+	+	+	-	-	+	+	+	Include
Kadkhodaie et al., 2020	+	+	+	+	+	-	-	+	+	+	Include
Ridgel et al., 2012	+	+	+	+	+	+	+	+	-	+	Include
Cikajlo & Peterlin, 2019	+	+	+	+	+	-	-	+	+	+	Include
Malling et al., 2019	+	+	+	+	+	+	+	+	+	+	Include
Jitkritsadakul et al., 2017	+	+	+	+	+	-	-	+	-	+	Include
Jitkritsadakul et al., 2015	+	+	+	+	+	-	-	+	-	+	Include

+: Yes, -: No

Table 2: General characteristics of the studies

Study	Country	Study design	Mean age	Sample size (Men/Women/Total)			Diagnoses	Outcome measure
				Control group	Intervention group	Total		
Kashif et al., 2022	Pakistan	Prospective	62.32 ± 4.61 63.86 ± 4.57	13/9/22	12/10/22	25/19/44	PD-idiopathic	UPDRS part III
Kadkhodaie et al., 2020	Iran	Randomized Clinical Trial	67.40 67.82	8/2/10	4/7/11	12/9/21	PD (tremulous or rigid akinetic types)	Restingtremor amplitude, and postural tremor
Ridgel et al., 2012	USA	Randomized control study	64 ± 2.1	NA	4/6/10	4/6/10	Idiopathic PD	Tremor measurement using a sensor
Cikajlo & Peterlin, 2019	Slovenia	Randomized parallel study	69.7 68.5	4/6/10	5/5/10	9/11/20	PD	Average tremor indicator
Malling et al., 2019	Denmark	Randomized control study	66 ± 8.9 65 ± 9.2	17/17/34	26/19/45	43/36/79	PD-idiopathic	Rest and postural hand tremor characteristics, inter-hand coherence
Jitkritsadakul et al., 2017	Thailand	Randomized control study	64.33 ± 9.54 63.40 ± 10.92	8/7/15	6/9/15	14/16/30	PD	UPDRS-tremor
Jitkritsadakul et al., 2015	Thailand	Single-group observational study	65.29 ± 8.72	NA	18/16/34	18/16/34	PD-Type 1	Hand tremor at both resting and postural positions

NA: Not applicable; PD: Parkinson's disease

Table 3: Treatment-related characteristics

Study	Treatment characteristics		Follow up duration
	Group 1	Group 2	
Kashif et al., 2022	**Virtual reality (VR) and motor imagery (MI) training:** Participants received 60-minute sessions every other day for 12 weeks, combining standard physical therapy with VR and motor imagery MI training. The sessions included 40 mins of basic physical therapy, 10–15 mins of VR, and 5–10 mins of MI.	**Control group**: Standard physiotherapy for 12 weeks, with sessions occurring three days a week. It included stretching exercises and walking.	16 weeks
Kadkhodaie et al., 2020	**Pure eccentric training**: Eccentric training was conducted for a duration of 6 weeks, with sessions occurring three days per week and lasting approximately 35–45 minutes each.	**Control group**: No additional interventions other than maintaining the usual physical activity for 6 weeks.	6 weeks
Ridgel et al., 2012	**Actively assisted cycling:** 40 minutes of actively assisted cycling using a submaximal cycle ergometer.	**NA**	Within 10 minutes of each session
Cikajlo & Peterlin, 2019	**Immersive 3D virtual reality:** Participants engaged in 10 sessions of immersive 3D virtual reality for 3 weeks. Each session had a duration of up to 30 minutes, providing ample time to complete the VR task five times.	**Immersive 2D exergaming:** Participants completed 10 sessions of non-immersive 2D exergaming within 3 weeks. Each session had a duration of up to 30 minutes, allowing for the completion of the exergaming task five times.	3 weeks
Malling et al., 2019	**Transcranial pulsed electromagnetic therapy:** Transcranial pulsed electromagnetic fields daily for 8 weeks.	**Sham transcranial pulsed electromagnetic therapy:** Sham transcranial pulsed electromagnetic fields daily for 8 weeks.	8 weeks
Jitkritsadakul et al., 2017	**Sham glove group**: Sham gloves were applied to the hand with the most pronounced tremors for 30 minutes during each testing session.	**Tremor's glove group**: Tremor gloves were positioned on the hand with the most pronounced tremors for 30 minutes per testing session.	During stimulation
Jitkritsadakul et al., 2015	**Electrical muscle stimulation (EMS):** 50 Hz EMS over the abductor pollicis brevis and interosseous muscles for 10 seconds.	**NA**	During stimulation

NA: Not applicable

Table 4: Principal findings

Study	Principal findings	Effect size
Kashif et al., 2022	The group that combined virtual reality and motor imagery showed significant positive changes in various aspects of motor function compared to the group that only received physiotherapy. Specifically, the combined group demonstrated significant improvements in tremors at rest in the 6th week ($p = 0.028$), 12th week ($p = 0.05$), and 16th week ($p = 0.001$), rigidity in the 6th week ($p = 0.03$), 12th week ($p = 0.001$), and 16th week ($p = 0.001$), posture at the 12th week ($p = 0.005$) and 16th week ($p = 0.004$), and gait at the 6th ($p = 0.034$) week.	Action/postural tremor score of UPDRS part III *(between-group effect size)* 6th week: 0.195 12th week: 0.578 16th week: 0.314
Kadkhodaie et al., 2020	After the trial, the eccentric training group showed a significant decrease in hand tremor amplitude during rest, following exercise sessions ($p < 0.05$). In contrast, no increases in tremor amplitude were observed in the control group over the 6-week study period. However, the amplitude of postural tremors remained unchanged in both groups.	*(between-group effect size)* Maximum resting tremor (6th week): 0.490 Mean resting tremor (6th week): 0.477 Postural tremor (6th week): 0.176
Ridgel et al., 2012	Individuals with PD tolerated the active assisted cycling (AAC) paradigm well, experiencing minimal fatigue. Furthermore, most participants exhibited improvements in tremor and bradykinesia immediately after a single session of cycling.	*(within-group effect size)* Pre- and post-active assisted cycling effect size for tremor score: 0.622
Cikajlo & Peterlin, 2019	The 3D intervention group showed statistically significantly better performance when compared to the immersive 2D group in terms of average tremor (group x time, $p = 0.002$) and the Unified Parkinson's Disease Rating Scale (UPDRS) for the upper limb ($U3 = 0.35$).	*(between-group effect size)* Average tremor indicator: 0.799
Malling et al., 2019	The application of transcranial pulsed electromagnetic fields (T-PEMF) treatment resulted in a decrease in inter-hand coherence among individuals with unilateral postural tremors in the PD group, as compared to the sham treatment.	*(between-group effect size)* Resting tremor: 0.173 Postural tremor: 0.24
Jitkritsadakul et al., 2017	Significant reductions in the tremor score in UPDRS were observed during stimulation with the Tremor's glove, compared to the sham groups ($p < 0.05$, for each comparison).	*(between-group effect size)* UPDRS-tremor during off period: 0.244 UPDRS-tremor during on period: 0.253
Jitkritsadakul et al., 2015	The study showed that electrical muscle stimulation was effective in temporarily improving resting tremors in medically intractable patients with PD. The UPDRS tremor score decreased significantly from an average of 10.59 SD=1.74 before stimulation to 8.85 SD=2.19 during stimulation ($p < 0.001$).	*(within-group effect size)* Resting tremor: 0.203

Most of the articles included in this review were from Asian countries. This may suggest that PD is an emerging public health concern in Asia (Muangpaisan et al., 2009). The incidence of PD in Asian countries has been reported to be less than that in Western countries, but the incidence is increasing and the burden of the disease is also substantial, with the years lived with disability (YLD) increasing with an increase in life expectancy (Ou et al., 2021). Overall, there was no difference between men and women represented in the studies. PD affects both genders but with almost twice the rate in men compared to women (Cerri et al., 2019). This fact was not evident from the study participants as there were often almost equal numbers of men and women. Tremor is reported to be a prominent symptom in women (Cerri et al., 2019) and clear gender differences have been reported in PD symptoms. However, the included studies generally had fewer women participants than men. The included articles have used various classifications for PD with overlapping salient features, which is again an impediment to drawing overall conclusions (Pedrero-Sánchez et al., 2023).

The intervention methods used in the included studies varied from commonly used physiotherapy methods like eccentric exercises (Kadkhodaie et al., 2020) and electrical stimulation (Jitkritsadakul et al., 2015) to sophisticated virtual reality interventions (Cikajlo & Peterlin, 2019). Kadkhodaie et al. (2020) focused on reducing hand tremor intensity in PD patients through eccentric-based rehabilitation. The primary outcome of their study was the amplitude of resting tremor, which was measured using a smartphone-based accelerometer system, ensuring precise and objective quantification of tremor levels. The secondary outcome was postural tremor, which did not change significantly after the intervention. In contrast, Cikajlo & Peterlin (2019) examined the effectiveness of virtual reality-based rehabilitation, with the primary outcome being the improvement in hand functionality, measured by the Box & Blocks Test (BBT) and the Unified Parkinson's Disease Rating Scale (UPDRS). Tremor intensity and manipulation time were also measured using a Leap Motion Controller for kinematic analysis.

Interestingly, in the latter study, virtual reality was both the experimental and control intervention, with the 3D immersive environment outperforming the 2D control regarding functional improvement and perceived competence. These outcomes highlight the range of available physiotherapy methods in the reporting countries, with technology playing a significant role in measuring and delivering the interventions. Moreover, these studies' primary objective extended from tremor reduction to overall symptom management in PD.

The follow-up period between studies varied significantly from the same day to 16 weeks. Overall, the effects of the studied interventions were largely temporary, with minimal long-term carry-over, suggesting the necessity for continuous therapy for optimal symptom management in PD (Rafferty et al., 2021). For example, Kadkhodaie et al. (2020) demonstrated that eccentric-based rehabilitation led to significant reductions in resting tremor, attributed to neuroplasticity effects on motor pathways in the basal ganglia and cortex, which are disrupted in PD. Similarly, Ridgel et al. (2012) showed that active-assisted cycling improved both tremor and bradykinesia through mechanisms likely related to enhanced dopamine sparing and altered corticomotor excitability. These studies underscore the importance of targeted, high-intensity exercise interventions that reduce symptoms and modulate central neural mechanisms involved in PD.

The main limitations of this systematic review were the lack of homogeneity in classification, outcomes, and duration of intervention (ranging from same day to 16 weeks), which made it difficult to extract firm evidence from this review. Moreover, the wide variety of intervention studies also comes in the way of drawing evidence. Evidence was considered based on several key criterias: the methodological quality of the included studies, the consistency and reproducibility of outcomes across different trials, and the robustness of statistical analyses used to determine significance. However, the wide variety of intervention types and outcome measures introduced substantial heterogeneity, making it difficult to establish clear patterns or assumptions. To classify findings as evidence, consistency in study design, follow-up periods, and comparable outcome measures across trials would have been necessary, but these factors were not consistently met across the included studies, limiting the strength of the conclusions drawn from this review (Burns et al., 2011).

This systematic review attempted to explore evidence for physiotherapeutic methods to control tremors in PD. The seven included studies are vastly heterogeneous in the classification of PD, outcomes used to quantify/ qualify tremors, and intervention duration, which makes it difficult to draw conclusions. Overall, it appears that irrespective of type, physiotherapeutic measures were temporarily useful in controlling tremors in PD. These studies should uniformly implement the MDS-UPDRS for

assessing motor symptoms, which offers a comprehensive and validated approach to classify PD severity and tremor. Standardizing intervention duration and frequency across studies will also enhance comparability and validity. Future research should focus on long-term interventions to ascertain sustained effects, with a frequency of sessions determined based on preliminary dose-response studies that evaluate the efficacy of different physiotherapeutic techniques in controlling PD tremors.

5.0 CONCLUSIONS

In conclusion, this systematic review highlights the limited but promising evidence supporting the significance of physiotherapy treatment in managing tremors associated with PD. The included studies demonstrated temporary benefits with small effect sizes. However, the heterogeneity in PD classification, outcome measures, and intervention duration hindered the ability to draw definitive conclusions. Further high-quality research studies are needed to determine the optimal interventions and their parameters for managing tremors in PD.

Supplementary Materials: The following are available online at https://neuroscirn.org/ojs/index.php/nrnotes/article/view/359, Table S1: Search strategy; Table S2: Eligibility criteria.

Author Contributions: N.N. and K.B. conceptualized and designed the study's methodology. N.N. and A.T. curated and analyzed data and wrote the original draft of the research paper. K.B. reviewed and edited the paper.

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

References

Barker, T. H., Stone, J. C., Sears, K., Klugar, M., Tufanaru, C., Leonardi-Bee, J., Aromataris, E., & Munn, Z. (2023). The revised JBI critical appraisal tool for the assessment of risk of bias for randomized controlled trials. *JBI Evidence Synthesis, 21*(3), 494–506. https://doi.org/10.11124/jbies-22-00430

Booth, A. M., Wright, K. E., & Outhwaite, H. (2010). Centre for Reviews and Dissemination databases: value, content, and developments. *International Journal of Technology Assessment Health Care, 26*(4), 470–472. https://doi.org/10.1017/s0266462310000978

Borovac, J. A. (2016). Side effects of a dopamine agonist therapy for Parkinson's disease: a mini-review of clinical pharmacology. *Yale Journal of Biology and Medicine, 89*(1), 37–47.

Bronstein, J. M., Tagliati, M., Alterman, R. L., Lozano, A. M., Volkmann, J., Stefani, A., Horak, F. B., Okun, M. S., Foote, K. D., Krack, P., Pahwa, R., Henderson, J. M., Hariz, M. I., Bakay, R. A., Rezai, A., Marks, W. J., Jr., Moro, E., Vitek, J. L., Weaver, F. M., Gross, R. E. and DeLong, M. R. (2011). Deep brain stimulation for Parkinson disease: an expert consensus and review of key issues. *Archives of Neurology, 68*(2), 165. https://doi.org/10.1001/archneurol.2010.260

Burns, P. B., Rohrich, R. J., & Chung, K. C. (2011). The levels of evidence and their role in evidence-based medicine. *Plastic & Reconstructive Surgery, 128*(1), 305–310. https://doi.org/10.1097/PRS.0b013e318219c171

Cerri, S., Mus, L., & Blandini, F. (2019). Parkinson's Disease in Women and Men: What's the Difference? *Journal of Parkinson's Disease, 9*(3), 501–515. https://doi.org/10.3233/jpd-191683

Cikajlo, I., & Peterlin, P. K. (2019). Advantages of using 3D virtual reality-based training in persons with Parkinson's disease: a parallel study. *Journal of Neuroengineering and Rehabilitation, 16*(1), 119. https://doi.org/10.1186/s12984-019-0601-1

Delrobaei, M., Memar, S., Pieterman, M., Stratton, T. W., McIsaac, K., & Jog, M. (2018). Towards remote monitoring of Parkinson's disease tremor using wearable motion capture systems. *Journal of the Neurological Sciences, 384*, 38–45. https://doi.org/10.1016/j.jns.2017.11.004

Dhiman, V., Menon, G. R., Kaur, S., Mishra, A., John, D., Vishnu, M. V. R., Tiwari, R. R., & Dhaliwal, U. S. (2021). A Systematic Review and Meta-analysis of Prevalence of Epilepsy, Dementia, Headache, and Parkinson Disease in India. *Neurology India, 69*(2). https://doi.org/10.4103/0028-3886.314588

Diaz, N. L., & Louis, E. D. (2010). Survey of medication usage patterns among essential tremor patients: movement disorder specialists vs. general neurologists. *Parkinsonism & Related Disorders, 16*(9), 604–607. https://doi.org/10.1016/j.parkreldis.2010.07.011

Dineshkumar, V., Dolly, D. R. J., Jagannath, D. J., & Peter, J. D. (2022). Assistive Methodologies for Parkinson's Disease Tremor Management-A Health Opinion. *Frontiers in Public Health, 10,* 850805. https://doi.org/10.3389/fpubh.2022.850805

GBD 2016 Parkinson's Disease Collaborators. (2018). Global, regional, and national burden of Parkinson's disease, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurology, 17*(11), 939–953. https://doi.org/10.1016/s1474-4422(18)30295-3

Hariz, M. I., Krack, P., Alesch, F., Augustinsson, L. E., Bosch, A., Ekberg, R., Johansson, F., Johnels, B., Meyerson, B. A., N'Guyen, J. P., Pinter, M., Pollak, P., von Raison, F., Rehncrona, S., Speelman, J. D., Sydow, O., & Benabid, A. L. (2008a). Multicentre European study of thalamic stimulation for parkinsonian tremor: a 6-year follow-up. *Journal of Neurology, Neurosurgery and Psychiatry, 79*(6), 694–699. https://doi.org/10.1136/jnnp.2007.118653

Hariz, M. I., Rehncrona, S., Quinn, N. P., Speelman, J. D., & Wensing, C. (2008b). Multicenter study on deep brain stimulation in Parkinson's disease: an independent assessment of reported adverse events at 4 years. *Movement Disorders, 23*(3), 416–421. https://doi.org/10.1002/mds.21888

Jitkritsadakul, O., Thanawattano, C., Anan, C., & Bhidayasiri, R. (2015). Exploring the effect of electrical muscle stimulation as a novel treatment of intractable tremor in Parkinson's disease. *Journal of the Neurological Sciences, 358*(1-2), 146–152. https://doi.org/10.1016/j.jns.2015.08.1527

Jitkritsadakul, O., Thanawattano, C., Anan, C., & Bhidayasiri, R. (2017). Tremor's glove-an innovative electrical muscle stimulation therapy for intractable tremor in Parkinson's disease: A randomized sham-controlled trial. *Journal of the Neurological Sciences, 381*, 331–340. https://doi.org/10.1016/j.jns.2017.08.3246

Kadkhodaie, M., Sharifnezhad, A., Ebadi, S., Marzban, S., Habibi, S. A., Ghaffari, A., & Forogh, B. (2020). Effect of eccentric-based rehabilitation on hand tremor intensity in Parkinson disease. *Neurological Sciences, 41*(3), 637–643. https://doi.org/10.1007/s10072-019-04106-9

Kashif, M., Ahmad, A., Bandpei, M. A. M., Syed, H. A., Raza, A., & Sana, V. (2022). A Randomized Controlled Trial of Motor Imagery Combined with Virtual Reality Techniques in Patients with Parkinson's Disease. *Journal of Personalized Medicine,* 12(3), 450. https://doi.org/10.3390/jpm12030450

Keus, S. H., Munneke, M., Nijkrake, M. J., Kwakkel, G., & Bloem, B. R. (2009). Physical therapy in Parkinson's disease: evolution and future challenges. *Movement Disorders, 24*(1), 1–14. https://doi.org/10.1002/mds.22141

Kouli, A., Torsney, K. M., & Kuan, W. L. (2018). Parkinson's Disease: Etiology, Neuropathology, and Pathogenesis. In T. B. Stoker (Eds.) et. al., *Parkinson's Disease: Pathogenesis and Clinical Aspects.* Codon Publications. https://doi.org/10.15586/codonpublications.parkinsonsdisease.2018.ch1

Kumar, M., Shelji, S., Varghese, P., Thomas, D. W., & Paul, A. (2020). Gyro Glove: Stabilizing the Lives of Those with the Hand Tremor. *Ilkogretim Online - Elementary Education Online, 20*(4), 4781–4794. https://doi.org/10.17051/ilkonline.2021.04.514

Lees, M., Regier, L., & Jensen, B. (2010). Pharmacologic management of essential tremor. *Canadian Family Physician, 56*(3), 250–252.

Louis, E. D., Rios, E., & Henchcliffe, C. (2010). How are we doing with the treatment of essential tremor (ET)? Persistence of patients with ET on medication: data from 528 patients in three settings. *European Journal of Neurology, 17*(6), 882–884. https://doi.org/10.1111/j.1468-1331.2009.02926.x

Malling, A. S. B., Morberg, B. M., Wermuth, L., Gredal, O., Bech, P., & Jensen, B. R. (2019). The effect of 8 weeks of treatment with transcranial pulsed electromagnetic fields on hand tremor and inter-hand coherence in persons with Parkinson's disease. *Journal of Neuroengineering and Rehabilitation, 16*(1), 19. https://doi.org/10.1186/s12984-019-0491-2

McKay, G. N., Harrigan, T. P., & Brašić, J. R. (2019). A low-cost quantitative continuous measurement of movements in the extremities of people with Parkinson's disease. *MethodsX, 6*, 169–189. https://doi.org/10.1016/j.mex.2018.12.017

Muangpaisan, W., Hori, H., & Brayne, C. (2009). Systematic review of the prevalence and incidence of Parkinson's disease in Asia. *Journal of Epidemiology, 19*(6), 281–293. https://doi.org/10.2188/jea.je20081034

O'Connor, R., & Kini, M. (2011). Non-pharmacological and non-surgical interventions for tremor: A systematic review. *Parkinsonism & Related Disorders, 17*, 509–515. https://doi.org/10.1016/j.parkreldis.2010.12.016

Ola, V., Puri, I., Goswami, D., Vibha, D., Shukla, G., Goyal, V., Srivastava, A., & Behari, M. (2022). Annual Cost of Care of Parkinson's Disease and Its Determinants in North India - A Cost of Illness Study with Patient Perspective. *Annals of Indian Academy of Neurology, 25*(4), 660–663. https://doi.org/10.4103/aian.aian_779_21

Ou, Z., Pan, J., Tang, S., Duan, D., Yu, D., Nong, H., & Wang, Z. (2021). Global Trends in the Incidence, Prevalence, and Years Lived with Disability of Parkinson's Disease in 204 Countries/Territories From 1990 to 2019. *Frontiers in Public Health, 9*, 776847. https://doi.org/10.3389/fpubh.2021.776847

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., . . . Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Systematic Reviews, 10*(1), 89. https://doi.org/10.1186/s13643-021-01626-4

Pedrero-Sánchez, J. F., Belda-Lois, J. M., Serra-Añó, P., Mollà-Casanova, S., & López-Pascual, J. (2023). Classification of Parkinson's disease stages with a two-stage deep neural network. *Frontiers in Aging Neuroscience, 15*, 1152917. https://doi.org/10.3389/fnagi.2023.1152917

Postuma, R. B., Aarsland, D., Barone, P., Burn, D. J., Hawkes, C. H., Oertel, W., & Ziemssen, T. (2012). Identifying prodromal Parkinson's disease: pre-motor disorders in Parkinson's disease. *Movement Disorders, 27*(5), 617–626. https://doi.org/10.1002/mds.24996

Rafferty, M. R., Nettnin, E., Goldman, J. G., & MacDonald, J. (2021). Frameworks for Parkinson's Disease Rehabilitation Addressing When, What, and How. *Current Neurology and Neuroscience Report, 21*(3), 12. https://doi.org/10.1007/s11910-021-01096-0

Rajan, R., Divya, K. P., Kandadai, R. M., Yadav, R., Satagopam, V. P., Madhusoodanan, U. K., Agarwal, P., Kumar, N., Ferreira, T., Kumar, H., Sreeram Prasad, A. V., Shetty, K., Mehta, S., Desai, S., Kumar, S., Prashanth, L. K., Bhatt, M., Wadia, P., Ramalingam, S., . . . Sharma, M. (2020). Genetic Architecture of Parkinson's Disease in the Indian Population: Harnessing Genetic Diversity to Address Critical Gaps in Parkinson's Disease Research. *Frontiers in Neurology, 11,* 524. https://doi.org/10.3389/fneur.2020.00524

Ridgel, A. L., Peacock, C. A., Fickes, E. J., & Kim, C. H. (2012). Active-assisted cycling improves tremor and bradykinesia in Parkinson's disease. *Archives of Physical Medicine and Rehabilitation, 93*(11), 2049–2054. https://doi.org/10.1016/j.apmr.2012.05.015

Umesh, S., Asokan, U., & Srinivas, T. (2015). Parkinsonian hand tremor measurement device based on fiber bragg grating sensor. *2015 International Conference on Smart Sensors and Systems (IC-SSS)*, *2015*, 1–3. https://doi.org/10.1109/SMARTSENS.2015.7873611

Vial, F., Kassavetis, P., Merchant, S., Haubenberger, D., & Hallett, M. (2019). How to do an electrophysiological study of tremor. *Clinical Neurophysiology Practice, 4,* 134–142. https://doi.org/10.1016/j.cnp.2019.06.002

Xu, F. L., Hao, M. Z., Xu, S. Q., Hu, Z. X., Xiao, Q., & Lan, N. (2016). Development of a closed-loop system for tremor suppression in patients with Parkinson's disease. *38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), 2016*, 1782–1785. https://doi.org/10.1109/embc.2016.7591063