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Original Article

Physiotherapy Section

Physiotherapy Interventions to Improve Mobility in Children with Spastic Diplegic Cerebral Palsy: A Systematic Review

SHRIKRISHNA SHINDE[1], MOH'D IRSHAD QURESHI[2], RAGHUMAHANTI RAGHUVEER[3], HV SHARATH[4]

ABSTRACT

Introduction: Spastic diplegic Cerebral Palsy (SDCP) is a common paediatric motor disorder primarily affecting lower limb mobility. While various physiotherapy interventions have been developed to improve mobility, their comparative effectiveness remains inconclusive.

Aim: To systematically review Randomised Controlled Trials (RCTs) evaluating physiotherapy interventions aimed at enhancing mobility in children with SDCP.

Materials and Methods: This review included RCTs published between January 2014 and December 2024 that involved children aged 2-18 years diagnosed with SDCP. Comprehensive searches were conducted in PubMed, Medline, Embase, and Web of Science. Twelve eligible RCTs were evaluated for intervention type, outcomes, duration, and methodological quality using the PEDro scale.

Results: Interventions such as task-specific training, treadmill-based therapy, neurodevelopmental treatment, virtual reality, and functional electrical stimulation demonstrated varying levels of improvement in gross motor function, gait, and balance. While most studies showed moderate methodological quality, comparisons were limited due to diverse outcome measures.

Conclusion: Task-oriented, repetitive physiotherapy interventions appear effective in improving mobility among children with SDCP. However, further high-quality trials using standardised measures and long-term follow-up are needed to strengthen clinical guidance.

Keywords: Exercise therapy, Gait, Motor coordination, Physical therapy modalities, Rehabilitation

INTRODUCTION

Cerebral Palsy (CP) is a neurological condition characterised by a combination of sensory, motor, cognitive, and behavioural challenges resulting from damage to the developing brain [1]. Children affected by CP often exhibit abnormal movement patterns and postural control, in addition to difficulties with oral motor coordination, speech, and hearing [2]. It remains a significant cause of childhood disability [3]. One of the most prominent features of CP is spasticity- a form of hypertonia defined by a velocity-dependent increase in muscle tone- which has long been considered a major contributor to physical dysfunction [4]. Spasticity leads to muscle sarcomere loss and increased stiffness, promoting contracture formation and altered muscle tissue properties [5]. As such, interventions aimed at preserving or improving soft-tissue length are essential in managing CP. To this end, a range of motion assessments are frequently utilised to evaluate muscle contractures and treatment outcomes [6].

Physiotherapy plays a central role in managing CP, with nearly all diagnosed individuals referred for therapeutic services. Its goal is to facilitate functional independence, promote physical fitness, and improve health outcomes by minimising the impact of impairments on the lives of children and their families [7]. Physiotherapists implement various techniques to enhance voluntary movement, strength, autonomy, and the overall quality of life. Despite its widespread use, the efficacy of physiotherapy remains a topic of debate globally [8].

Recent trends emphasise evidence-based practice, urging clinicians to abandon ineffective or redundant therapies. This shift encourages a broader perspective- focusing not only on impairments but also on daily functioning and environmental interaction, aligned with frameworks such as the International Classification of Functioning, Disability and Health (ICF) [9]. These changes highlight the need to consider multiple dimensions of child and family well-being in intervention planning [10]. As rehabilitation options diversify, there is increasing pressure to support clinical decisions with solid evidence due to limited resources and higher expectations from health professionals.

Formulating clear questions about treatment efficacy is central to an evidence-based approach [11]. Systematic reviews and RCTs offer high-quality evidence; however, physiotherapists often face obstacles like a lack of time, limited research literacy, or restricted access to databases. Therefore, synthesised summaries of robust evidence are essential.

Children with SDCP are typically referred to physiotherapy as a standard aspect of their care. Given the critical role of physiotherapists in managing this condition, they must rely on the most up-to-date and internationally benchmarked evidence while remaining sensitive to local contexts. This systematic review aimed to map available evidence on physiotherapy interventions for children with SDCP, providing insights that can guide future research and inform effective clinical strategies.

MATERIALS AND METHODS

This systematic review followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, covering protocol formulation, literature search, screening, quality assessment, data extraction, and synthesis [12]. Eligibility criteria were defined a priori using the Population, Intervention, Comparison, Outcome, and Study design. (PICOS) framework, focusing on RCTs of physiotherapy interventions for children with SDCP. The review protocol was approved by the Institutional Ethics Committee at the Datta Meghe Institute of Medical Sciences (Approval No.: Ref. No. DMIMS(DU)/IEC/2022/958) prior to the commencement of the study. Registration with PROSPERO was not possible since it only allows prior registration before data collection. As the review was already underway when I tried to register, the Institutional ethical approval served as the official protocol documentation.

Inclusion criteria: Studies were included based on PICOS guidelines:

- Population: Children aged 2-18 years diagnosed with SDCP.
- Intervention: Physiotherapy-based treatments aimed at improving mobility outcomes, such as gait, balance, and gross motor function.
- Comparator: Conventional physiotherapy, alternate physiotherapy approaches
- Outcomes: Must include at least one mobility-related assessment (e.g., GMFM scores, gait parameters, balance scales).
- Design: Only RCTs were considered.
- Language: English.
- Publication timeframe: January 2014 to December 2024.
- Accessibility: Full-text articles available in peer-reviewed journals.

Exclusion criteria:

- Studies that used non physiotherapy interventions (e.g., pharmacological, surgical, aquatic, or passive treatments).
- Studies with outcome measures not directly related to mobility or motor function.
- Non RCT designs, such as observational, case series, or quasi-experimental studies.

Study Procedure

A thorough electronic search was performed across four major databases: PubMed, Medline, Embase, and Web of Science. The search period covered January 2014 to December 2024. Additionally, reference lists of selected articles were manually reviewed to identify further eligible studies [Table/Fig-1].

Primary databases searched included PubMed, Embase, Web of Science, and MEDLINE. Secondary searches involved reference list screening, citation searching via Google Scholar, and hand-searching relevant conference proceedings [Table/Fig-2].

All search results were exported to a reference manager for duplicate removal. Two reviewers (SS and IQ) independently screened titles and abstracts. Full-text articles were retrieved for those that appeared relevant. Discrepancies in selection were resolved through discussion or involvement of a third reviewer (RR).

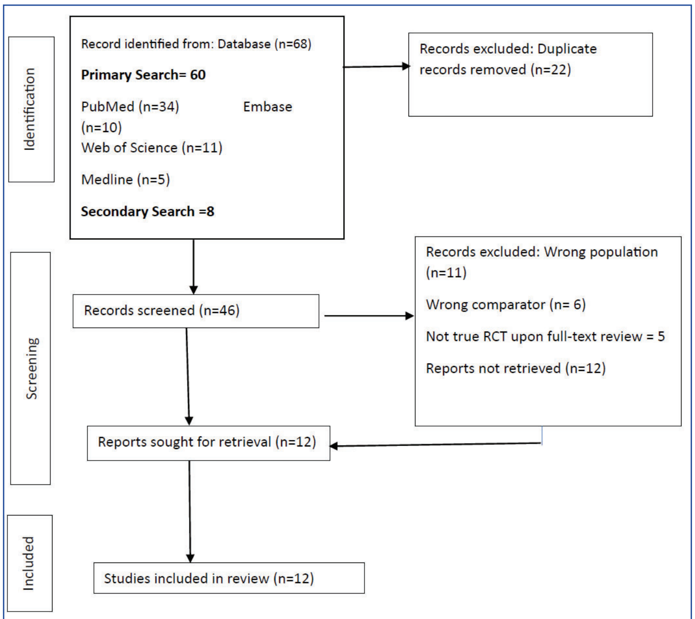
Data extraction was conducted using a standardised form. Key information collected included: author(s), publication year, country, participant demographics {age, gender, Gross Motor Function Classification System (GMFCS) level, sample size} type and duration of intervention, control group treatments, outcome measures used, and principal findings. Extraction was performed independently by RR and SV, and consensus was used to resolve any differences.

Grey literature sources (conference proceedings, theses, and non indexed reports) were identified through institutional repository searches and citation tracking. All sources were screened against predefined inclusion and exclusion criteria. Methodological quality of both indexed and grey literature was assessed using the PEDro scale, an 11-item checklist evaluating randomisation, blinding, allocation concealment, and intention-to-treat analysis [13]. Studies scoring six or above were considered to have moderate to high rigour.

Owing to substantial clinical and methodological heterogeneity in intervention type, dosage, comparators, outcomes, and participant characteristics, a meta-analysis was not feasible. Instead, a structured, systematic synthesis was undertaken, grouping

Database	Keywords Used	Articles Retrieved
PubMed (34)	Spastic Diplegia AND Neuromuscular Electrical Stimulation (NMES)	7
	Spastic Diplegic Cerebral Palsy (SDCP) (ti) AND children AND physical therapy modalities	3
	SDCP (ti) AND children AND Rehabilitations	4
	SDCP (ti) AND children AND Exercise therapy	4
	SDCP (ti) AND children AND Gait training	2
	SDCP (ti) AND children AND motor functions	3
	SDCP (ti) AND children AND Motor training	2
	SDCP (ti) AND Children AND motor functions	3
	Child With Diplegic CP AND Walking and Fitness	1
	Pelvic Proprioceptive Neuromuscular Facilitation" AND "Balance" AND "Gait" AND "Children" AND "Spastic Diplegia"	1
	Neurodevelopmental Treatment" AND "Sensory Integration Therapy" AND "Gross Motor Function" AND "Balance" AND "Gait" AND "Spastic Diplegia" AND "Children"	1
	"Loaded Sit-to-Stand" AND "Resistance Exercise" AND "Children" AND "Mild Spastic Diplegia" AND "Randomised Clinical Trial"	1
	"Whole-Body Vibration" AND "Muscle Strength" AND "Balance" AND "Diplegic CP " AND "RCT"	1
	"Strength Training" AND "Hip Extensors" AND "Knee Extensors" AND "SDCP " AND "Children"	1
Embase (10)	"SDCP AND CP AND Physiotherapy treatment AND RCT AND full text AND OR training AND rehabilitation AND therapy"	10
Medline (5)	{"SDCP "(Title) OR "spastic diplegia"(Title)} AND (physiotherapy OR "physical therapy" OR "exercise therapy" OR "motor training") AND (gait OR balance OR "gross motor function") AND (RCT OR Clinical trial)	5

[Table/Fig-1]: Search strategy.



[Table/Fig-2]: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram.

studies by physiotherapy intervention and their effects on mobility outcomes. Certainty of evidence for each intervention-outcome pair was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach, which considers risk of bias, inconsistency, indirectness, imprecision, and publication bias, with ratings classified as high, moderate, low, or very low [14].

RESULTS

From the combined electronic and manual searches, 68 articles were initially identified. After the removal of 22 duplicate records, 46 studies were screened by title and abstract. Although the search aimed for RCTs, some studies initially labelled as RCTs were later found not to adhere to this design upon full-text review. Twelve reports were listed as 'not retrieved' due to paywall restrictions or incomplete bibliographic records, and were excluded for transparency. Of these, 12 RCTs met the predefined inclusion criteria and were incorporated into the final review [Table/Fig-2].

Sample sizes in the included studies ranged from 18 to 40 children. Physiotherapy interventions examined were diverse, covering balance, mobility, strength, and task-specific training methods. Outcomes were primarily assessed using the Gross Motor Function Measure (GMFM), Paediatric Balance Scale (PBS), and gait-related parameters including stride length, cadence, velocity, and lower limb strength [Table/Fig-3] [15-26].

The risk of bias assessment using the PEDro scale showed that all included RCTs demonstrated moderate to high methodological quality, with scores ranging from 7 to 9. Common strengths included clearly defined eligibility criteria, random allocation, baseline comparability, adequate follow-up, intention-to-treat analysis, and appropriate between-group comparisons. However, consistent limitations were noted, particularly the absence of participant and therapist blinding, while assessor blinding and allocation concealment were reported only in a few studies [Table/Fig-4] [18,21,24,25]. To minimise detection bias, several trials used blinded outcome assessors; notably, Warutkar VB et al., employed an independent assessor, enhancing internal validity [25]. Overall, the studies present a moderate risk of bias.

The GRADE assessment indicated that most interventions provided moderate certainty of evidence, including Biodex balance training, Antigravity Treadmill (AGT), Whole-Body Vibration (WBV), hip/knee strength training, Neuromuscular Electrical Stimulation (NMES) with casting, NDT versus SIT, pelvic PNF, and proprioceptive-visual feedback, primarily due to consistent reporting of significant functional improvements despite limitations such as small sample sizes and short intervention durations [17,21,23-25]. In contrast, suspension training, Action Observation Training (AOT), and SIT were supported by low certainty of evidence, largely because of high risk of bias, reliance on single small trials, or non-random sampling [Table/Fig-5] [20,22,23].

S. No.	Author (Year)	Intervention	Outcome measures	Design and methodology	Participants	Duration and frequency	Key findings and effectiveness
1	El-Shamy SM and Abd El-Kafy EM (2014) [15]	Biodex Balance Training	Balance Score, GMFM	RCT	30 children with spastic diplegia (10-12 y)	30 min/day, 3×/week, 3 months	Biodex training improved postural balance control
2	Emara HAE (2014) [16]	Antigravity Treadmill (AGT) Training	Dynamic Balance Assessment	Randomised Study	Children aged 6-8 y	3 months, 3×/week	Significant balance improvement in AGT group
3	El-Shamy SM (2014) [17]	Whole-Body Vibration (WBV) Training	Muscle Strength, Stability Index	RCT	Children with diplegic CP	3 months, 5×/week	Significant muscle strength improvement
4	Emara HA and El-Gohary TM (2016) [18]	Suspension vs. Treadmill Training	GMFM, Walking Speed	Assessor-blinded RCT	Children aged 6-8 y	12 weeks, 3×/week	Suspension training improved walking ability
5	Aye T et al., (2016) [19]	Hip/Knee Extensor Strength Training	GMFM, Strength Levels	Controlled Study	Children with spastic diplegia	6 weeks, 3×/week	Improved motor function and strength
6	El-Gohary TM and Emara HA (2017) [20]	Biodex vs. Conventional Balance Training	Balance, GMFM	RCT	Children with spastic diplegia	3×/week, 12 weeks	Biodex more effective than conventional balance training
7	Hussein ZA et al., (2019) [21]	Proprioceptive-visual Feedback Training	Gait parameters (spatial, temporal, kinetic)	Randomised study	30 children (4-6 y)	8 weeks, 3×/week	Improved step length & cadence
8	Jeong Y and Lee BH (2020) [22]	Action Observation Training (AOT)	GMFM, Paediatric Reaching Test	Randomised Study	Children with spastic diplegia	6 weeks, 3×/week	Improved gross motor function and balance
9	Salphale VG et al., (2022) [23]	Pelvic PNF training	Balance, gait parameters	Randomised study	Children aged 8-12 y	4 weeks, 6×/week	Significant improvements in balance & gait
10	Raipure A et al., (2023) [24]	NDT vs. Sensory Integration Therapy (SIT)	GMFM, balance Scale	Experimental Study	Children aged 8-12 y	4 weeks, 5×/week	SIT more effective for balance and gait
11	Warutkar VB et al., (2023) [25]	SIT	Functional mobility, Sensory Profile	Experimental study	Children with spastic diplegia	4 weeks, 5×/week	Significant improvement in mobility
12	Abd Elmonem YM (2024) [26]	NMES + Serial Casting	ROM, Strength, Gait Function	Randomised Comparative Trial	33 children with spastic diplegia	8 weeks, 3×/week	NMES + casting improved gait function

[Table/Fig-3]: Summary of included studies [15-26].

PEDro Scale Item	El-Shamy SMand Abd El-Kafy EM (2014) [15]	Emara HAE (2014) [16]	El-Shamy SM (2014) [17]	Emara HA and El-Gohary TM [18]	Aye T et al., (2016) [19]	El-Gohary TM and Emara HA (2017) [20]	Hussein ZA et al., (2019) [21]	Jeong Y and Lee BH (2020) [22]	Salphale VG et al., (2022) [23]	Raipure A et al., (2023) [24]	Warutkar VB et al., (2023) [25]	Abd El-monem YM (2024) [26]
1. Eligibility criteria specified	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Random allocation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3. Concealed allocation	No	No	Yes	No	No	No	No	No	Yes	Yes	No	Yes

4. Baseline comparability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5. Blinding of subjects	No	No	No	No	No	No	No	No	No	No	No	No
6. Blinding of therapists	No	No	No	No	No	No	No	No	No	No	No	No
7. Blinding of assessors	No	No	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes (external assessor)	No
8. >85% follow-up	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9. Intention-to-treat analysis	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10. Between-group comparisons	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11. Point & variability measures	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total Score	**7**	**7**	**8**	**8**	**8**	**7**	**8**	**7**	**8**	**9**	**8**	**8**

[Table/Fig-4]: Qualitative evaluation of included study using PEDro scale scale [18,21,24,25].

Authors (Year)	Outcomes	Effect	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Certainty of Evidence
El-Shamy SM and Abd El-Kafy EM (2014) [15]	Muscle strength, balance	↑ Significant strength gains	Moderate (assessors not blinded)	No Serious	Direct	Short duration	Unclear	• • • ○ Moderate
El-Shamy SM, Abd El-Kafy EM (2014) [17]	Muscle strength, balance	↑ Significant strength & balance gains	Moderate (assessors not blinded)	No Serious	Direct	Short duration	Unclear	• • • ○ Moderate
Emara HAE (2014) [16],	Balance, GMFM	↑ Significant improvement	Moderate (unblinded assessors)	No Serious	Direct	Small sample sizes	Unclear	• • • ○ Moderate
Emara HA and El-Gohary TM (2016) [18]	Dynamic balance, gait	↑ Over conventional therapy	Moderate	No Serious	Direct	Small sample, no long-term follow-up	Unclear	• • • ○ Moderate
Aye T et al., (2016) [19]	GMFM, muscle strength	↑ Improved motor outcomes	Moderate	No Serious	Direct	Sample size unclear	Not Detected	• • • ○ Moderate
El-Gohary TM and Emara HA al., (2017) [20]	GMFM, walking speed	↑ Walking ability	High (no assessor blinding)	Serious	Direct	Small sample	Unclear	• • ○ ○ Low
Hussein ZA et al., (2019) [21]	Strength, ROM, gait	↑ Greater improvement	Moderate	No Serious	Direct	Moderate sample	Suspected	• • • ○ Moderate
Jeong Y and Lee BH (2020) [22]	GMFM, motor control	↑ Motor function	High (single small RCT)	Unclear	Direct	Very small sample	Detected	• • ○ ○ Low
Salphale VG et al., (2022) [23]	Functional mobility	↑ Mobility, sensory profile	High (non-random sampling)	Serious	Direct	Small sample	Unclear	• • ○ ○ Low
Raipure A et al., (2023) [24]	GMFM, balance, gait	↑ SIT more effective	Moderate	No Serious	Direct	Small sample	Unclear	• • • ○ Moderate
Warutkar VB et al. (2023) [25]	Balance, gait	↑ Improved symmetry & gait	Moderate	No Serious	Direct	Small sample	Unclear	• • • ○ Moderate
Abd Elmonem YM (2024) [26]	Gait parameters	↑ Step length, cadence	Moderate	No Serious	Direct	Short follow-up	Suspected	• • • ○ Moderate

[Table/Fig-5]: GRADE ratings reflect the certainty of evidence based on risk of bias, consistency, directness, precision, and publication bias [15-16].

DISCUSSION

This systematic review synthesised findings from 12 RCTs that evaluated the effects of physiotherapy interventions in children diagnosed with SDCP. Across the studies, consistent gains were reported in areas such as gross motor function, gait performance, and balance. Interventions included Biodex balance training, AGT, body-weight support training, NMES with casting, AOT, WBV, Neurodevelopmental Therapy (NDT) versus SIT, pelvic Proprioceptive Neuromuscular Facilitation (PNF), proprioceptive-visual feedback training, SIT, and strength-based interventions

Biodex balance training was reported by El-Shamy SM and Abd El-Kafy EM and Emara HA and El-Gohary TM to improve postural control and gross motor function, with significant increases in PBS and GMFM scores [15,18]. Progressive balance activities for children with CP improved balance and stability [19]. AGT training was shown by Emara HAE to enhance dynamic balance and gait, demonstrating superior functional outcomes compared to conventional therapy [16]. The combination of NMES with serial casting preserved muscle strength and improved gait parameters, according to Abd Elmonem YM et al., [26]. AOT led to enhanced motor coordination and balance, likely through mirror neuron activation and cognitive-motor integration, as demonstrated by Jeong Y and Lee BH [22]. WBV interventions were found to increase muscle strength and balance, as evidenced by improvements in multiple Biodex outcome measures [23]. Comparative studies between NDT and SIT indicated that SIT was more effective in enhancing gait, balance, and gross motor outcomes [24]. Pelvic PNF techniques were found to improve gait speed, pelvic alignment, and balance, as reported by Salphale VG et al., [23]. Additionally, proprioceptive-visual feedback interventions led to improvements in gait cadence and step length, outperforming standard gait training, as observed by Hussein ZA et al., [26]. SIT resulted in better functional mobility and sensory integration outcomes compared to conventional physiotherapy, according to Warutkar VB et al., [25]. Targeted strength training of the hip and knee extensors was associated with improvements in GMFM scores and limb strength in the study by Aye T et al., [19].

The findings of this review are aligned with prior systematic reviews and meta-analyses, such as the 2022 analysis by Merino-Andrés, which highlighted the significance of intensive, task-oriented interventions in paediatric rehabilitation [27]. Multisensory techniques that combine motor learning and sensory feedback consistently show greater efficacy than unimodal approaches. The consistency of benefits observed in this review further strengthens the evidence supporting such integrative interventions in the CP population.

Limitation(s)

Although outcomes were promising, most studies had small sample sizes, limiting statistical power and generalisability. Methodological quality ranged from moderate to high, with random allocation and baseline comparability generally maintained. However, assessor blinding and allocation concealment were inconsistently applied, and participant/therapist blinding was not feasible, introducing risks of bias. Considerable heterogeneity in intervention type, frequency, duration, and outcome measures hindered direct comparison. Most trials excluded children at GMFCS levels IV and V, reducing applicability to those with severe impairments. Broader impacts, such as activities of daily living and psychosocial well-being, were rarely assessed. Variations in assessment tools, timing, and clinical settings, along with differences in participant characteristics and intervention protocols, limited direct comparisons across studies. Due to this clinical heterogeneity, a quantitative meta-analysis was not feasible; instead, a structured narrative synthesis by intervention type was used to interpret the findings.

CONCLUSION(S)

The present review summarises findings from 12 RCTs investigating physiotherapy for children with SDCP. Interventions like Biodex balance training, AGT therapy, NMES, and strengthening programs were linked to improved gross motor function, gait, and balance. Techniques such as action observation, WBV, and SIT showed promising results, but evidence is limited due to small sample sizes and varied study designs. Intensive, task-oriented, and goal-based therapy appears most effective. Future physiotherapy plans should be individualised, incorporating both conventional and innovative techniques, with a focus on long-term follow-up and family involvement.

Authors' contributions: SS conceived the review, developed the search strategy, and drafted the manuscript; IQ participated in study selection, data extraction, and risk of bias assessment; RR and SV contributed to the critical revision of the manuscript and supervised the overall process. All authors read and approved the final manuscript.

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Authors used an AI language tool solely to refine grammar and clarity of expression. All scientific content, literature searches, data extraction, analyses and interpretations were performed by the authors, who accept full responsibility for the work." The authors would like to thank all staff of Ravi Nair Physiotherapy College for their guidance and support during the preparation of this manuscript.

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PARTICULARS OF CONTRIBUTORS:
1. PhD Scholar, Ravi Nair Physiotherapy College, Datta Meghe Institute of Higher Education and Research, Wardha, India.
2. Principal, Ravi Nair Physiotherapy College, Datta Meghe Institute of Higher Education and Research, Wardha, India.
3. Head, Ravi Nair Physiotherapy College, Datta Meghe Institute of Higher Education and Research, Wardha, India.
4. Assistant Professor, Ravi Nair Physiotherapy College, Datta Meghe Institute of Higher Education and Research, Wardha, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Shrikrishna Shinde,
PhD Scholar, Ravi Nair Physiotherapy College, Datta Meghe Institute of Higher Education and Research, Sawangi (Meghe), Wardha-442001, Maharashtra, India.
Email: krishnashinde12989@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: May 31, 2025
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- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

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