RESEARCH PAPER

Effect Of Stationary Cycling On Lower Extremity Motor Function And Balance In Children With Spastic Cerebral Palsy: A Systematic Review

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Abstract

Background: Spastic cerebral palsy (CP) often impairs lower-extremity strength, coordination, and balance, affecting gait and functional independence. Stationary cycling is increasingly used as a task-specific, low-impact intervention to improve motor function, muscle activation, and postural control in children with CP.

Objective: To systematically review evidence on the effectiveness of stationary cycling in improving lower-extremity motor function and balance among children with spastic cerebral palsy.

Methods: Relevant studies were identified from databases including PubMed, Scopus, and Web of Science. Randomized controlled trials involving stationary or FES-assisted cycling were included. Outcomes examined were lower-limb strength, gross motor function, gait performance, cycling motor control, and balance.

Results: Findings indicate that stationary cycling improves lower-extremity muscle strength, enhances cadence and motor control, and produces small-to-moderate gains in gross motor function (GMFM D & E) and endurance. Balance outcomes show modest but variable improvements. FES-assisted cycling may further enhance cadence and training intensity, though evidence remains limited by small sample sizes and heterogeneous protocols.

Conclusion: Stationary cycling is a safe, feasible, and effective adjunct intervention for improving lower-extremity strength and selected motor outcomes in children with spastic CP. While promising benefits for balance exist, stronger evidence from standardized, large-scale trials is needed to define optimal training parameters and long-term effects.

Keywords: Spastic Cerebral Palsy, Stationary Cycling, Lower-Extremity Motor Function, Balance, Gross Motor Function, FES-Assisted Cycling, Rehabilitation.

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Introduction

Cerebral palsy (CP) is a permanent, non-progressive neurodevelopmental condition resulting from injury to the developing brain, leading to long-term disturbances in movement, posture, and functional performance.[1] Spastic cerebral palsy represents the most prevalent clinical subtype and is characterized by hypertonia, impaired selective motor control, poor coordination, muscle weakness, and balance dysfunction. These neuromotor impairments significantly restrict a child's ability to perform daily activities, compromise gait efficiency, and negatively impact overall quality of life. Consequently, rehabilitation for children with spastic CP emphasizes muscle strengthening, enhancement of motor coordination, balance training, and the promotion of functional independence through task-specific therapeutic strategies.[2]

In recent years, stationary cycling has gained recognition as an effective intervention within pediatric neurorehabilitation. The rhythmic and reciprocal nature of pedaling provides a controlled environment for activating lower-limb muscle groups while simultaneously improving joint mobility. Additionally, cycling minimizes the postural demands associated with upright functional tasks such as walking, thereby enabling children with moderate to severe motor impairments to participate in repetitive, high-intensity lower-limb training.[3] Existing evidence indicates that structured cycling programs contribute to improvements in muscle strength, cadence consistency, cardiovascular endurance, and motor control, all of which are vital components of functional mobility in children with CP.[4] Cycling interventions can also be customized using adapted equipment such as modified pedals, trunk supports, and foot straps, allowing participation across a wide range of Gross Motor Function Classification System (GMFCS) levels. Furthermore, functional electrical stimulation (FES)–assisted cycling enhances

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muscle activation and is especially beneficial for children with more pronounced neuromuscular deficits.[5] Strong evidence from structured intervention programs, including the Pediatric Endurance and Limb Strengthening (PEDALS) trial, has demonstrated significant improvements in lower-limb strength, aerobic fitness, and gross motor function following multi-week stationary cycling training.[6]

Balance impairments remain one of the major functional challenges faced by children with spastic CP and are closely associated with limitations in gait performance and independent mobility. Although stationary cycling is primarily a seated activity, enhancements in lower-limb strength and neuromuscular coordination obtained through cycling interventions have been shown to contribute positively to dynamic balance and functional postural control.[7] Nevertheless, the literature presents mixed findings regarding the direct transfer of cycling-related improvements to upright balance tasks, with some studies reporting modest benefits and others observing limited effects.

Given the increasing clinical utilization of stationary cycling and the variability in reported functional outcomes, there is a clear need for consolidated evidence. Therefore, a systematic review examining the effects of stationary cycling on lower-extremity motor function and balance in children with spastic cerebral palsy is both timely and essential.

Methods

This systematic review followed a structured approach to identify, evaluate, and synthesize available evidence on the effects of stationary cycling interventions on lower-extremity motor function and balance in children with spastic cerebral palsy (CP). The methodological framework was based on PRISMA guidelines to ensure transparency and rigor in the search, selection, and analysis process.

Search Strategy:

A comprehensive literature search was conducted across major electronic databases, including PubMed, Scopus, Web of Science, PEDro, and Google Scholar. The search included studies published up to 2025. Keywords and Boolean combinations used were: *"cerebral palsy"*, *"spastic cerebral palsy"*, *"stationary cycling"*, *"cycling training"*, *"pedaling"*, *"FES cycling"*, *"lower limb motor function"*, and *"balance"*. Reference lists of relevant articles and systematic reviews were also screened manually to identify additional eligible studies.

Inclusion Criteria:

The eligibility criteria included children or adult aged between 5-58 years diagnosed with spastic cerebral palsy. Studies involving interventions such as stationary cycling, volitional cycling, adapted cycling, and functional electrical stimulation (FES)–assisted cycling were considered. Relevant outcomes focused on lower-extremity motor function, including muscle strength, gait parameters, Gross Motor Function Measure (GMFM) scores, cadence, and balance-related measures. Eligible study designs comprised randomized controlled trials only and were published in English language were included.

Exclusion Criteria:

Studies involving adults with CP, non-spastic CP without subgroup analysis, cycling performed outdoors rather than on stationary devices, and studies lacking quantitative outcome measures were excluded. Single case reports were excluded unless they provided relevant mechanistic insights.

Study Selection:

Two reviewers independently screened titles and abstracts. Full-text articles were assessed for eligibility according to inclusion criteria. Disagreements were resolved through consensus.

Data Extraction:

Key data extracted included study design, participant characteristics, intervention duration, cycling modality, frequency and intensity, outcome measures, and main findings. Outcome categories were: (1) muscle strength, (2) gross motor function, (3) gait/endurance, (4) cycling motor control, and (5) balance.

Quality Assessment:

The PEDro scale was used for RCTs. Methodological concerns included small sample sizes, limited blinding, and intervention variability.

This structured approach ensured a balanced and comprehensive synthesis of the existing literature on stationary cycling in children with spastic CP.

Results

The results of this systematic review indicate that stationary cycling, including adapted and FES-assisted cycling, has a positive and clinically meaningful effect on lower-extremity motor function in children with spastic cerebral palsy. Across the included studies, consistent improvements were observed in lower-limb muscle strength, particularly in the quadriceps, hamstrings, and ankle musculature, along with significant gains in Gross Motor Function Measure (GMFM) scores, especially in standing and walking-related dimensions. Gait parameters such as walking speed, cadence, step length, and endurance also showed notable enhancement following cycling-based interventions. Improvements in cycling motor control, including pedaling symmetry and coordination, were widely reported. Balance outcomes demonstrated variable but generally modest improvements, with better dynamic postural control observed in some studies, likely secondary to gains in strength and neuromuscular coordination. Despite methodological limitations such as small sample sizes and variability in intervention protocols, the overall evidence supports stationary cycling as an effective and feasible adjunct therapy for improving lower-extremity motor performance and

functional mobility in children with spastic cerebral palsy.

Discussion

This systematic review consolidated existing evidence on the effects of stationary cycling on lower-extremity motor function and balance in children with spastic cerebral palsy (CP). The synthesized findings indicate that stationary cycling, including adapted and FES-assisted modalities, consistently enhances lower-limb muscle strength, gross motor performance, gait characteristics, and cycling motor control, while balance outcomes show variable yet generally favorable trends. These findings reinforce the role of cycling as a task-specific, repetitive, and functionally meaningful intervention in pediatric neurorehabilitation.[3]

The documented improvements in lower-limb muscle strength, particularly in the quadriceps, hamstrings, and ankle musculature, are strongly supported by earlier studies emphasizing the role of repetitive pedaling in facilitating reciprocal muscle activation and resistance-based strengthening. In contrast to conventional strengthening exercises that demand high levels of postural control, stationary cycling enables children with compromised trunk stability to safely perform high-repetition lower-limb training. Furthermore, FES-assisted cycling has demonstrated superior muscle recruitment and greater strength gains, especially in children with more severe motor impairments, highlighting its added therapeutic value.

The observed improvements in Gross Motor Function Measure (GMFM) Dimensions D and E signify meaningful functional transfer from stationary cycling to standing and ambulatory activities. These results align with established motor learning principles that emphasize repetition, task specificity, and training intensity in functional recovery [2,6]. Enhancements in gait speed, cadence, step length, and walking endurance reported across studies further suggest that regular cycling contributes to improved neuromuscular coordination and aerobic conditioning in children with spastic CP.

Balance-related outcomes presented mixed findings across the reviewed literature. Since stationary cycling is predominantly performed in a seated position, its direct influence on upright postural control mechanisms remains limited. However, modest improvements in dynamic balance reported in some studies may be attributed to secondary gains in lower-limb strength, improved motor symmetry, and enhanced functional stability during standing and ambulatory tasks. These observations indicate that while cycling alone may not be sufficient for comprehensive balance rehabilitation, it serves as an effective preparatory intervention when integrated with upright balance-specific training programs.[6]

From a clinical applicability standpoint, stationary cycling is a safe, adaptable, and highly accessible intervention for children across multiple GMFCS levels with the use of external supports such as trunk stabilization, foot straps, and FES assistance. Additionally, cycling contributes positively to cardiovascular fitness and endurance, which are commonly reduced in children with CP due to limited participation in physical activities. The motivational aspect of cycling further enhances adherence and engagement in long-term rehabilitation programs.

Despite these promising outcomes, several methodological limitations were identified within the existing literature. Most studies were characterized by small sample sizes, short intervention durations, absence of long-term follow-up, and considerable heterogeneity in cycling protocols and outcome measures. Inconsistent assessor blinding further increases the risk of measurement bias, thereby limiting the strength of definitive conclusions regarding optimal training dosage and sustained effectiveness.[7]

Future research should prioritize high-quality randomized controlled trials with standardized cycling parameters, clearly defined training intensity, and extended follow-up periods to evaluate the longevity of functional benefits. Greater emphasis on multidimensional outcome measures, including balance, participation, and quality-of-life indicators, is also warranted. Moreover, combined intervention approaches integrating stationary cycling with task-oriented gait training and balance-specific exercises may yield superior functional outcomes. Collectively, the current evidence supports stationary cycling as a valuable, evidence-based adjunct for enhancing lower-extremity motor function and mobility in children with spastic cerebral palsy.

Conclusion

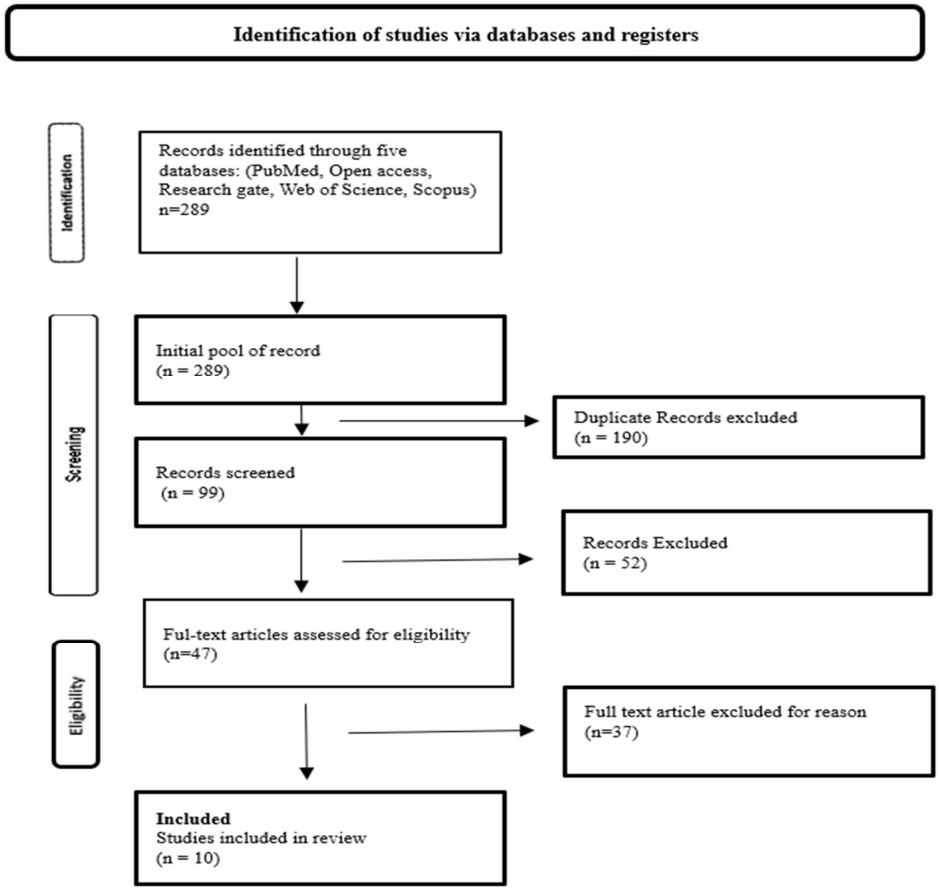
This systematic review concludes that stationary cycling is an effective, safe, and feasible therapeutic intervention for improving lower-extremity motor function in children with spastic cerebral palsy. Consistent improvements were observed in muscle strength, gross motor function, gait parameters, endurance, and cycling motor control following structured cycling programs. Although balance outcomes showed variable results, modest improvements in dynamic postural control were noted, likely as a secondary effect of enhanced lower-limb strength and neuromuscular coordination. Adapted and FES-assisted cycling further broaden the applicability of this intervention across different severity levels. Despite existing methodological limitations within the reviewed studies, the overall evidence supports the inclusion of stationary cycling as a valuable adjunct to conventional rehabilitation programs. Future high-quality randomized controlled trials with standardized protocols and long-term follow-up are recommended to establish optimal training parameters and long-term functional benefits.

List of literatures that is reviewed

Table. 1

S. No.	Author (Year)	Study Design	Sample Size	Age group	Intervention Type	Key Findings
1	Eileen G. Fowler et.al (2010)	RCT	62	7-18	Stationary cycling	Significant improvements in locomotor endurance, gross motor function, and some measures of strength were found for the cycling group but not the control group, providing preliminary support for this intervention.
2	SHARON K DEMUTH et.al (2012)	RCT	62	7-18	PEDALS Stationary cycling	A beneficial influence of exercise on pediatric emotional well-being and parental treatment expectations was found
3	Ragab K. Elnaggar et.al (2021)	RCT	42	8-12	Stretch-shortening cycling exercise	The evidence from this study suggests that SSC exercises besides standard physical rehabilitation appear to be effective for improving gait symmetry and boosting balance capabilities in children with UCP.
4	Duygu Türker et.al (2023)	RCT	20	-	Functional Electrical stimulation cycling	FES-C applied in addition to conventional physical therapy in children with diplegic cerebral palsy is more effective than conventional physical therapy for increasing functional muscle strength, improving gross motor function functions, and reducing energy expenditure.
5	Ellen L Armstrong et.al (2019)	RCT	40	6-8	FES Cycling	Significant result on the children with FES Cycling
6	Diane L. Damiano et.al (2017)	RCT	27	5-17	Motor assisted cycle training	Task-specific effects were similarly positive across groups, but no transfer was seen to gait or function.
7	C.-L. Chen et.al (2012)	RCT	27	6-12	Virtual cycling	Analytical findings suggest that the muscle strengthening program is more specific in enhancing bone density for children with CP than general physical activity.
8	Punnee Peungsuwan et.al (2017)	RCT	15	7-16	Combined exercise training	Combined exercise training improved walking ability, functional lower limb strength, and balance in participants with cerebral palsy
9	Iqra Mahnoor et.al (2024)	RCT	24	6-12	PEDALS	PEDALS program as well as lower limb strength training is equally effective in improving endurance, gross motor function and ROM in children with diplegic CP
10	Lisbeth Hoejkjaer L arsen et.al (2025)	RCT	23	13-58	Coach led virtual home base cycling	Our findings suggest that virtual cycling at home is a safe and feasible approach to engage in moderate- to high-intensity exercise, enhance physical capacity, and improve functional activity outcomes for individuals with activity limitations

PRISMA Flowchart of the Search Process



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