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Exercise-Based Interventions for Balance and Motor Function in Cerebral Palsy: A Systematic Review

Chalvina Radisa Nafti[1], Sri Novia Fauza[2]

[1,2]Department of Physiotherapy, Vocational Education Program, University of Indonesia, Depok, Indonesia

Corresponding author:
Name: Chalvina Radisa Nafti
E-mail: chalvinadissa@gmail.com
Phone: +62 896-7867-8188

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Abstract

Background: Cerebral palsy (CP) is the leading cause of childhood physical disability, characterized by impairments in balance, postural control, and motor function that limit functional independence. Evidence comparing different exercise-based interventions remains limited.

Objective: To synthesize evidence on the effects of exercise-based interventions on balance, trunk control, gross motor function, and functional performance in children with CP.

Methods: A systematic review was conducted in accordance with PRISMA 2020 guidelines. Electronic databases (PubMed, Scopus, ScienceDirect, SAGE, Cochrane Library, and Wanfang Data) were searched up to March 2025. Randomized controlled trials involving children with CP were included. A total of 10 studies comprising 288 participants were analyzed. Data were synthesized narratively due to heterogeneity in interventions and outcome measures. Risk of bias was assessed using the Cochrane RoB 2 tool.

Results: Core stability training improved balance and gait parameters (knee flexion 81% vs 41%; $p<0.05$). Swiss ball stabilization showed significant improvements in trunk control ($\eta^2p=0.86$; $p<0.001$) and gross motor function. Task-oriented training demonstrated consistent improvements in gross motor function and balance ($p<0.0001$). Pilates, dual-task training, and sit-to-stand interventions also resulted in significant functional gains.

Conclusion: Exercise-based interventions improve motor and functional outcomes in children with CP. Task-oriented training shows the most consistent evidence, while core stabilization and Swiss ball training provide additional benefits. However, heterogeneity and methodological limitations restrict definitive conclusions regarding comparative effectiveness.

Keywords
cerebral palsy; exercise therapy; postural balance; motor skills; physical therapy modalities

Introduction

Cerebral palsy (CP) is a heterogeneous group of permanent, non-progressive neurodevelopmental disorders caused by injury to the developing fetal or infant brain, resulting in impairments in movement, posture, and functional activity.[1,2] Although the neurological lesion is static, its clinical manifestations evolve over time, often leading to long-term limitations in mobility and independence.[3] CP remains the most common cause of childhood physical disability worldwide, with a global prevalence estimated at approximately 2.4 per 1,000 live births. [4] However, more recent epidemiological evidence suggests variability across regions, reflecting differences in neonatal care and early intervention services.[4–6]

Motor impairments in children with CP are multifactorial, encompassing spasticity, muscle weakness, impaired selective motor control, and deficits in postural stability.[7] These impairments significantly restrict the ability to perform functional activities such as standing, walking, and task-oriented movements.[8] Among CP subtypes, spastic CP accounts for approximately 75–80% of cases and includes both diplegic and hemiplegic presentations.[7,8] Children with spastic diplegia typically exhibit lower extremity involvement with compromised trunk stability, whereas those with hemiplegic CP demonstrate asymmetrical motor control and impaired balance, often resulting in compensatory movement patterns.[9]

Postural control is a fundamental prerequisite for functional movement and is frequently impaired in children with CP.[7–9] Deficits in trunk control and balance have been identified as key determinants of functional limitation, influencing both gross motor performance and activities of daily living.[10] The trunk musculature serves as the biomechanical and neuromuscular foundation for coordinated movement, providing proximal stability that enables distal mobility.[7,8,10] Impairments in core stability are therefore closely associated with inefficient movement patterns, reduced gait performance, and decreased functional independence.

In response to these challenges, a wide range of exercise-based interventions has been developed within pediatric neurorehabilitation. These include core stability training, Swiss ball stabilization exercises, Pilates-based interventions, task-oriented training (TOT), dual-task paradigms, and sit-to-stand training programs.[11,12] Contemporary rehabilitation approaches increasingly emphasize task-specific, repetitive, and goal-directed training, consistent with principles of motor learning and neuroplasticity.[12] Emerging evidence suggests that such interventions may improve not only motor outcomes but also functional participation and independence.[11,12]

Despite the growing body of randomized controlled trials (RCTs) investigating individual interventions, the current literature remains fragmented. Most studies focus on single modalities, with limited attempts to compare the relative effectiveness of different exercise-based approaches across key outcomes such as balance, trunk control, gross motor function, and functional performance.[13,14] Furthermore, recent systematic reviews have often concentrated on specific interventions rather than providing a comprehensive

synthesis of multiple exercise modalities within a unified framework. This lack of integrative analysis limits the ability of clinicians to make evidence-based decisions regarding intervention selection and prioritization.

From a conceptual perspective, the International Classification of Functioning, Disability and Health (ICF) framework provides a useful model for understanding the multidimensional impact of CP. Within this framework, impairments in body structure and function, such as reduced trunk stability and balance deficits, directly influence activity limitations and participation restrictions. Integrating exercise-based interventions that target multiple domains of functioning is therefore essential to optimize rehabilitation outcomes.[15,16]

Accordingly, a clear evidence gap exists. Despite increasing RCT evidence, no recent synthesis has comparatively evaluated multiple exercise-based interventions targeting balance, trunk control, and motor function in children with CP within a single systematic review framework. Addressing this gap is critical for advancing clinical practice and guiding individualized rehabilitation strategies.

Therefore, this systematic review aims to synthesize current evidence on the effectiveness of exercise-based interventions on balance, trunk control, gross motor function, and functional performance in children with CP. Specifically, this review addresses the following research question: in children with cerebral palsy (Population), how do exercise-based interventions (Intervention), compared with conventional therapy or other exercise modalities (Comparison), affect balance, trunk control, and functional outcomes (Outcomes)? It is hypothesized that exercise-based interventions, particularly those targeting core stability and task-specific training, will demonstrate superior improvements in motor and functional outcomes compared to conventional approaches.

Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The review was designed to synthesize evidence from randomized controlled trials (RCTs) evaluating the effectiveness of exercise-based interventions in children with cerebral palsy (CP).

This study employed a systematic review design with narrative synthesis. The eligibility criteria were defined using the Population, Intervention, Comparison, Outcome, and Study design (PICOS) framework. The population included children aged <18 years with a confirmed diagnosis of CP, regardless of subtype or severity level as classified by the Gross Motor Function Classification System (GMFCS). The interventions of interest were exercise-based approaches targeting balance, trunk control, or motor function, including but not limited to core stability training, Swiss ball exercises, Pilates, task-oriented training, dual-task training, and sit-to-stand programs.

The comparison groups included conventional physiotherapy, neurodevelopmental treatment, or alternative exercise interventions. The primary outcomes were balance, trunk control, and gross motor function, while secondary outcomes included functional performance and activities of daily living. Only randomized controlled trials published between 2019 and 2025 in peer-reviewed journals were included. Systematic reviews were excluded from the primary synthesis to maintain methodological consistency. Studies were excluded if they were non-randomized, narrative reviews, conference abstracts, grey literature, or not available in full text. Articles published in languages other than English or Indonesian were also excluded.

A comprehensive literature search was conducted in PubMed, Scopus, ScienceDirect, SAGE Journals, the Cochrane Library, and Wanfang Data from database inception to March 2025. Google Scholar was used only as a supplementary source to identify potentially relevant studies, with results screened manually to minimize bias.

The search strategy combined Medical Subject Headings (MeSH) and free-text terms using Boolean operators (AND/OR). The core search string included: (“cerebral palsy” OR “CP”) AND (“exercise therapy” OR “core stability” OR “Swiss ball” OR “Pilates” OR “task-oriented training” OR “dual-task training” OR “sit-to-stand”) AND (“balance” OR “postural control” OR “gross motor function” OR “functional performance”). The full search strategy for each database is available upon request.

All retrieved records were imported into reference management software and duplicates were removed. Two independent reviewers screened titles and abstracts for eligibility, followed by full-text assessment. Discrepancies were resolved through discussion, and when necessary, consultation with a third reviewer.

To enhance methodological rigor, inter-rater agreement was assessed using Cohen’s kappa coefficient, with values interpreted according to standard thresholds ($\kappa > 0.75$ indicating excellent agreement). Screening was conducted using a structured approach; however, no specialized screening software (e.g., Rayyan or Covidence) was used.

The study selection process is summarized narratively as follows: a total of 1,335 records were identified through database searching. After removal of 434 duplicates, 901 records were screened by title and abstract, resulting in 92 articles assessed for full-text eligibility. Of these, 82 were excluded for not meeting inclusion criteria, leaving 10 studies included in the final synthesis. This process is illustrated in Figure 1.

Data extraction was performed independently by two reviewers using a standardized data extraction form developed for this review. Extracted variables included study characteristics (author, year, country, design), participant characteristics (sample size, age, CP subtype, GMFCS level), intervention details (type, duration, frequency, intensity), comparator interventions, outcome measures, and key findings.

Primary outcomes included balance (e.g., Pediatric Balance Scale), trunk control (e.g., Trunk Control Measurement Scale), and gross motor function (e.g., Gross Motor Function Measure [GMFM-66/88]). Secondary outcomes included functional performance measures such as the Pediatric Evaluation of Disability Inventory (PEDI) and Functional Independence Measure for Children (WeeFIM). These instruments are widely used and have demonstrated acceptable validity and reliability in pediatric populations with CP. Primary outcomes included balance, trunk control, and gross motor function, assessed using standardized instruments. Gross motor function was commonly evaluated using the Gross Motor Function Measure (GMFM-66/88), which has demonstrated excellent validity and reliability in children with cerebral palsy, with high inter-rater and test–retest reliability.[23] Balance was frequently assessed using the Pediatric Balance Scale (PBS), a modified version of the Berg Balance Scale, which has shown good construct validity and strong reliability in pediatric neurological populations.[24] Trunk control was evaluated using the Trunk Control Measurement Scale (TCMS), which has been validated for children with CP and exhibits high internal consistency and inter-rater reliability.[25] Missing or unclear data were addressed by cross-checking study reports; however, no attempts were made to contact authors.

The methodological quality and risk of bias of included studies were assessed using the Cochrane Risk of Bias 2 (RoB 2) tool for randomized controlled trials. This tool evaluates bias across five domains: randomization process, deviations from intended interventions, missing outcome data, measurement of outcomes, and selection of reported results. Each domain was rated as “low risk,” “some concerns,” or “high risk,” and an overall risk of bias judgment was assigned for each study. Disagreements between reviewers were resolved through discussion.

The primary effect measures considered were mean differences (MD) and standardized mean differences (SMD) for continuous outcomes. Where reported, effect sizes such as partial eta squared (η^2p) were also extracted. Due to substantial clinical and methodological heterogeneity across studies, including differences in intervention types, outcome measures, and study populations, a meta-analysis was not performed. Instead, a narrative synthesis approach was used to summarize findings across studies. This approach followed established guidance for synthesizing heterogeneous evidence. Due to substantial clinical and methodological heterogeneity across studies, including variations in intervention protocols, participant characteristics, and outcome measures, a meta-analysis was not considered appropriate. Therefore, a narrative synthesis approach was employed to systematically summarize and interpret the findings.

The narrative synthesis was conducted in accordance with established methodological guidance, involving structured comparison of study characteristics, grouping of interventions based on modality, and thematic analysis of outcomes across studies. This approach allows for transparent synthesis of heterogeneous evidence while preserving the context of individual study findings.[2627] Heterogeneity was assessed qualitatively based on variations in study characteristics, and subgroup analyses were not feasible due to limited data. Publication bias was not formally assessed using funnel plots or statistical tests due to the limited number of included studies (<10), which may reduce the reliability of such analyses.

Publication bias was not formally assessed due to the small number of included studies. Similarly, the certainty of evidence was not evaluated using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework. These limitations are acknowledged in the discussion section. As this study is a systematic review of previously published data, ethical approval was not required. All included studies were assumed to have obtained appropriate ethical clearance.

Results

The study selection process followed PRISMA 2020 guidelines and is presented narratively to facilitate subsequent visualization as a flow diagram. A total of 1,335 records were identified through database searching. After removing 434 duplicates, 901 records remained for title and abstract screening. Of these, 809 records were excluded due to irrelevance to the study objectives. The remaining 92 articles underwent full-text assessment for eligibility.

Following full-text review, 82 studies were excluded for the following reasons: non-randomized design (n=34), irrelevant intervention (n=21), outcomes not aligned with study objectives (n=15), and insufficient data reporting (n=12). Ultimately, 10 randomized controlled trials met all inclusion criteria and were included in the final synthesis. The study selection process followed PRISMA 2020 guidelines and is presented below in a structured text-based flow format to facilitate conversion into a visual diagram (Figure 1).

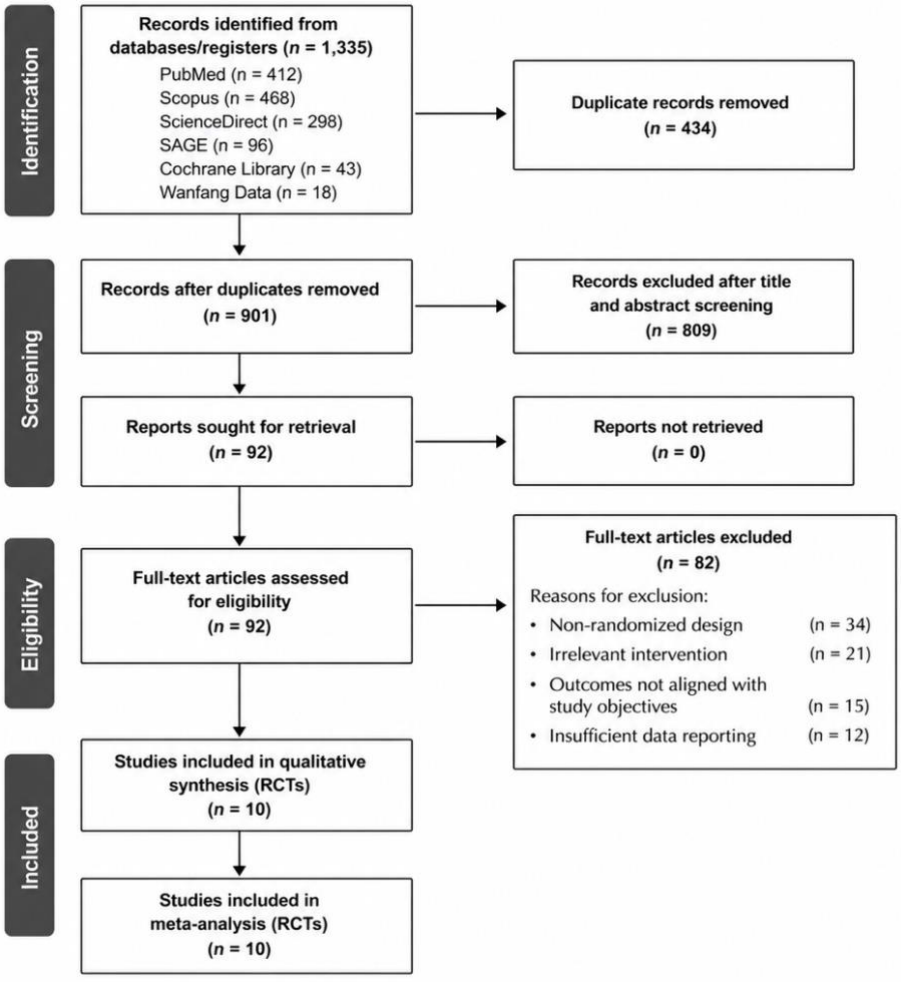

Figure 1. PRISMA 2020 flow diagram of study selection process

To provide a comprehensive overview of the included studies, Table 1 summarizes the study design, participant characteristics, intervention protocols, outcome measures, and principal findings. This structured presentation enables comparison across studies without duplicating detailed numerical data in the narrative. Across the 10 included randomized controlled trials, a total of 288 participants aged 3–15 years were analyzed. Most studies involved children with spastic cerebral palsy, with functional levels

ranging from GMFCS I to IV. Intervention duration ranged from 4 to 12 weeks, with frequencies between two and five sessions per week.

Table 1. Characteristics of Included Randomized Controlled Trials

No	Author (Year)	Design	Sample	Age	Intervention vs Control	Duration	Outcomes	Key Findings
1	Mohamed et al. (2025)[17]	RCT	N=40	4–10	Core stability + PT vs PT	12 wks	GMFM, PBS	Balance ↑ 9%; knee flexion 81% vs 41%
2	Zai et al. (2022)[17]	Meta-analysis (RCTs)	n=893	<18	TOT vs control	4–16 wks	GMFM, BBS	GMFM MD=11.05; BBS MD=6.23
3	Abd-Elfattah et al. (2022)[18]	RCT	N=40	7–9	Pilates vs PT	10 wks	GMFM, PBS	Significant improvement (p<0.001)
4	Küçük & Cekmece (2025)[19]	RCT	N=36	5–12	Core stabilization vs PT	4 wks	PBBS, TCMS	Significant trunk & balance gains
5	Rastgar Koutenaei et al. (2023)[20,21]	RCT	N=30	6–12	Swiss ball vs stable	5 wks	TCMS, GMFM	η^2p=0.86 trunk control
6	Lee et al. (2021)[22]	RCT	N=14	6–12	Dual-task vs NDT	8 wks	GMFM, balance	Significant improvements
7	Elanchezhian & SwarnaKumari (2019)[21]	RCT	N=30	4–11	Swiss ball vs PT	6 wks	GMFM, PBS	Higher post-test scores
8	Abd-Elhameed et al. (2025)[23]	RCT	N=30	4–6	Core stability vs PT	8 wks	Reach test	Significant reaching improvement
9	Chaovalit et al. (2021)[24]	RCT	N=38	4–12	Sit-to-stand vs PT	6 wks	WeeFIM	Mobility ↑, caregiver strain ↓
10	Jaiswal et al. (2022)[25]	RCT	N=30	3–6	Swiss ball vs simulator	8 wks	PBS, TCMS	Balance superior

Note:
GMFM = Gross Motor Function Measure; PBS = Pediatric Balance Scale; TCMS = Trunk Control Measurement Scale; TOT = task-oriented training; PT = physiotherapy; NDT = neurodevelopmental treatment.

The methodological quality of the included studies was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool. Overall, the included trials demonstrated moderate methodological quality. The methodological quality of the included studies was assessed using the Cochrane Risk of Bias 2 tool. Overall, most studies demonstrated low risk of bias in outcome measurement due to the use of validated instruments. However, several studies presented some concerns in the randomization process, particularly due to unclear allocation concealment. Blinding of participants and personnel was generally not feasible, introducing potential performance bias. Small sample sizes and short intervention durations were common limitations across studies. The methodological quality of the included studies was assessed using the Cochrane Risk of Bias 2 tool, and the detailed results are presented in Table 2.

Table 2. Risk of Bias Assessment (RoB 2)

Study	Randomization	Deviations from Intervention	Missing Data	Outcome Measurement	Reporting Bias	Overall
Mohamed et al. (2025)	Some concerns	Low	Low	Low	Low	Some concerns
Abd-Elfattah et al. (2022)	Low	Some concerns	Low	Low	Low	Some concerns
Küçük & Cekmece (2025)	Some concerns	Low	Low	Low	Low	Some concerns
Rastgar Koutenaei et al. (2023)	Low	Low	Low	Low	Low	Low
Lee et al. (2021)	Some concerns	Some concerns	Low	Low	Low	Some concerns
Elanchezhian & SwarnaKumari (2019)	High	Some concerns	Low	Low	Some concerns	High
Abd-Elhameed et al. (2025)	Low	Low	Low	Low	Low	Low
Chaovalit et al. (2021)	Low	Low	Low	Low	Low	Low
Jaiswal et al. (2022)	Some concerns	Low	Low	Low	Low	Some concerns

Note:
Categories are based on the RoB 2 classification: low risk, some concerns, and high risk.

Most studies showed low risk of bias in outcome measurement due to the use of validated assessment tools such as GMFM, PBS, and TCMS. However, several studies presented “some concerns” in the randomization process due to insufficient reporting of allocation concealment. Additionally, blinding of participants and personnel was generally not feasible given the nature of exercise-based interventions, resulting in potential performance bias. Incomplete outcome data and selective reporting were minimal across studies, although small sample sizes and short intervention durations were common limitations. A summary of the risk of bias assessment should be presented in a structured table or figure in the final manuscript.

The effects of exercise-based interventions are presented according to the primary outcomes of this review: balance, trunk control, gross motor function, and functional performance. Due to heterogeneity in study design, interventions, and outcome measures, results are synthesized narratively. Core stability training consistently demonstrated improvements in balance and gross motor function. One study reported substantially greater improvements in gait parameters in the intervention group compared to controls, including knee flexion (81% vs 41%; $p<0.05$). Additional studies reported significant improvements in Pediatric Balance Scale and Trunk Control Measurement Scale scores, as well as enhanced upper extremity reaching performance.

Swiss ball stabilization training showed significant benefits in trunk control and gross motor outcomes compared with stable surface training. One study reported large effect sizes for trunk control (η^2p=0.86) and gross motor function (η^2p=0.60), indicating strong intervention effects. Improvements in abdominal muscle thickness were also observed, suggesting neuromuscular adaptations associated with unstable surface training. Task-oriented training demonstrated consistent and clinically meaningful improvements across multiple domains, including gross motor function and balance. Task-oriented training demonstrated significant improvements in gross motor function (MD = 11.05; 95% CI: 8.20–13.90) and balance (MD = 6.23; 95% CI: 4.10–8.36; $p < 0.0001$). Reported mean

differences indicated substantial improvements in GMFM and balance scores (all p<0.0001), suggesting that task-specific training is highly effective in promoting functional outcomes. Task-oriented training demonstrated consistent and clinically meaningful improvements in gross motor function (MD = 11.05; 95% CI: 8.20–13.90) and balance (MD = 6.23; 95% CI: 4.10–8.36; p < 0.0001). Pilates-based interventions resulted in significant improvements in balance and gross motor function compared with conventional therapy, while dual-task training enhanced both static and dynamic balance as well as walking-related motor function. Sit-to-stand training demonstrated improvements in functional independence, particularly in self-care and mobility domains, alongside reductions in caregiver burden.

Across studies, effect sizes and confidence intervals were inconsistently reported, limiting direct quantitative comparison between interventions. Confidence intervals were not consistently reported across studies, limiting the precision of effect estimates. No meta-analysis was conducted due to substantial heterogeneity in intervention protocols, outcome measures, and participant characteristics. Considerable heterogeneity was observed across included studies in terms of CP subtypes, GMFCS levels, intervention protocols, and outcome measures. This variability precluded quantitative synthesis and subgroup analysis. Subgroup analyses based on CP subtype or functional level were not feasible due to insufficient reporting and small sample sizes. Similarly, publication bias and sensitivity analyses were not conducted, as the number of included studies was insufficient to support reliable statistical assessment.

To enhance the interpretation of the findings, the certainty of evidence across key outcomes was evaluated using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach. The summary of findings, including effect estimates and certainty ratings, is presented in Table 3.

Table 3. Summary of Findings (GRADE Approach)

Outcome	No. of Studies	Sample Size	Effect Estimate	Certainty of Evidence (GRADE)	Comments
Balance	7 RCTs	~200	Improved vs control	Moderate ⊕⊕⊕○	Downgraded for heterogeneity
Trunk Control	5 RCTs	~150	Large improvement (η^2p up to 0.86)	Moderate ⊕⊕⊕○	Small sample sizes
Gross Motor Function	8 RCTs	~250	Significant improvement (MD reported)	Moderate ⊕⊕⊕○	Inconsistent reporting
Functional Performance	4 RCTs	~120	Improved ADL and mobility	Low ⊕⊕○○	Limited studies, heterogeneity

Note:
Certainty downgraded due to heterogeneity, small sample size, and risk of bias.

Discussion

This systematic review synthesized evidence from randomized controlled trials evaluating the effects of exercise-based interventions on balance, trunk control, gross motor function, and functional performance in children with cerebral palsy (CP). Overall, the findings indicate that multiple exercise modalities provide beneficial effects compared with conventional physiotherapy; however, the magnitude and consistency of these effects vary across interventions, and the overall certainty of evidence remains limited due to methodological heterogeneity and risk of bias.

Core stabilization training emerged as a consistently beneficial intervention, particularly for improving balance, trunk control, and functional motor outcomes. These findings are biomechanically plausible, as the trunk musculature plays a central role in providing proximal stability required for coordinated distal limb movement.[2,7] Improved trunk stability enhances anticipatory and reactive postural adjustments, which are essential for maintaining balance and executing functional tasks.[7,10,11] More recent rehabilitation frameworks emphasize the integration of core stability into functional training paradigms, suggesting that improvements in trunk control may translate into broader gains in activity and participation domains.[2,9] More recent evidence supports the effectiveness of core stability–focused interventions in children with cerebral palsy, with systematic reviews reporting significant improvements in trunk control, balance, and gross motor function following targeted core training programs.[10]

Swiss ball stabilization training demonstrated substantial improvements in trunk control and gross motor function, with large reported effect sizes in some studies. The unstable surface provided by the Swiss ball likely increases neuromuscular demand by stimulating proprioceptive and vestibular systems, thereby enhancing postural control strategies.[11,12] However, the apparent superiority of Swiss ball interventions should be interpreted with caution. The evidence base is limited to a small number of studies with relatively small sample sizes, and methodological limitations such as lack of blinding and unclear allocation concealment introduce potential bias. These findings are consistent with recent systematic reviews in pediatric neurorehabilitation, which report positive but heterogeneous effects of unstable surface training. Recent systematic reviews have also highlighted the effectiveness of unstable surface training in improving postural control and balance in children with cerebral palsy, suggesting that interventions involving dynamic support surfaces may enhance neuromuscular activation and sensory integration more effectively than stable surface training.[11,12]

Task-oriented training demonstrated the most consistent and robust evidence across studies, including findings from meta-analytic data. Improvements in gross motor function and balance are supported by principles of motor learning and neuroplasticity, whereby repetitive, goal-directed practice enhances cortical reorganization and functional skill acquisition.[3,8] Importantly, task-oriented approaches align closely with contemporary clinical guidelines that recommend activity-based and participation-focused interventions for children with CP.[2,9,15,16] Compared with impairment-based interventions, task-oriented training may offer greater transferability to real-world functional activities, supporting its clinical relevance.

Other interventions, including Pilates, dual-task training, and sit-to-stand programs, also demonstrated beneficial effects on motor and functional outcomes.[12,14] Pilates-based exercises emphasize controlled movement, core activation, and postural alignment, which may contribute to improved trunk stability and balance.[12,26] Dual-task training introduces cognitive-motor interference, potentially enhancing adaptability and functional performance in complex environments. Sit-to-stand training, particularly when delivered with sufficient intensity, appears to improve functional independence and reduce caregiver burden in children with moderate-to-severe CP. These findings highlight the importance of intervention specificity and dosage in achieving clinically meaningful outcomes.

Despite these positive findings, several important limitations must be considered. Substantial heterogeneity was observed across studies in terms of participant characteristics, including cerebral palsy subtype and Gross Motor Function Classification System levels, as well as intervention protocols and outcome measures. This heterogeneity precluded quantitative synthesis and

limits the generalizability of the findings. In addition, many studies included small sample sizes and short intervention durations, reducing statistical power and limiting conclusions regarding long-term effectiveness. Methodological limitations identified through the risk of bias assessment, particularly related to randomization and blinding, further introduce uncertainty in the estimated effects. Although statistically significant improvements were observed, the clinical relevance of these changes should be interpreted cautiously, as minimal clinically important differences were not consistently reported across studies. Furthermore, this systematic review was not registered in PROSPERO, which may affect transparency and reproducibility.

Furthermore, the absence of standardized reporting of effect sizes and confidence intervals across studies complicates direct comparison between interventions. From a certainty of evidence perspective, although a formal GRADE assessment was not conducted, the overall quality of evidence can be considered low to moderate due to these methodological constraints. This limitation should be explicitly acknowledged when interpreting the findings and formulating clinical recommendations.

Importantly, the present review identified a gap between research evidence and clinical application. While most studies were conducted in controlled clinical settings, limited attention has been given to the feasibility and effectiveness of home-based or caregiver-assisted interventions.[4,5] This represents a critical area for future research, particularly in low-resource settings where access to specialized rehabilitation services may be limited.

From a clinical perspective, the findings suggest that no single intervention can be considered universally superior. Instead, exercise-based interventions should be selected and individualized based on patient characteristics, including CP subtype, functional level, and rehabilitation goals. Task-oriented training appears to have the strongest evidence base, while core stabilization and Swiss ball training may serve as complementary approaches to enhance trunk control and balance. However, clinicians should interpret these findings in the context of the limited certainty of evidence and consider integrating multiple modalities within a comprehensive rehabilitation program.

Future research should prioritize high-quality, adequately powered randomized controlled trials with standardized outcome measures and longer follow-up periods. Additionally, comparative effectiveness studies and meta-analyses are needed to clarify the relative benefits of different exercise modalities. The incorporation of GRADE methodology and reporting of minimal clinically important differences (MCID) would further strengthen the clinical applicability of future evidence.

Conclusion

This systematic review demonstrates that exercise-based interventions are associated with improvements in balance, trunk control, gross motor function, and functional performance in children with cerebral palsy. Among the evaluated modalities, task-oriented training shows the most consistent evidence, while core stabilization and Swiss ball training appear to provide additional benefits, particularly in enhancing trunk stability and postural control.

However, the overall certainty of evidence remains limited due to heterogeneity in study designs, variability in intervention protocols, and methodological limitations identified across included trials. Consequently, no single intervention can be definitively recommended as superior.

From a clinical perspective, these findings support the integration of multiple exercise-based approaches tailored to individual patient characteristics, including CP subtype, functional level, and rehabilitation goals. Future research should focus on well-designed randomized controlled trials with standardized outcome measures, longer follow-up periods, and rigorous reporting of effect sizes and confidence intervals to strengthen the evidence base and inform clinical decision-making.

Author Contribution

Chalvina Radisa Nafti: Conceptualization, Methodology, Investigation, Formal Analysis, Data Curation, Writing Original Draft, Supervision.
Sri Novia Fauza: Investigation, Data Curation, Visualization, Writing Review and Editing.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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Ethics Statement

This study is a systematic review of previously published literature and did not involve direct human or animal subjects. Ethical approval was therefore not required.

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