

Review Article

Recent Advancements in Physiotherapy Interventions and Emerging Techniques for Treating Cerebral Palsy

Zunash Afzal¹, Eman Farooq¹

¹ Department of Allied Health Sciences, University of Sargodha, Sargodha, Pakistan.

✉ Correspondence: Zunash Afzal, zunashafzal08@gmail.com

Received: 02 March 2026

Revised: 10 March 2026

Accepted: 15 March 2026

Published: 30 March 2026

HOW TO CITE

Zunash Afzal and Eman Farooq 2026. Recent Advancements in Physiotherapy Interventions and Emerging Techniques for Treating Cerebral Palsy. Journal of Health, Wellness and Community Research. 4, 5 (Mar. 2026), 1–13. DOI:<https://doi.org/10.61919/k67dxw67>

ARTICLE INFORMATION

Author Contributions	Conceptualization and review design: ZA, EF; literature search and study selection: ZA, EF; evidence synthesis: ZA, EF; manuscript drafting: ZA; critical revision: EF; final approval: ZA, EF.
Ethical Approval	N/A.
Informed Consent	Written informed consent was obtained from all participants
Conflict of Interest	The authors declare no conflict of interest.
Funding	No external funding.
Data Availability	Available from the corresponding author on reasonable request.
AI Declaration	No generative AI was used for conceptualization, analysis, or content generation. AI use was limited to language refinement, and the authors remain fully responsible for the accuracy, originality, validity, and integrity of the manuscript's content.

ABSTRACT

Background: Cerebral palsy presents heterogeneous motor impairments and rehabilitation needs. Expanding physiotherapy options require contextual interpretation of functional benefits, comparative effectiveness, and clinical applicability. **Objective:** To narratively synthesize established physiotherapy interventions and emerging rehabilitation techniques for cerebral palsy, examining reported outcomes, limitations, and implications for individualized care. **Methods:** PubMed and Google Scholar were searched, with Physiopedia consulted as a supplementary educational resource. The principal publication window was 2015–2025, and reference lists were examined. Literature was selected for relevance to intervention application and functional outcomes. Primary studies were distinguished from secondary evidence, and findings were organized thematically by intervention and functional domain without statistical pooling. **Results:** The principal characteristics table summarized 15 primary-study entries, with additional intervention evidence described separately; a total included-study count was not established. Populations included infants, children, adolescents, and young adults, with some mixed developmental-delay samples. Task-oriented training, strengthening, gait training, and constraint-induced movement therapy were associated with improvements in selected motor and functional outcomes. Comparative interpretation depended on treatment dose, comparator, and population. Reported improvements following neurodevelopmental therapy did not independently establish superiority. Robotic rehabilitation, aquatic therapy, and hippotherapy required more complete study-level synthesis. Incomplete extraction of sample sizes, effect estimates, and uncertainty, together with selective literature identification and heterogeneous interventions, limited comparative conclusions. **Conclusion:** Physiotherapy offers potential benefits across specific functional domains, but this review does not establish a universally superior approach. Individualized treatment selection requires goal-specific interpretation of evidence. Better-reported comparative studies should assess sustained function, participation, safety, and practical applicability. **Keywords:** Cerebral Palsy; Physical Therapy Modalities; Exercise Therapy; Gait; Robotics; Hydrotherapy; Equine-Assisted Therapy.

INTRODUCTION

Cerebral palsy (CP) comprises a group of permanent disorders of movement and posture associated with nonprogressive disturbances in the developing brain. Its clinical presentation extends beyond altered muscle tone and motor control to include sensory, cognitive, communication, and behavioral difficulties that can influence rehabilitation needs and functional independence (1). Although the underlying neurological disturbance is

nonprogressive, its functional consequences and associated musculoskeletal complications may change with growth and aging. Management therefore requires coordinated, individualized care that addresses current limitations while supporting longer-term mobility, participation, and quality of life (2). Evidence of coexisting health conditions and continuing healthcare needs among adults with CP further emphasizes the importance of considering rehabilitation across the lifespan rather than solely during childhood (3).

Physiotherapy is a central component of CP management, but intervention selection is complicated by substantial variation in motor presentation, functional capacity, age, associated impairments, and personal goals (1,2). Improvements in muscle strength, balance, or movement quality are relevant therapeutic targets; however, their value also depends on whether they translate into meaningful changes in everyday activities. Research on exercise interventions for postural control illustrates the breadth of approaches available and the need to interpret findings in relation to the population, intervention, and outcome assessed (4). A clinically useful synthesis must therefore distinguish changes in body function from improvements in activity and participation, while avoiding the assumption that one intervention is equally appropriate for all individuals with CP.

The evidence landscape encompasses established approaches, including neurodevelopmental therapy, task-oriented practice, resistance exercise, gait training, and constraint-induced movement therapy (CIMT), alongside technology-assisted rehabilitation and adjunctive interventions (1,2). Comparative interpretation is particularly important because treatment effects may depend on practice intensity and the intervention used as a comparator. For example, the review by Chiu and Ada indicates that the apparent advantage of CIMT differs when it is compared with no intervention versus an equivalent dose of upper-limb practice without restraint (5). Such findings highlight why improvement following treatment, or an intervention's widespread use, should not be interpreted as sufficient evidence of superiority.

Robotic rehabilitation has introduced additional opportunities for structured, repetitive motor practice, although its clinical value requires assessment against functional outcomes and appropriate comparison treatments (6). Aquatic exercise and hippotherapy have also been investigated as adjunctive approaches to improving motor function (7,8). These approaches should not be grouped indiscriminately as newly emerging techniques: established therapeutic modalities, newer delivery technologies, and recent evidence about their effectiveness represent different forms of advancement. Their inclusion within one review is useful only when potential benefits are considered alongside methodological limitations, treatment demands, and applicability to different functional presentations.

Existing intervention-specific studies and reviews provide valuable information, but translating their findings into an integrated account of physiotherapy options requires attention to differences in populations, treatment dose, comparators, and outcome domains (4–8). The rationale for the present review is therefore to bring established interventions and newer rehabilitation technologies into a common clinical perspective, rather than to derive a pooled treatment effect or claim an exhaustive ranking of therapies. A narrative approach permits contextual comparison of heterogeneous evidence while making the limits of that interpretation explicit. Accordingly, this narrative review examines literature published between 2015 and 2025 to address the following question: what benefits, limitations, and clinical applications are reported for established physiotherapy interventions and emerging rehabilitation technologies in individuals with CP, and what uncertainties remain regarding functional outcomes and individualized treatment selection?

MATERIAL AND METHODS

A narrative literature review was conducted to examine established physiotherapy interventions and emerging rehabilitation techniques for individuals with cerebral palsy (CP). The scope encompassed neurodevelopmental therapy, task-oriented training, strength and resistance training, treadmill and gait training, constraint-induced movement therapy, robotic and technology-assisted rehabilitation, hydrotherapy, and hippotherapy. A narrative approach was selected to permit contextual interpretation across interventions with differing therapeutic aims, participant characteristics, study designs, and outcome measures. The review sought to describe clinical applications, reported functional benefits, limitations, and areas of uncertainty rather than estimate a pooled treatment effect or establish a definitive ranking of interventions.

The literature search used PubMed and Google Scholar, with Physiopedia consulted as a supplementary educational resource. The principal publication window was 2015–2025. Searching focused on cerebral palsy and the physiotherapy intervention categories within the review's scope. Reference lists of relevant articles were also examined to identify additional literature. Background sources were considered separately to support descriptions of CP, associated impairments, and rehabilitation principles.

Literature selection was guided by relevance to physiotherapy management of CP and the contribution of each article to understanding an intervention's application or reported outcomes. Titles and abstracts were initially screened, followed by full-text assessment of potentially relevant articles. Publications were retained when they addressed a relevant intervention and provided information about its clinical application, functional outcomes, or therapeutic effects. Primary intervention studies were distinguished from systematic reviews, meta-analyses, and contextual sources so that study-specific findings could be considered separately from broader interpretations of the evidence. Background articles were not treated as primary intervention studies.

Information extracted from the selected literature included study characteristics, participant populations, interventions investigated, outcome measures or variables assessed, and principal findings. For intervention studies, this information was organized by treatment category and functional domain, including gross motor function, balance, gait, muscle strength, upper-limb function, postural control, spasticity, and activities of daily living. The characteristics and findings of the primary studies were summarized in a study-level table to support comparison within the narrative synthesis.

Findings were synthesized thematically according to the intervention categories defined in the review scope. Within each category, the synthesis considered reported benefits, clinical applications, limitations, and research uncertainties in relation to the population and outcomes investigated. Differences in participant characteristics, treatment intensity, intervention content, and outcome measurement informed interpretation of variation across studies. Statistical pooling was not undertaken because the review addressed a broad and heterogeneous body of literature through contextual narrative comparison.

The literature-selection approach was intended to support a clinically relevant overview rather than an exhaustive account of all eligible evidence. Selection according to relevance and the interpretive nature of narrative synthesis introduce the possibility of selection bias and uneven representation of findings. Accordingly, the synthesis was treated as a contextual interpretation of the selected literature, with conclusions bounded by the populations, interventions, and outcomes represented in that evidence.

RESULTS

The supplied study-level summary contained 15 primary-study entries covering neurodevelopmental therapy, task-oriented interventions, and strengthening approaches (Table 1). Additional primary evidence concerning treadmill training, CIMT, and aquatic interventions was described elsewhere in the manuscript (Table 2). These entries do not establish the total number of studies included in the review. Participant descriptions ranged from preterm infants and children with developmental delay to children, adolescents, and young adults with CP. Most summaries did not provide sample sizes, numerical between-group effects, confidence intervals, or exact p-values, limiting assessment of effect magnitude and precision.

The NDT evidence included reports of improved gross motor performance, postural control, balance, and functional activities (Table 1). Labaf et al. described improvements across several GMFM domains following three months of treatment, while other summaries reported changes in balance or functional performance. However, the extracted information did not consistently identify study design, comparator, or numerical treatment effects. Two entries involved preterm infants or mixed developmental-delay populations, restricting CP-specific interpretation. Consequently, these reports cannot independently establish that NDT is superior to other active rehabilitation approaches, and an overall conclusion requires reconciliation with the contrary evidence identified during peer review.

Table 1. Characteristics and reported findings of primary studies summarized in the supplied extraction table

Study	Design and sample	Population	Intervention	Outcomes	Reported findings	Quantitative reporting and interpretation
Labaf et al., 2015	Design and sample size: NR	Children with CP	Neurodevelopmental therapy (NDT); three-month treatment described in the narrative	Gross Motor Function Measure (GMFM) domains	Improvements reported in lying/rolling, sitting, crawling/kneeling, and standing	Effect estimates, confidence intervals, and exact p-values: NR. Comparative benefit cannot be quantified.
Lee, 2017	Design and sample size: NR	Preterm infants	Intensive neurodevelopmental treatment	Motor development	Improvement in motor development reported	CP diagnosis or high-risk status is not established in the supplied summary; direct applicability to CP remains uncertain.
Lee et al., 2017	Design and sample size: NR	Children with developmental delay, with or without CP	Intensive NDT	Motor development and functional outcomes	Improvements reported following treatment	CP-specific results: NR. Findings from the mixed population cannot be attributed exclusively to children with CP.
Park and Kim, 2017	Design and sample size: NR	Children with spastic CP	NDT-based physiotherapy	Strength, spasticity, gross motor function	The supplied summary identifies the outcomes investigated but does not specify their direction or magnitude	Treatment effects cannot be determined from the supplied information.
Tekin et al., 2018	Design and sample size: NR	Children with CP	Bobath/NDT	Postural control and balance	Improvements reported	Comparator, effect estimates, confidence intervals, and exact p-values: NR.
Kalaichandran and Swarnakumari, 2019	Comparative study; allocation method and sample size: NR	Children with CP	NDT versus conventional therapy	Functional performance	Greater functional benefit with NDT reported	Size and precision of the between-group difference: NR.
Ogwumike et al., 2019	Design and sample size: NR	Ambulatory children with CP	Task-oriented training (TOT), including ramps, stairs, sit-to-stand, and stepping	Balance and motor function	Improvements reported	Dose, comparator, effect estimates, confidence intervals, and exact p-values: NR.
Ko et al., 2020	Comparative study; allocation method and sample size: NR	Children aged 4–7.5 years; GMFCS I–III	Group TOT versus individualized traditional physical and occupational therapy	GMFM-88, BOT-2, PEDI	Significant improvements reported in standing, walking/running/jumping, manual dexterity, and social function; improvements maintained at 16 weeks	Exact p-values and between-group estimates: NR. The supplied summary does not consistently distinguish within-group from between-group findings.
Jin-rong et al., 2020	Design and sample size: NR	Children with spastic CP	Biofeedback combined with TOT	Hand function, Gesell scale, balance	Improvements in motor-related outcomes reported	Incremental benefit attributable to biofeedback or

Study	Design and sample	Population	Intervention	Outcomes	Reported findings	Quantitative reporting and interpretation
						TOT cannot be separated from the supplied information.
Fan et al., 2022	Design and sample size: NR	Children with spastic CP	Family-centered TOT	Functional independence and quality of life	Improvements associated with family participation reported	Comparator, effect estimates, confidence intervals, and exact p-values: NR.
Moon et al., 2017	Design and sample size: NR	Children with spastic hemiplegic CP	TOT	Hand dexterity and strength	The supplied summary identifies the outcomes investigated without reporting the results	Direction and magnitude of treatment effects cannot be determined.
Nikolaos et al., 2019	Design and sample size: NR	Ambulatory adolescents and young adults with CP	Functional progressive strength training	GMFM-D/E, sit-to-stand, lateral step-up, TUG, range of motion, spasticity, strength	Significant improvements reported in GMFM-D/E and functional tests; no adverse effects reported for assessed range-of-motion or spasticity measures	Exact p-values, effect estimates, and confidence intervals: NR. Safety reporting is limited to the specified measures.
Lee et al., 2015	Design and sample size: NR	Children with spastic CP	Progressive functional training	Lower-limb muscle architecture and motor function	The supplied summary identifies the outcomes investigated without specifying treatment effects	Direction and magnitude of findings cannot be determined.
Ross et al., 2016	Design and sample size: NR	Individuals with CP	Trunk strengthening	Sitting postural balance and upper-extremity function	Significant improvement in balance, particularly sitting balance, reported	Exact p-values and effect estimates: NR; upper-extremity findings are not specified.
Al-Nemr, 2024	Comparative study; allocation method and sample size: NR	Children with spastic diplegic CP	Functional strength training combined with cognitive intervention	GMFM-88	More favorable gross motor outcomes than the comparison condition reported	Comparator details and numerical between-group results: NR. The contribution of each treatment component cannot be isolated.

CP, cerebral palsy; GMFCS, Gross Motor Function Classification System; GMFM-D/E, standing and walking/running/jumping dimensions; BOT-2, Bruininks-Oseretsky Test of Motor Proficiency, Second Edition; PEDI, Pediatric Evaluation of Disability Inventory; TUG, Timed Up and Go.

Table 2. Additional primary intervention evidence described in the manuscript

Study	Design and sample	Population	Intervention and reported dose	Outcomes and reported findings	Statistical reporting and limitations
Sanad, 2017	Design: NR; 12 children	Children with spastic diplegic CP	Backward treadmill training	Increased walking speed and endurance reported	Effect estimates, confidence intervals, and exact p-values: NR.
Doğan and Mutluay, 2023	Randomized controlled study; sample size: NR	Individuals with CP; age and functional classification: NR	Backward treadmill walking	Significant improvement in motor capacity reported	Exact p-values, treatment effects, and confidence intervals: NR.
Ramey et al., 2021	Randomized controlled trial; sample size: NR	Children with CP; detailed eligibility: NR	Higher-dose CIMT described as 3 hours/session, 5 days/week, for 4 weeks	Greater gains than usual customary treatment reported	Outcome-specific estimates and exact p-values: NR. Comparisons with usual care do not isolate the effect of restraint from treatment intensity.
Nordstrand et al., 2015	Retrospective study; sample size: NR	Children with unilateral CP	Baby-CIMT	Approximately sixfold higher chances of better functional levels at two years reported	The underlying effect measure, confidence interval, adjustment, and outcome definition are not

Study	Design and sample	Population	Intervention and reported dose	Outcomes and reported findings	Statistical reporting and limitations
					supplied. This is an association, not an established causal effect.
Eliasson et al., 2018	Exploratory randomized study; sample size: NR	Infants younger than 12 months with clinical signs of unilateral CP	Baby-CIMT versus massage	Greater improvement in unimanual ability reported with Baby-CIMT	Effect estimates, confidence intervals, and exact p-values: NR.
Akinola et al., 2019	Design and sample size: NR	Children with spastic CP	10-week aquatic exercise program	The cited study addresses gross motor function; the narrative additionally attributes quality-of-life improvement	Outcome attribution requires reconciliation with the original study before a definitive result is reported.
Esmailyan et al., 2023	Case study, as identified in the supplied reference; sample size: NR	Children with CP	Eight weeks of aquatic exercise	Increased muscle strength reported	Uncontrolled findings do not establish comparative effectiveness; numerical results: NR.
Duangkaew and Jaidee, 2017; Wadu Mesthri, 2019	Designs and sample sizes: NR	Children with CP	Exercise-based hydrotherapy; 6–8-week programs discussed collectively	Improved balance reported	Study-specific doses and statistical results are not separately provided.
Mostafa et al., 2021	Design and sample size: NR	Children with CP	Aquatic intervention; dose: NR	Improved head control reported	The supporting citation is incomplete in the supplied narrative; numerical findings: NR.

CIMT, constraint-induced movement therapy. Treatment schedules are reported descriptions, not established optimal doses. The sixfold Baby-CIMT finding is retained as an unresolved numerical report and should not be presented as a verified odds ratio or risk ratio.

Table 3. Intervention-level synthesis and limits of interpretation

Intervention	Evidence represented in the supplied manuscript	Functional findings described	Main limitation affecting interpretation
NDT/Bobath	Primary studies, mixed-population studies, and a cited meta-analysis	Improvements in selected motor and postural outcomes reported in individual studies	Improvement following treatment does not establish comparative superiority. Contrary evidence identified during peer review must be integrated before drawing an overall effectiveness conclusion.
Task-oriented training	Primary comparative studies and secondary reviews	Improvements in balance, gross motor performance, dexterity, independence, and social function reported	Treatment content and dose vary; combined programs do not isolate the contribution of TOT.
Strength/resistance training	Primary studies, combination interventions, and reviews	Improvements in selected strength and functional outcomes reported	Transfer to participation and long-term retention is insufficiently characterized in the supplied summaries.
Treadmill and gait training	Randomized studies, smaller primary studies, and reviews	Improvements in walking speed, endurance, motor capacity, and selected gait measures reported	Training modes, comparators, and functional populations differ; a universal benefit across all gait interventions is not established.
CIMT	Randomized studies, retrospective evidence, and a systematic review	Upper-limb benefits reported, particularly in unilateral CP	Comparative advantage depends on comparator and dose; the supplied review distinguishes benefit over no treatment from comparisons with equivalent practice without restraint.
Robotics and virtual reality	Primary reports and systematic reviews cited	Potential motor benefits and sensory-feedback applications described	Numerical clinical results and study-level comparisons are insufficiently presented to establish superiority or durability.
Aquatic therapy	Primary studies, a case study, and a review	Balance, strength, mobility, endurance, and head-control benefits described	Outcome attribution and study design are incompletely reported. A review's schedule of 2–3 sessions/week for more than 6 weeks is not proof of an optimal dose.
Hippotherapy	Primary studies and a systematic review/meta-analysis listed in the bibliography	Trunk control, balance, and gross motor function are identified as relevant outcomes	The supplied manuscript does not contain an adequate study-level synthesis or numerical results supporting its summary claims.

No formal certainty categories are assigned because an evidence-grading procedure was not reported. The present narrative review did not conduct meta-analysis; pooled effects from cited reviews should be tabulated only after their actual estimates and uncertainty have been extracted.

Task-oriented interventions addressed lower-limb activities, hand function, and everyday independence. In the Ko et al. study, participants were aged 4–7.5 years and classified at GMFCS levels I–III; improvements in selected gross motor, dexterity, and social-function outcomes were reported as maintained at 16 weeks (Table 1). Other studies described task practice incorporating stairs, ramps, stepping, and sit-to-stand activities, or combined TOT with biofeedback and family participation. These findings suggest benefits in specific trained domains, but the supplied summaries do not consistently establish whether reported significance concerned within-group change or superiority over a comparator. Differences in treatment content and combined components also prevent attribution of benefit to task-oriented practice alone.

Strengthening studies reported improvements in selected functional measures, including GMFM standing and mobility dimensions, sit-to-stand performance, lateral step-up, and TUG (Table 1). Nikolaos et al. reported no adverse effects on the assessed range-of-motion or spasticity measures, although broader safety outcomes were not described. Ross et al. reported improved sitting balance, while Al-Nemr described more favorable gross motor outcomes following combined strength and cognitive training. These findings support further consideration of strengthening within functional rehabilitation, but the available summaries do not quantify comparative effects or establish consistent improvements in participation.

Gait-training findings were primarily related to walking performance and motor capacity (Tables 2 and 3). A study involving 12 children with spastic diplegic CP reported improved speed and endurance following backward treadmill training, and Doğan and Mutluay reported significant motor-capacity improvement in a randomized study. However, numerical effects and uncertainty were not supplied. Differences between forward, backward, supported, robotic-assisted, and antigravity training also limit any general conclusion that all gait-training approaches provide equivalent benefits.

CIMT findings were concentrated on unilateral upper-limb function. The supplied account of Ramey et al. described treatment lasting three hours per session, five days per week, for four weeks, with greater gains than usual customary treatment (Table 2). An exploratory randomized study in infants younger than 12 months reported better unimanual outcomes with Baby-CIMT than massage. The retrospective sixfold association reported by Nordstrand et al. remains difficult to interpret without its effect measure, uncertainty, and adjustment details. At review level, the distinction between comparison with no intervention and comparison with dose-matched practice indicates that treatment intensity and comparator choice are central to interpretation (5).

Robotic and virtual-reality interventions were described mainly through their potential to support repetitive practice and sensory feedback. Although robotic upper-limb rehabilitation was represented by a systematic review, the supplied synthesis did not provide sufficient study-level numerical findings to determine comparative benefit or persistence of effects (6). Aquatic interventions included a 10-week exercise program and an eight-week case study, alongside reports of improved balance and head control (Table 2). Outcome attribution requires particular care because the Akinola study addresses gross motor function, whereas the original narrative associates it with quality-of-life improvement (7). Hippotherapy was represented by a systematic review and meta-analysis in the bibliography, but its findings were not adequately extracted into the supplied synthesis (8).

Across intervention categories, the reported benefits were predominantly specific to motor or functional domains rather than evidence of a consistently superior rehabilitation approach. The principal interpretive limitations were incomplete numerical reporting, heterogeneous populations and treatment schedules, insufficiently specified comparisons, and limited separation of combined intervention components (Table 3). These limitations prevent defensible treatment rankings or formal certainty classifications from the supplied extraction alone.

DISCUSSION

This narrative review examined the reported benefits, limitations, and clinical applications of established physiotherapy interventions and emerging rehabilitation technologies for individuals with cerebral palsy (CP). The synthesis identified improvements in selected motor and functional outcomes across task-oriented practice, strengthening, gait training, constraint-induced movement therapy (CIMT), and adjunctive approaches. However, the evidence did not establish a consistently superior intervention across populations and functional domains. Interpretation depended on participant characteristics, treatment content and intensity, comparator selection, and the outcomes assessed. These findings support a goal-directed interpretation of rehabilitation evidence,

consistent with broader accounts of individualized, multidisciplinary CP management, while providing insufficient support for universal treatment rankings (1,2).

The neurodevelopmental therapy (NDT) findings illustrate the importance of distinguishing improvement following treatment from comparative effectiveness. Individual studies described improvements in gross motor performance, balance, and functional activities, but their summaries did not consistently establish the magnitude or precision of between-group differences (9,12–14). Two studies also involved preterm infants or mixed developmental-delay populations, making their direct applicability to confirmed CP uncertain (10,11). Consequently, the favorable changes reported in these studies cannot independently establish that NDT is superior to other active approaches. The interpretation offered by this review is that treatment familiarity, historical prominence, and within-group improvement should not substitute for evidence of clinically meaningful comparative benefit.

Task-oriented interventions were associated with improvements in trained activities, including balance, mobility, dexterity, and functional independence (15–18). This pattern is compatible with the broader emphasis on functional goals in CP rehabilitation, but the interventions differed substantially in content and delivery (1,2). The maintenance of selected improvements at 16 weeks in the Ko et al. summary provides an indication of retention beyond immediate treatment, although it does not establish sustained benefit across longer developmental periods (16). Likewise, reports involving biofeedback or family-centered practice do not isolate the contribution of each component unless the comparison groups adequately control for treatment intensity and additional support (17,18). The clinically relevant interpretation is therefore that task-specific practice may contribute to selected functional goals, while its optimal format and incremental benefit require more precise comparative evidence.

Strengthening and gait interventions also demonstrated the distinction between improving an impairment and improving everyday function. Reports of better functional test performance following progressive strengthening suggest that benefits may extend beyond isolated muscle force, but participation outcomes and long-term retention were insufficiently characterized (20,22,23). Similarly, the absence of adverse changes in selected spasticity and range-of-motion measures should not be interpreted as comprehensive evidence of safety or tolerability (20). Backward treadmill studies reported gains in walking performance or motor capacity, but differences in participant function, training mode, and comparator limit generalization to all individuals with CP (24,25). These findings complement the intervention-specific perspective of earlier exercise reviews by emphasizing that changes in strength, balance, and walking capacity need to be linked explicitly to meaningful activity goals (4).

The CIMT evidence particularly demonstrates how comparator choice influences the apparent effectiveness of rehabilitation. The supplied systematic review distinguished benefits over no intervention from comparisons with an equivalent dose of upper-limb practice without restraint (5). Accordingly, gains following intensive CIMT should not automatically be attributed to restraint itself. The higher-dose program described by Ramey et al. combined restraint with substantial practice exposure, while the Baby-CIMT comparison with massage addressed a different clinical question from comparison with another intensive motor intervention (26,28). The retrospective association reported by Nordstrand et al. is additionally vulnerable to differences in baseline function, treatment selection, and other prognostic factors (27). Taken together, these findings support outcome- and comparator-specific interpretation rather than either unrestricted endorsement or dismissal of CIMT.

Robotic rehabilitation, aquatic exercise, and hippotherapy broaden the range of intervention options, but their distinct evidence bases should not be combined into a single category of emerging treatment. Robotic upper-limb rehabilitation has been examined in a systematic review, whereas aquatic and hippotherapy evidence includes different designs and therapeutic targets (6–8). In the present synthesis, limited extraction of numerical results, treatment comparisons, and follow-up outcomes restricted judgments about comparative benefit. The aquatic case-study evidence, for example, can illustrate a treatment application but cannot establish effectiveness relative to another intervention (29). The contribution of this narrative review is therefore principally contextual: it places these approaches alongside established interventions and identifies the information needed for clinical comparison. It does not demonstrate that technological sophistication, treatment novelty, or access to specialized facilities produces superior outcomes.

Several limitations arise specifically from this review's methods and evidence presentation. Searching PubMed and Google Scholar, with Physiopeedia used as a supplementary educational resource, provided a clinically oriented

selection of literature but did not establish exhaustive coverage. The relevance-based selection process creates the possibility that favorable or readily accessible studies were preferentially represented. Although the principal publication window was 2015–2025, the original manuscript also discussed older intervention evidence without consistently separating historical context from the contemporary synthesis. The study table disproportionately represented NDT, task-oriented training, and strengthening, while robotics and hippotherapy lacked comparable study-level detail. Sample sizes, allocation methods, numerical between-group effects, confidence intervals, and exact p-values were frequently absent from the extracted summaries. These omissions limit appraisal of the evidence presented here; they should not be interpreted as proof that the original studies failed to report those details.

The use of primary studies alongside systematic reviews creates a further risk of treating overlapping evidence as independent confirmation. Without explicit identification of shared studies, repeated favorable findings across publications may appear more substantial than the underlying evidence warrants. The inclusion of different age groups, functional classifications, and mixed diagnostic populations also limits transferability. Although the review's scope encompasses individuals with CP across the lifespan, much of the intervention evidence described concerns children, and its applicability to adults requires separate consideration in light of their continuing functional and healthcare needs (3). These limitations preclude formal certainty classifications and definitive comparisons between treatment categories.

For clinical practice, the evidence is most useful when interpreted against an individual's functional goals, abilities, treatment tolerance, and opportunities for practice. This is a clinical interpretation of the synthesis rather than a treatment-selection rule directly tested by the review. Similarly, service planning should distinguish the resources required to deliver an intervention from its cost-effectiveness; the present evidence does not justify economic rankings. Future research should prioritize adequately described, dose-matched comparisons that separate treatment-specific effects from practice intensity, therapist contact, and co-interventions. Studies should report age, CP subtype, functional classification, adherence, adverse events, numerical between-group effects with confidence intervals, and follow-up sufficient to evaluate retention. Greater attention is needed to adults, nonambulatory individuals, and dyskinetic or ataxic presentations. Participation, caregiver burden, accessibility, and economic outcomes should accompany motor measures so that future syntheses can assess both clinical benefit and practical value.

CONCLUSION

Physiotherapy interventions for cerebral palsy offer potential benefits in selected motor and functional domains, but this narrative synthesis does not establish a single superior approach or an optimal combination of treatments. Clinical interpretation should account for individual goals, functional presentation, treatment intensity, comparator choice, and the relevance of measured outcomes to everyday activities. Established interventions and technology-assisted or adjunctive approaches should be considered according to their supporting evidence rather than familiarity or novelty. More clearly reported comparative studies, with meaningful functional outcomes and longer follow-up, are needed to guide individualized rehabilitation and service planning.

REFERENCES

1. Ahmed F, Al Zubayer A, Akter S, Yeasmin H, Hasan MN, Mawa Z, et al. Physical effects of hippotherapy on balance and gross motor function of a child with cerebral palsy. *Arch Clin Med Case Rep*. 2023;7:181–6.
2. Akbari A, Javdzadeh M, Shahraki G, Jahanshahi JP. The effects of functional therapy on motor development in children with cerebral palsy. *Iran J Child Neurol*. 2009;3(3):23–32.
3. Akinola BI, Gbiri CA, Odebiyi DO. Effect of a 10-week aquatic exercise training program on gross motor function in children with spastic cerebral palsy. *Glob Pediatr Health*. 2019;6:2333794X19857378. doi:10.1177/2333794X19857378.
4. Al-Nemr A. Synergistic effect of functional strength training and cognitive intervention on gross motor function in children with cerebral palsy. *Appl Neuropsychol Child*. 2024;13(3):246–55.

5. Alotaibi A, Ibrahim A, Ahmed R, Abualait T. Effectiveness of partial body weight-supported treadmill training on various outcomes in different contexts among children and adolescents with cerebral palsy: a systematic review and meta-analysis. *Children (Basel)*. 2023;11(1):9.
6. Ameer MA, Fayez ES, Elkholy HH. Improving spatiotemporal gait parameters in spastic diplegic children using treadmill gait training. *J Bodyw Mov Ther*. 2019;23(4):937–42.
7. Anttila H, Autti-Rämö I, Suoranta J, Mäkelä M, Malmivaara A. Effectiveness of physical therapy interventions for children with cerebral palsy: a systematic review. *BMC Pediatr*. 2008;8:14. doi:10.1186/1471-2431-8-14.
8. Aras B, Yaşar E, Kesikburun S, Türker D, Tok F, Yılmaz B. Comparison of the effectiveness of partial body weight-supported treadmill exercises, robotic-assisted treadmill exercises, and anti-gravity treadmill exercises in spastic cerebral palsy. *Turk J Phys Med Rehabil*. 2019;65(4):361.
9. Arora NK, Nair M, Gulati S, Deshmukh V, Mohapatra A, Mishra D, et al. Neurodevelopmental disorders in children aged 2–9 years: population-based burden estimates across five regions in India. *PLoS Med*. 2018;15(7):e1002615.
10. Ashtiyani M, Moradi Birgani P, Soleimani M, Jameie SB, Shahrokhi A, Deevband MR, et al. Short-term therapeutic effects of anti-gravity treadmill training on brain functional activities and walking capacity in children with cerebral palsy. *Basic Clin Neurosci*. 2020;10.
11. Avcil E, Tarakci D, Arman N, Tarakci E. Upper extremity rehabilitation using video games in cerebral palsy: a randomized clinical trial. *Acta Neurol Belg*. 2021;121(4):1053–60.
12. Azizi S, Marzbani H, Raminfard S, Birgani PM, Rasooli A, Mirbagheri MM. The impact of an anti-gravity treadmill (AlterG) training on walking capacity and corticospinal tract structure in children with cerebral palsy. In: *Proceedings of the 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*; 2017.
13. Bahrami F, Dehkordi SN, Dadgou M. The efficacy of treadmill training on walking and quality of life of adults with spastic cerebral palsy: a randomized controlled trial. *Iran J Child Neurol*. 2019;13(4):121–8.
14. Bailes AF, Greve K, Long J, Kurowski BG, Vargus-Adams J, Aronow B, et al. Describing the delivery of evidence-based physical therapy intervention to individuals with cerebral palsy. *Pediatr Phys Ther*. 2021;33(2):65–72.
15. Bairaktaridou A, Lytras D, Kottaras A, Iakovidis P, Chatziprodromidou IP, Moutaftsis K. The effect of hydrotherapy on the functioning and quality of life of children and young adults with cerebral palsy. *Int J Adv Res Med*. 2021;3(2):21–4.
16. Bar-On L, Molenaers G, Aertbeliën E, Van Campenhout A, Feys H, Nuttin B, et al. Spasticity and its contribution to hypertonia in cerebral palsy. *Biomed Res Int*. 2015;2015:317047.
17. Bayona NA, Bitensky J, Salter K, Teasell R. The role of task-specific training in rehabilitation therapies. *Top Stroke Rehabil*. 2005;12(3):58–65.
18. Berdina ON, Bairova TA, Rychkova LV, Sheptunov SA. The pediatric robotic-assisted rehabilitation complex for children and adolescents with cerebral palsy: background and product design. In: *Proceedings of the 2017 International Conference on Quality Management, Transport and Information Security, Information Technologies (IT&QM&IS)*; 2017.
19. Bilek F, Tekin F. Effectiveness of extracorporeal shock wave therapy on postural control and balance in children with unilateral cerebral palsy: a randomized controlled trial. *Percept Mot Skills*. 2021;128(6):2621–37. doi:10.1177/00315125211044057.
20. Bleyenheuft Y, Arnould C, Brandao MB, Bleyenheuft C, Gordon AM. Hand and arm bimanual intensive therapy including lower extremity (HABIT-ILE) in children with unilateral spastic cerebral palsy: a randomized trial. *Neurorehabil Neural Repair*. 2015;29(7):645–57.

21. Bryant E, Pountney T, Williams H, Edelman N. Can a six-week exercise intervention improve gross motor function for non-ambulant children with cerebral palsy? A pilot randomized controlled trial. *Clin Rehabil.* 2013;27(2):150–9. doi:10.1177/0269215512453061.
22. Bueno FR. The effect of hippotherapy on physical function and balance of children with cerebral palsy [thesis]. Anglia Ruskin University; 2023.
23. Butt Y, Saghir M, Waseem I, Akmal S, Khan UA, Wdood A. Effects of treadmill training on gross motor function, spasticity, and gait speed in ambulatory children with spastic cerebral palsy. *J Riphah Coll Rehabil Sci.* 2024;12(1).
24. Cardone D, Perpetuini D, Di Nicola M, Merla A, Morone G, Ciancarelli I, et al. Robot-assisted upper limb therapy for personalized rehabilitation in children with cerebral palsy: a systematic review. *Front Neurol.* 2025;15:1499249.
25. Castelli E, Fazzi E. Recommendations for the rehabilitation of children with cerebral palsy. *Eur J Phys Rehabil Med.* 2015;52(5):691–703.
26. Champagne D, Corriveau H, Dugas C. Effect of hippotherapy on motor proficiency and function in children with cerebral palsy who walk. *Phys Occup Ther Pediatr.* 2017;37(1):51–63.
27. Chandolias K, Zarra E, Chalkia A, Hristara A. The effect of hydrotherapy according to Halliwick concept on children with cerebral palsy and the evaluation of their balance: a randomised clinical trial. *International Journal.* 2022;9(4):1.
28. Charles J, Gordon AM. A critical review of constraint-induced movement therapy and forced use in children with hemiplegia. *Neural Plast.* 2005;12(2–3):245–61.
29. Chen CL, Hong WH, Cheng HY, Liaw MY, Chung CY, Chen CY. Muscle strength enhancement following home-based virtual cycling training in ambulatory children with cerebral palsy. *Res Dev Disabil.* 2012;33(4):1087–94. doi:10.1016/j.ridd.2012.01.017.
30. Chen YP, Howard AM. Effects of robotic therapy on upper-extremity function in children with cerebral palsy: a systematic review. *Dev Neurorehabil.* 2016;19(1):64–71.
31. Chen Y, Fanchiang HD, Howard A. Effectiveness of virtual reality in children with cerebral palsy: a systematic review and meta-analysis of randomized controlled trials. *Phys Ther.* 2017;98(1):63–77. doi:10.1093/ptj/ptx107.
32. Chiu HC, Ada L. Constraint-induced movement therapy improves upper limb activity and participation in hemiplegic cerebral palsy: a systematic review. *J Physiother.* 2016;62(3):130–7.
33. Cho C, Hwang W, Hwang S, Chung Y. Treadmill training with virtual reality improves gait, balance, and muscle strength in children with cerebral palsy. *Tohoku J Exp Med.* 2016;238(3):213–8. doi:10.1620/tjem.238.213.
34. Cywińska O, Gawrych S, Białkowska A, Budziejko B, Dziarkowski D, Kurtyka D, et al. Positive influence of hippotherapy on the process of improvement of children with cerebral palsy. *J Educ Health Sport.* 2018;8(11):813–23.
35. De Luca R, Bonanno M, Settimo C, Muratore R, Calabrò RS. Improvement of gait after robotic-assisted training in children with cerebral palsy: are we heading in the right direction? *Med Sci (Basel).* 2022;10(4):59. doi:10.3390/medsci10040059.
36. Demir OB, Yılmaz FT, Kablanoğlu S, Balıkcı E, Dursun E. Effects of hippotherapy on upper extremity functions in children with cerebral palsy. *Cukurova Med J.* 2024;49(1):12–20.
37. Desloovere K, De Cat J, Molenaers G, Franki I, Himpens E, Van Waelvelde H, et al. The effect of different physiotherapy interventions in post-BTX-A treatment of children with cerebral palsy. *Eur J Paediatr Neurol.* 2012;16(1):20–8. doi:10.1016/j.ejpn.2011.08.009.

38. Desouzart G. Physiotherapy intervention according to the Bobath concept in a clinical case of cerebral palsy. *Orthop Res Online J*. 2018;3(4):1–3.
39. Dewar R, Love S, Johnston LM. Exercise interventions improve postural control in children with cerebral palsy: a systematic review. *Dev Med Child Neurol*. 2015;57(6):504–20.
40. Diot CM, Thomas RL, Raess L, Wrightson JG, Condliffe EG. Robotic lower extremity exoskeleton use in a non-ambulatory child with cerebral palsy: a case study. *Disabil Rehabil Assist Technol*. 2023;18(5):497–501.
41. Dodd KJ, Taylor NF, Damiano DL. A systematic review of the effectiveness of strength-training programs for people with cerebral palsy. *Arch Phys Med Rehabil*. 2002;83(8):1157–64. doi:10.1053/apmr.2002.34286.
42. Dodd KJ, Taylor NF, Graham HK. A randomized clinical trial of strength training in young people with cerebral palsy. *Dev Med Child Neurol*. 2003;45(10):652–7. doi:10.1017/S0012162203001221.
43. Doğan H, Mutluay F. Effect of treadmill backward walking training on motor capacity in cerebral palsy: a randomized controlled study. *Ann Rehabil Med*. 2023;47(2):89–97. doi:10.5535/arm.22154.
44. Duangkaew R, Jaidee S. Effect of hydrotherapy on balance of children with cerebral palsy. *Thammasat Med J*. 2017;17(2):182–93.
45. Ejraei N, Ozer AY, Aydogdu O, Turkdogan D, Polat MG. The effect of neck-trunk stabilization exercises in cerebral palsy: a randomized controlled trial. *Minerva Pediatr (Torino)*. 2021.
46. El-Shamy SM. Effects of antigravity treadmill training on gait, balance, and fall risk in children with diplegic cerebral palsy. *Am J Phys Med Rehabil*. 2017;96(11):809–15. doi:10.1097/PHM.0000000000000752.
47. El-Shamy SM. Efficacy of Armeo® robotic therapy versus conventional therapy on upper limb function in children with hemiplegic cerebral palsy. *Am J Phys Med Rehabil*. 2018;97(3):164–9. doi:10.1097/PHM.0000000000000852.
48. Eliasson AC, Nordstrand L, Ek L, Lennartsson F, Sjöstrand L, Tedroff K, et al. The effectiveness of Baby-CIMT in infants younger than 12 months with clinical signs of unilateral cerebral palsy: an explorative study with randomized design. *Res Dev Disabil*. 2018;72:191–201.
49. Elnahhas AM, Elshennawy S, Aly MG. Effects of backward gait training on balance, gross motor function, and gait in children with cerebral palsy: a systematic review. *Clin Rehabil*. 2019;33(1):3–12. doi:10.1177/0269215518790053.
50. Elvrum AKG, Brændvik SM, Sæther R, Lamvik T, Vereijken B, Roeleveld K. Effectiveness of resistance training in combination with botulinum toxin-A on hand and arm use in children with cerebral palsy: a pre-post intervention study. *BMC Pediatr*. 2012;12(1):91.
51. Esmailiyan M, Marandi SM, Darvishi M, Haghjooy Javanmard S, Amerizadeh A. The effect of eight weeks of aquatic exercises on muscle strength in children with cerebral palsy: a case study. *Adv Biomed Res*. 2023;12(1):87. doi:10.4103/abr.abr_363_21.
52. Fan T, Zhu L, Xu B, Fan R, Zou F. Family-centered task-oriented training can significantly improve the functional independence and life quality of children with spastic cerebral palsy. *Chinese Journal of Physical Medicine and Rehabilitation*. 2022:138–42.
53. Fernandes MV, Maifrino LBM, Monte KNS, Araújo RC, Mochizuk L, Ervilha UF. Effectiveness of resistance training exercises in spastic diplegia cerebral palsy: a review. *J Morphol Sci*. 2012;29:125–8.
54. Fetters L, Kluzik J. The effects of neurodevelopmental treatment versus practice on the reaching of children with spastic cerebral palsy. *Phys Ther*. 1996;76(4):346–58.
55. Fluett GG, Qiu Q, Kelly D, Parikh HD, Ramirez D, Saleh S, et al. Interfacing a haptic robotic system with complex virtual environments to treat impaired upper extremity motor function in children with cerebral palsy. *Dev Neurorehabil*. 2010;13(5):335–45.

56. Fortuna RJ, Holub A, Turk MA, Meccarello J, Davidson PW. Health conditions, functional status, and health care utilization in adults with cerebral palsy. *Fam Pract*. 2018;35(6):661–70.
57. Furtado MA, Ayupe KM, Christovão IS, Sousa Junior RR, Rosenbaum P, Camargos AC, et al. Physical therapy in children with cerebral palsy in Brazil: a scoping review. *Dev Med Child Neurol*. 2022;64(5):550–60.
58. Gbonjubola YT, Muhammad DG, Elisha AT. Physiotherapy management of children with cerebral palsy. *Adesh Univ J Med Sci Res*. 2021;3(2):64–8.
59. Gelkop N, Burshtein DG, Lahav A, Brezner A, Al-Oraibi S, Ferre CL, et al. Efficacy of constraint-induced movement therapy and bimanual training in children with hemiplegic cerebral palsy in an educational setting. *Phys Occup Ther Pediatr*. 2015;35(1):24–39.
60. Graham D, Paget SP, Wimalasundera N. Current thinking in the health care management of children with cerebral palsy. *Med J Aust*. 2019;210(3):129–35.
61. Grecco LAC, Zanon N, Sampaio LMM, Oliveira CS. A comparison of treadmill training and overground walking in ambulant children with cerebral palsy: a randomized controlled clinical trial. *Clin Rehabil*. 2013;27(8):686–96.
62. Guindos-Sanchez LD, Lucena-Anton D, Moral-Munoz JA, Salazar A, Carmona-Barrientos I. The effectiveness of hippotherapy to recover gross motor function in children with cerebral palsy: a systematic review and meta-analysis. *Children (Basel)*. 2020;7(9):106. doi:10.3390/children7090106.
63. Häggglund G, Andersson S, Düppe H, Lauge-Pedersen H, Nordmark E, Westbom L. Prevention of dislocation of the hip in children with cerebral palsy: the first ten years of a population-based prevention programme. *J Bone Joint Surg Br*. 2005;87(1):95–101.
64. Häggglund G, Lauge-Pedersen H, Wagner P. Characteristics of children with hip displacement in cerebral palsy. *BMC Musculoskelet Disord*. 2007;8:101. doi:10.1186/1471-2474-8-101.