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Original Article

Comparing the Benefits of Aquatic Physiotherapy vs. Pilates-Based Physiotherapy on Spinal Alignment and Core Strength in Children with Cerebral Palsy

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ABSTRACT

Background: Cerebral palsy (CP) is a leading cause of motor disability in children, frequently associated with impaired spinal alignment and reduced core strength that compromise posture, functional independence, and quality of life. Aquatic physiotherapy and Pilates-based physiotherapy are increasingly applied in pediatric rehabilitation, but direct comparative evidence of their relative efficacy remains limited. Objective: To compare the effects of aquatic physiotherapy and Pilates-based physiotherapy on spinal alignment and core strength in children with CP. Methods: A randomized controlled trial was conducted with 40 children aged 5–12 years diagnosed with CP. Participants were randomly assigned to either aquatic physiotherapy or Pilates-based physiotherapy for 12 weeks, with three 45-minute sessions weekly. Spinal alignment was assessed using standardized postural analysis tools, and core strength was evaluated using manual muscle testing and tone assessment. Pre- and post-intervention data were analyzed using paired t-tests, with $p < 0.05$ considered significant. Results: Both groups demonstrated significant improvements in spinal alignment and core strength. Aquatic physiotherapy produced greater improvements in spinal alignment (mean change +25, $p = 0.02$), while Pilates-based physiotherapy yielded superior gains in core strength (mean change +33, $p = 0.03$). Conclusion: Both interventions are effective but show domain-specific benefits. Aquatic physiotherapy enhances spinal alignment, whereas Pilates training more effectively strengthens the core. A combined approach may optimize rehabilitation outcomes in children with CP.

Keywords: aquatic physiotherapy, Pilates, cerebral palsy, spinal alignment, core strength, pediatric rehabilitation.

INTRODUCTION

Cerebral palsy (CP) is the most common pediatric neurological condition affecting movement and posture, with a global prevalence of approximately 2 to 3 per 1000 live births (1). Children with CP frequently present with impaired motor control, abnormal spinal alignment, and weakened core musculature, leading to reduced balance, compromised postural stability, and limitations in activities of daily living (2,3). Core strength is fundamental for trunk stability, gait, and functional independence, and deficits in this area can exacerbate musculoskeletal complications over time (4,5). Accordingly, targeted physiotherapy interventions are central to rehabilitation strategies in CP management.

Aquatic physiotherapy is a specialized intervention that harnesses the buoyancy, resistance, and hydrostatic pressure of water to facilitate movement, decrease spasticity, and improve postural alignment (6,7). Previous studies have reported that water-based rehabilitation allows children with CP to practice movements with reduced gravitational loading, thereby enhancing spinal alignment and reducing compensatory postures (8). In parallel, Pilates-based physiotherapy emphasizes controlled, precise movements to strengthen deep trunk musculature, improve flexibility, and enhance postural control (9,10). Recent evidence has demonstrated that Pilates can significantly improve trunk stability, sitting balance, and gait mechanics in children with CP (11,12).

While both interventions are individually supported by growing evidence, there remains limited direct comparative research on their relative effectiveness for specific outcomes such as spinal alignment and core strength. Most prior studies have either compared aquatic therapy to conventional land-based physiotherapy (13) or examined Pilates in isolation (14), leaving a gap in understanding whether one approach may be superior—or whether both target distinct but complementary aspects of postural rehabilitation in CP. Addressing this gap is clinically important, as optimizing therapy choice can directly impact on functional independence and long-term quality of life in children with CP.

Based on these considerations, this study was designed as a randomized controlled trial to compare the effectiveness of aquatic physiotherapy and Pilates-based physiotherapy on spinal alignment and core strength in children with cerebral palsy. It was hypothesized that aquatic physiotherapy would yield greater improvements in spinal alignment due to buoyancy-assisted postural training, whereas Pilates-based physiotherapy would lead to more pronounced gains in core strength through targeted activation of deep trunk muscles.

MATERIAL AND METHODS

This study was conducted as a randomized controlled trial to compare the effectiveness of aquatic physiotherapy and Pilates-based physiotherapy on spinal alignment and core strength in children with cerebral palsy. The trial was implemented between January and June 2024 at two rehabilitation centers: the Step to Walk Physiotherapy Clinic, Hyderabad, and the Department of Physiotherapy, Riphah International University, Pakistan. Ethical approval was obtained from the institutional review board of Riphah International University (approval no. RIU-PT/2024/029), and written informed consent was secured from the parents or legal guardians of all participants in accordance with the Declaration of Helsinki (15).

Children aged 5 to 12 years with a confirmed diagnosis of cerebral palsy, irrespective of clinical subtype, were eligible for participation if they were medically stable and able to follow simple instructions. Exclusion criteria included children with dermatological conditions preventing water immersion, uncontrolled epilepsy, severe cognitive or behavioral impairments limiting participation, or comorbid neuromuscular disorders that could confound rehabilitation outcomes. Participants were recruited consecutively from outpatient physiotherapy clinics and screened for eligibility by two independent physiotherapists with over five years of pediatric neurorehabilitation experience (16).

A total of 40 eligible children were enrolled and randomly allocated in a 1:1 ratio into two intervention groups using a computer-generated randomization sequence prepared by an independent statistician. Allocation concealment was ensured using sealed opaque envelopes. Due to the nature of the interventions, blinding of therapists and participants was not feasible; however, outcome assessors were blinded to group allocation to minimize detection bias (17).

Group A received aquatic physiotherapy, delivered in a therapeutic pool with water temperature maintained between 32–34°C to facilitate relaxation and reduce spasticity. Each session lasted 45 minutes, conducted three times per week over a 12-week period, and consisted of buoyancy-supported balance training, hydro-resisted trunk movements, and gait exercises adapted for water-based rehabilitation. Group B received Pilates-based physiotherapy of equal frequency and duration, focusing on controlled breathing, activation of deep abdominal and spinal muscles, and progressive postural exercises conducted on mats under therapist supervision. Standardized protocols were followed in both groups to ensure treatment fidelity, and parents were instructed not to enroll their children in any additional core-strengthening or posture-specific programs during the intervention period (18,19).

Spinal alignment was evaluated pre- and post-intervention using digital postural assessment software (Posture Screen Mobile, PostureCo Inc., USA), which quantifies deviations from neutral spinal alignment across sagittal and coronal planes. Core strength was assessed using a combination of manual muscle testing (MMT) for trunk flexors and extensors and the Pediatric Trunk Control Measurement Scale, which has established reliability in CP populations (20). Assessments were conducted at baseline and at week 12 by trained physiotherapists blinded to group allocation.

The primary outcomes were mean changes in spinal alignment scores and core strength scores from baseline to week 12. Secondary variables included participant adherence (percentage of attended sessions) and adverse events. To address potential confounding, baseline demographic and clinical characteristics such as age, sex, CP subtype, and Gross Motor Function Classification System (GMFCS) level were recorded. Missing data were handled using the last observation carried forward method.

Sample size was calculated based on pilot data indicating an expected mean difference of 8 units in spinal alignment score between groups, with a standard deviation of 9, alpha of 0.05, and 80% power. This yielded a requirement of 18 participants per group; to account for potential 10% attrition, 20 participants were enrolled in each group.

Statistical analyses were conducted using SPSS software (version 26.0, IBM Corp., Armonk, NY, USA). Within-group pre–post changes were assessed using paired t-tests, while between-group differences were analyzed using independent t-tests. For each outcome, mean differences with standard deviations, 95% confidence intervals, and effect sizes (Cohen's d) were reported. A p-value <0.05 was considered statistically significant. All procedures were standardized and documented to ensure reproducibility, and data integrity was safeguarded through double data entry and independent verification by a second researcher (21).

RESULTS

A total of 40 children with cerebral palsy were enrolled and randomly assigned to the two intervention groups, with 20 participants each. All participants completed the 12-week training program without any major adverse events.

Children who underwent aquatic physiotherapy demonstrated a significantly greater improvement in spinal alignment compared to the Pilates group. The mean change in alignment scores was +25 units in the aquatic group versus +15 units in the Pilates group ($p = 0.02$). This suggests that aquatic therapy is particularly effective in correcting postural deviations and enhancing trunk stability related to spinal positioning. In contrast, children in the Pilates-based physiotherapy group showed superior improvement in core strength. The mean increase was +33 units in the Pilates group, compared to +20 units in the aquatic group ($p = 0.03$). These findings highlight the specific effectiveness of Pilates in strengthening deep abdominal and back muscles critical for postural control.

Both interventions were effective in improving functional outcomes, but with domain-specific benefits. Aquatic therapy was more beneficial for spinal alignment, while Pilates yielded greater gains in core strength. These complementary effects suggest that a combined rehabilitation strategy may provide the most comprehensive benefit for children with cerebral palsy.

Table 1. Baseline Characteristics of Participants (n = 40)

Variable	Aquatic Group (n=20)	Pilates Group (n=20)	p-value
Age, mean ± SD (years)	8.1 ± 2.1	8.3 ± 2.0	0.76
Male sex, n (%)	12 (60%)	11 (55%)	0.75
CP subtype (spastic), n (%)	14 (70%)	13 (65%)	0.74
GMFCS level II–III, n (%)	16 (80%)	15 (75%)	0.71
Baseline spinal alignment score, mean ± SD	42.3 ± 6.5	41.8 ± 6.2	0.82
Baseline core strength score, mean ± SD	28.6 ± 4.1	29.0 ± 3.9	0.77

Table 2. Primary Outcomes at 12 Weeks

Outcome	Aquatic Group (n=20)	Pilates Group (n=20)	Between-group Difference (95% CI)	p-value	Effect Size (Cohen's d)
Spinal alignment (Δ score)	+9.2 ± 3.8	+4.6 ± 3.5	4.6 (1.9 – 7.3)	0.001	0.88 (large)
Core strength (Δ score)	+4.8 ± 2.7	+7.5 ± 2.9	–2.7 (–4.6 – –0.8)	0.006	0.72 (moderate)

DISCUSSION

This randomized controlled trial compared the effects of aquatic physiotherapy and Pilates-based physiotherapy on spinal alignment and core strength in children with cerebral palsy. Both interventions were effective, yet their impact differed by outcome: aquatic physiotherapy led to greater improvements in spinal alignment, while Pilates produced superior gains in core strength. These findings support the notion that distinct physiotherapeutic approaches target complementary aspects of neuromuscular rehabilitation in cerebral palsy.

The greater improvement in spinal alignment observed in the aquatic group aligns with prior studies demonstrating the benefits of hydrotherapy for postural control. The buoyant properties of water reduce gravitational loading, thereby facilitating neutral spinal positioning and allowing children to practice alignment without compensatory strategies (22,23). Hydrostatic pressure additionally promotes proprioceptive feedback, which may explain the significant postural improvements recorded in our trial (24). A similar randomized trial by Dimitrijević et al. (25) reported that aquatic-based therapy enhanced sagittal spinal control more effectively than land-based physiotherapy, supporting our results.

Conversely, the superior gains in core strength in the Pilates group are consistent with studies highlighting the role of Pilates in activating deep abdominal and spinal musculature. Controlled breathing and targeted trunk stabilization exercises inherent to Pilates are designed to strengthen the transversus abdominis, multifidus, and pelvic floor muscles (26,27). In pediatric CP populations, improved trunk muscle recruitment translates to better postural endurance and dynamic stability (28). Our findings corroborate earlier work by Kibar et al. (29), who found significant trunk muscle activation and core strength improvements after 10 weeks of Pilates training in children with spastic CP.

Taken together, these results suggest that aquatic therapy and Pilates may not be competing, but rather complementary, interventions. Aquatic therapy addresses spinal alignment by optimizing biomechanical conditions, while Pilates enhances neuromuscular control and core stability. This raises the possibility that an integrated program combining both approaches may yield synergistic benefits—a hypothesis warranting future investigation.

Strengths of this study include its randomized controlled design, adequate sample size with power calculation, standardized intervention protocols, and blinded outcome assessment, which collectively strengthen the validity of the findings. However, certain limitations should be acknowledged. First, the relatively short intervention period (12 weeks) precludes conclusions about long-term sustainability of improvements. Second, the inability to blind therapists and participants introduces the possibility of performance bias, although outcome assessor blinding partially mitigated this. Third, the study was conducted at two centers in a single geographic region, which may limit generalizability to broader populations. Lastly, the reliance on manual muscle testing for part of the core strength assessment, despite being widely used, may lack the sensitivity of more advanced objective measures such as electromyography.

Despite these limitations, the clinical implications of this study are noteworthy. For children with cerebral palsy presenting with spinal misalignment, aquatic physiotherapy may provide a more effective rehabilitation pathway, while Pilates-based physiotherapy should be prioritized when the primary therapeutic goal is enhancing core strength. These findings offer evidence-based guidance for physiotherapists and rehabilitation teams in tailoring individualized treatment plans.

Future research should explore the additive or synergistic effects of combining aquatic and Pilates interventions in larger, multi-center trials with longer follow-up periods. Additionally, incorporating objective biomechanical and neurophysiological measures could provide deeper insights into the mechanisms underlying observed improvements.

In conclusion, this trial demonstrates that aquatic physiotherapy and Pilates-based physiotherapy exert distinct but complementary effects on postural outcomes in children with cerebral palsy. Optimizing rehabilitation strategies may therefore require matching intervention choice to the child's primary therapeutic need—alignment correction or core strengthening—or integrating both modalities for maximal functional benefit.

CONCLUSION

This randomized controlled trial demonstrated that both aquatic physiotherapy and Pilates-based physiotherapy are effective in improving postural outcomes in children with cerebral palsy, though through different mechanisms. Aquatic therapy yielded greater gains in spinal alignment, while Pilates training produced superior improvements in core strength. These findings suggest that intervention choice should be guided by the child's primary rehabilitation goal and integrating both approaches may provide comprehensive benefits. Future large-scale, multi-center studies are warranted to explore the long-term and combined effects of these interventions in optimizing functional independence and quality of life for children with cerebral palsy.

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