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IMPACT OF PROGRESSIVE STRENGTH AND FUNCTIONAL TASK-ORIENTED TRAINING ON MOBILITY AND GROSS MOTOR FUNCTION IN CHILDREN WITH SPASTIC CEREBRAL PALSY: A QUASI-EXPERIMENTAL STUDY

Original Research

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ABSTRACT

Background: Spastic diplegic cerebral palsy is characterized by muscle weakness, impaired motor control, and balance deficits that limit mobility and functional independence. Although progressive strength training and task-oriented rehabilitation have demonstrated benefits independently, evidence evaluating their combined effect within structured pediatric rehabilitation programs remains limited, particularly in Pakistani clinical settings.

Objective: To evaluate the effects of combined progressive strength and task-oriented training on mobility, balance, gait speed, and function in children.

Methods: A quasi-experimental single-group pretest–posttest study was conducted in a hospital-based pediatric rehabilitation department in KP. 28 children aged 5–12 years with spastic diplegic cerebral palsy (GMFCS Levels I–III) completed an 8-week individualized intervention combining progressive strength training and functional task-oriented activities delivered three times per week. Outcomes included the Gross Motor Function Measure (GMFM-66), Pediatric Balance Scale (PBS), Timed Up and Go (TUG), and 10-Meter Walk Test (10MWT). Paired t-tests were used to compare pre- and post-intervention scores, and Cohen's d was calculated to determine effect sizes.

Results: Significant improvements were observed across all outcomes following the intervention. GMFM-66 scores improved by 7.6 points ($p < 0.001$), indicating enhanced gross motor function. PBS scores increased significantly ($p < 0.001$), reflecting improved balance and postural control. Functional mobility improved, with TUG times decreasing significantly ($p < 0.001$), while gait speed improved as demonstrated by reduced 10MWT completion time ($p < 0.001$). Effect sizes ranged from moderate to large ($d = 0.68–1.21$). Intervention adherence averaged 92%, and no adverse events were reported.

Conclusion: A combined progressive strength and functional task-oriented training program significantly improves mobility, balance, gait performance, and gross motor function in children with spastic diplegic cerebral palsy. This integrated approach addresses neuromuscular impairments and functional performance limitations, supporting motor learning and functional independence. The intervention is safe, clinically feasible, and well suited for hospital-based pediatric rehabilitation, including resource-limited settings. Further controlled trials are recommended to confirm long-term effectiveness and broader applicability.

Keywords: Cerebral palsy; spastic diplegia; pediatric rehabilitation; strength training; task-oriented training; mobility; gross motor function; neurorehabilitation.

INTRODUCTION

About two to three out of every 1,000 live births globally result in cerebral palsy (CP), the most prevalent cause of physical impairment in children (1). It refers to a set of persistent mobility and postural problems caused by non-progressive anomalies in the developing brain. Spastic diplegia is a prevalent subtype that mostly affects the lower limbs and is distinguished by muscular stiffness, weakness, poor selective motor control, and decreased postural stability (2). These disabilities impede movement, balance, and involvement in everyday activities.

Muscle weakness is a primary determinant of limitation in activity in children with CP, and it frequently contributes more to functional impairment than spasticity itself (3). Weakness in antigravity muscles impairs gait efficiency, balance control, and functional mobility. Progressive resistance training boosts muscular strength, gait performance, and gross motor outcomes while without increasing spasticity (4, 5). Recent systematic studies have confirmed moderate to considerable gains in gross motor function following strengthening therapies (6, 7). Task-oriented training is based on motor learning and neuroplasticity concepts. Neuroplasticity is the nervous system's ability to rearrange neuronal connections in response to repeated, meaningful action(8). Repetitive practice of functional tasks enhances cortical remodeling while also improving motor planning and coordination (9). Research reveals that task-specific therapies enhance balance and mobility outcomes in children with CP (10, 11), whereas functional task training improves postural control and motor performance in spastic diplegia(12).

According to Shumway-Cook and Woollacott (2017), motor performance can be further understood by dynamic systems theory as the interplay of musculoskeletal capability, sensory processing, task demands, and environmental influences. These mechanisms are impaired in children with spastic diplegic cerebral palsy (CP), which leads to ineffective movement patterns. Therefore, interventions that focus on both functional task performance and muscular strength may result in more effective motor techniques(13). The International Classification of Functioning, Disability and Health (ICF) framework, which prioritizes rehabilitation across the areas of participation, activity, and physical function, is also in line with the current intervention (14). Task-oriented training enhances activity performance and engagement, whereas strength training targets deficiencies at the level of bodily functions(11).

Despite strong international evidences, very few studies in Pakistan and Khyber Pakhtunkhwa have assessed organized rehabilitation programs that combine strength and functional training. Conventional treatment, which lacks progressive overload and functional specialization, is often used in clinical practice. Thus, the purpose of this study was to ascertain how children with spastic diplegic cerebral palsy will respond to progressive strength training in conjunction with functional task-oriented training in terms of their gross motor function and mobility.

METHODS

This quasi-experimental study employed a single-group pretest–posttest design to evaluate the effects of a progressive strength and functional task-oriented training program on mobility and gross motor function in children diagnosed with spastic diplegic cerebral palsy. The study was conducted over a six-month period in the pediatric physiotherapy and rehabilitation unit of the Department of Physical Therapy at Hayatabad Medical Complex, Peshawar. Participants were recruited through purposive sampling. Children aged 5–12 years who were classified within Gross Motor Function Classification System levels I–III and able to follow verbal instructions were eligible. Exclusion criteria included botulinum toxin injections within the previous three months, orthopedic surgery within the preceding six months, severe cognitive impairment limiting participation, or uncontrolled seizures. Written informed consent was obtained from parents or legal guardians prior to enrolment, and ethical approval was granted by the institutional review committee. Confidentiality and safety monitoring procedures were maintained throughout the study.

Sample size estimation was performed using G*Power software (version 3.1) for paired mean comparisons. Assuming a moderate-to-large effect size of 0.60 based on previous evidence demonstrating improvements in GMFM-66 following strengthening and task-oriented interventions (6, 7), a minimum of 28 participants was required to achieve 80% power at an alpha level of 0.05. To accommodate potential attrition, recruitment was increased by 20%, resulting in a target sample of 34 participants. Of these, 28 completed the intervention and post-treatment assessments, while six participants withdrew or were excluded during follow-up.

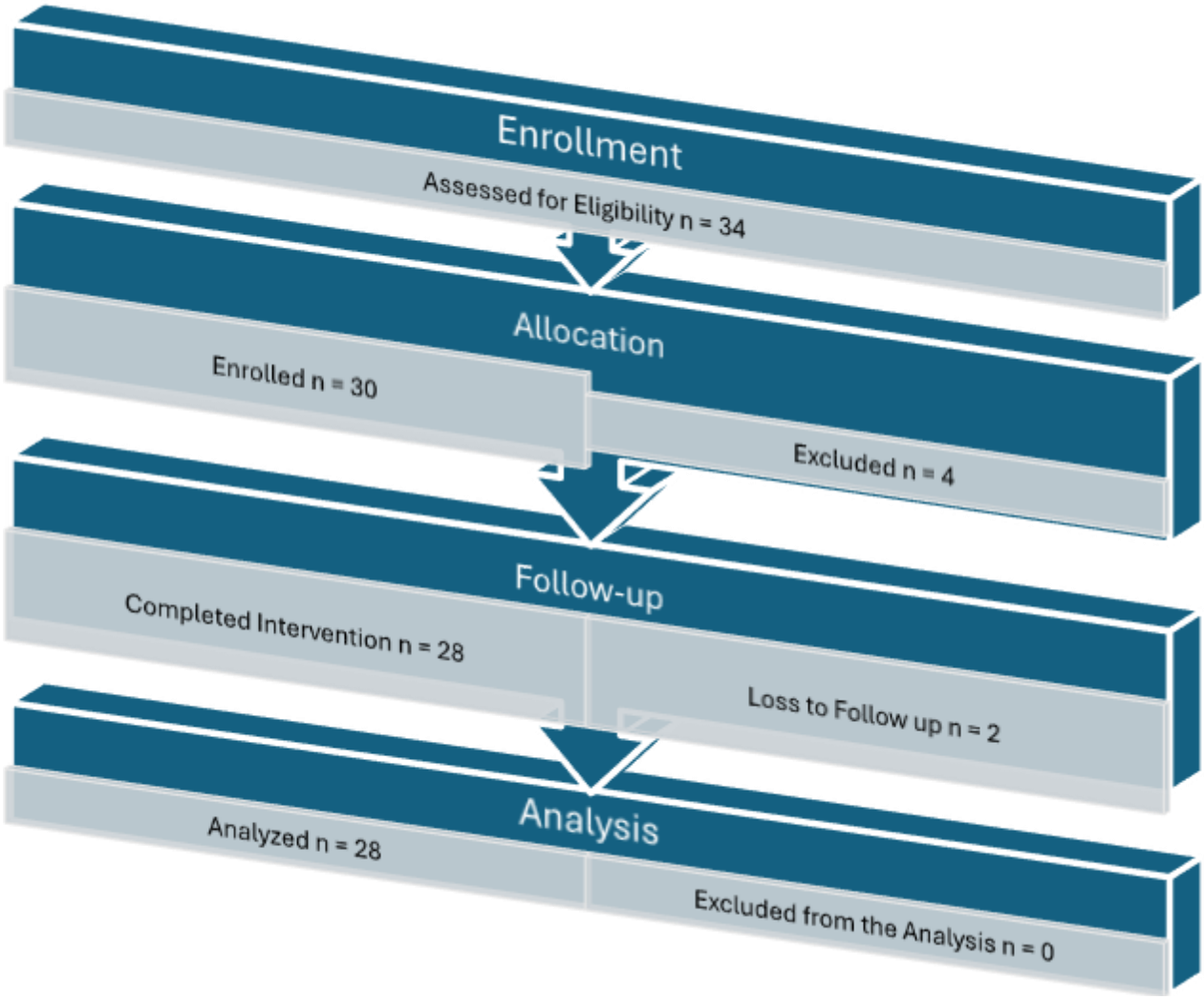

Figure 1Participant flow diagram illustrating enrollment, intervention completion, follow-up, and analysis

Baseline assessments were conducted before initiation of treatment and repeated after completion of the eight-week intervention. Gross motor function was assessed using the Gross Motor Function Measure-66, a validated instrument for evaluating motor capacity in children with cerebral palsy(15). Functional balance was measured using the Pediatric Balance Scale(16), mobility using the Timed Up and Go test(17), and gait speed using the 10-Meter Walk Test(18). These outcome measures have established reliability and validity in pediatric neurorehabilitation populations. All assessments were administered by trained physiotherapists who were familiar with standardized testing procedures.

The intervention was delivered individually by licensed physiotherapists three times per week for eight consecutive weeks. Each session lasted approximately 45–60 minutes and consisted of progressive strengthening exercises followed by functional task-oriented training. Strengthening focused primarily on lower-limb muscle groups essential for postural control and ambulation. Exercise intensity and task difficulty were progressively increased according to tolerance, typically by adjusting repetitions, resistance, or duration, consistent with principles of progressive overload and neuromuscular adaptation. Functional training emphasized repetitive, goal-directed tasks designed to improve balance, coordination, motor planning, and independence in mobility. Task progression was achieved by modifying environmental demands, reducing assistance, and increasing movement speed or cognitive complexity. Attendance and adherence were recorded, and participants were monitored for fatigue, discomfort, or adverse effects. No treatment-related complications or increases in spasticity were observed during the intervention period.

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Data analysis was conducted using SPSS version 27. Distribution normality was examined using the Shapiro–Wilk test prior to inferential analysis. Pre- and post-intervention outcomes were compared using paired-sample t-tests, and treatment magnitude was quantified using Cohen's d effect size. Statistical significance was set at $p < 0.05$.

RESULTS

Tables 1 and 2 provide the baseline characteristics of the study participants. The research comprised 28 ambulatory children with spastic diplegic cerebral palsy (mean age: 8.4 ± 2.1 years). The mean BMI of 15.7 ± 2.3 kg/m² was within the normal range as determined by WHO pediatric growth guidelines. Most individuals were identified in GMFCS Level II, indicating moderate functional limits. More than half of the youngsters walked independently, while others required help aids. The majority of the participants donned ankle-foot orthoses and had previously had physiotherapy sessions, whereas the majority were enrolled in school for formal education. Adherence to the intervention was substantial with a mean attendance rate of 92%. Participants tolerated the training well, and no adverse effects, musculoskeletal problems, excessive tiredness, or spasticity increases were reported. The personalized delivery strategy enabled therapists to tailor exercise intensity and task complexity to each child's tolerance and performance.

Table 1: Descriptive Statistics of the study subjects

Characteristic	Mean ± SD
Age (years)	8.4 ± 2.1
Height (cm)	124.5 ± 10.2
Weight (kg)	24.3 ± 5.8
Body Mass Index (kg/m²)	15.7 ± 2.3

Table 2. Baseline Demographic and Clinical Characteristics (n=28)

Variable	Category	Frequency n (%)
Gender	Male	16 (57.1%)
	Female	12 (42.9%)
GMFCS Level	Level I	8 (28.6%)
	Level II	12 (42.9%)
	Level III	8 (28.6%)
Assistive Device Use	None	15 (53.6%)
	Walker	9 (32.1%)
	Walking sticks	4 (14.3%)
Use of Ankle–Foot Orthoses (AFOs)		18 (64.3%)
Previous Physiotherapy (>6 months)		21 (75.0%)
School Attendance		20 (71.4%)

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Normality tests revealed that all outcome measures were normally distributed. The Shapiro-Wilk test findings were non-significant ($p > 0.05$), and the skewness and kurtosis values were within acceptable limits (-1 to +1), demonstrating distribution symmetry and the lack of excessive peaking. Thus, paired sample t-tests were used to compare pre- and post-intervention results (Fig. 2).

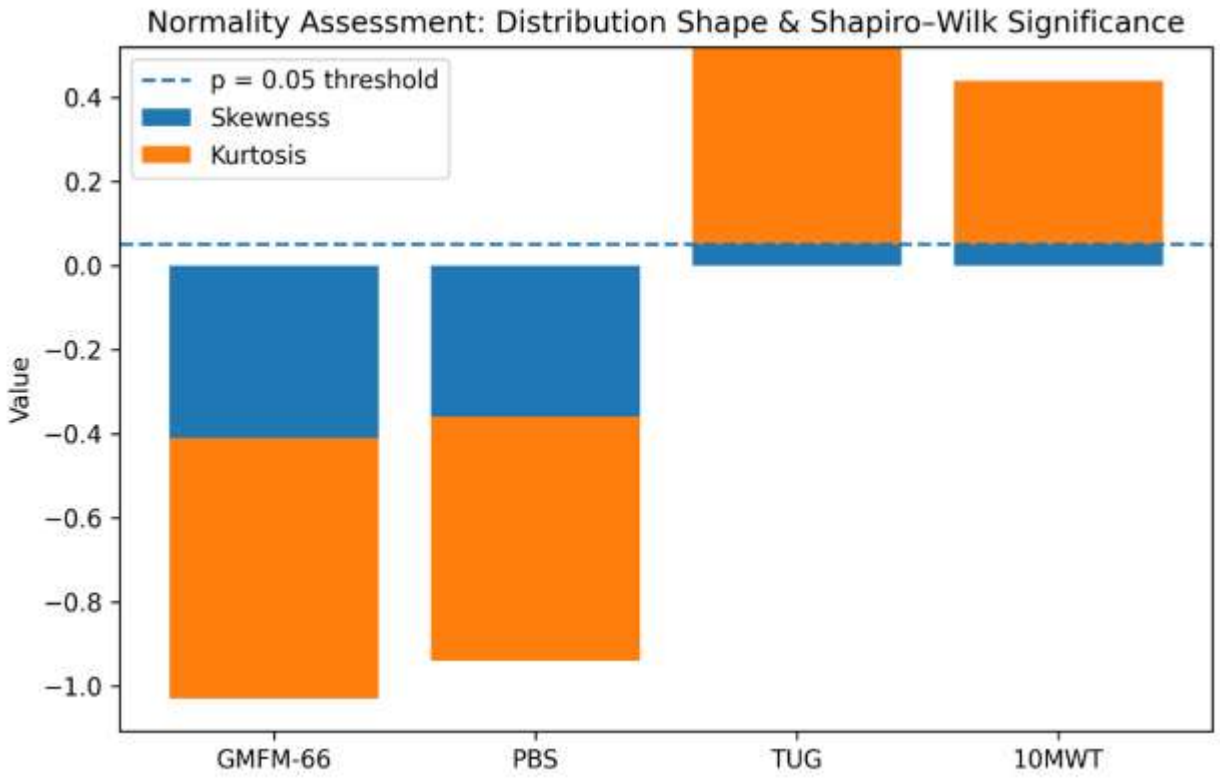

Figure 1 Combined visualization of distribution shape and normality testing. Skewness and kurtosis values for all outcome measures fall within acceptable ranges, and Shapiro–Wilk p-values exceed the 0.05 threshold, confirming normal distribution

Functional Outcomes

After the 8-week intervention, notable improvements were recorded in all outcome measures (Table 3). Gross motor function showed significant enhancement, with GMFM-66 scores rising by an average of 7.6 points ($p < 0.001$), indicating a 14% improvement from the baseline. Functional balance showed considerable enhancement ($p < 0.001$), indicated by elevated PBS scores. Participants demonstrated better postural stability, increased weight shifting capabilities, and improved balance maintenance during dynamic activities. Functional mobility significantly enhanced, as TUG performance reduced by an average of 2.7 seconds ($p < 0.001$). Gait speed showed notable enhancement, evidenced by a shorter completion time on the 10 MWT ($p < 0.001$). Participants showed enhanced step symmetry, greater walking confidence, and more fluid gait patterns. Effect size analysis showed moderate to large treatment effects for all outcomes ($d = 0.68–1.21$), suggesting that the improvements were both statistically significant and clinically relevant.

Table 3: Pre- and Post-Intervention Outcomes

Outcome	Pre	Post	Mean Difference	p- value	Effect Size
GMFM-66	54.2 ± 6.3	61.8 ± 6.7	+7.6	<0.001	1.21
PBS	33.5 ± 5.1	39.6 ± 5.4	+6.1	<0.001	1.13
TUG (sec)	12.8 ± 2.4	10.1 ± 2.0	−2.7	<0.001	1.05
10MWT (sec)	9.6 ± 1.8	7.9 ± 1.5	−1.7	<0.001	0.68

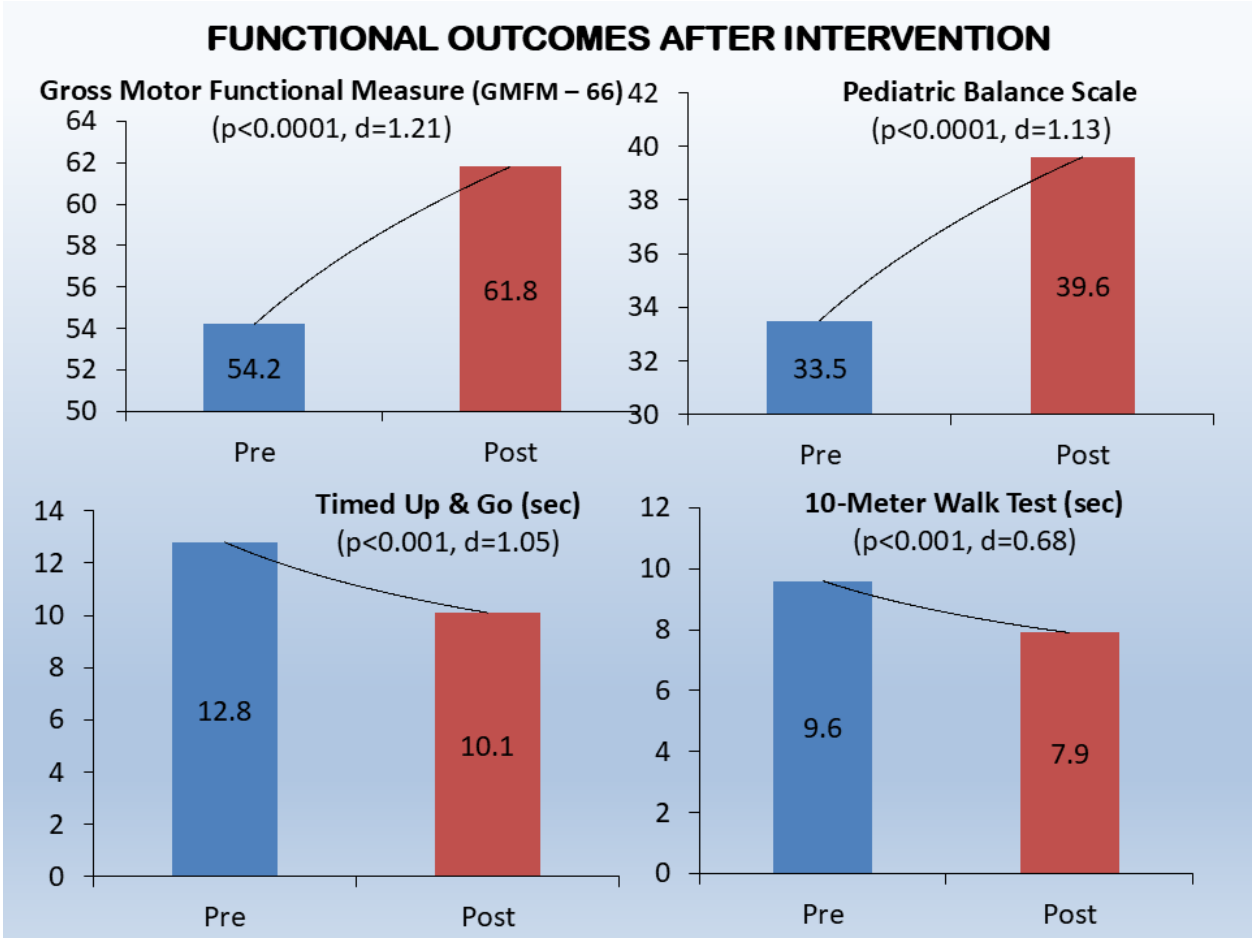

Figure 2 Functional outcomes following the 8-week intervention: (A) GMFM-66, (B) Pediatric Balance Scale, (C) Timed Up and Go, and (D) 10-Meter Walk Test. Significant improvements were observed in gross motor function (A), balance (B), mobility (C), and gait speed (D)) ($p < 0.001$.

DISCUSSION

The present study demonstrated meaningful improvements in gross motor function, balance, mobility, and gait speed following an eight-week program integrating progressive strengthening with functional task-oriented training in children with spastic diplegic cerebral palsy. These findings aligned with contemporary neurorehabilitation frameworks that emphasize activity-dependent recovery and functional skill acquisition rather than impairment reduction alone. The observed improvements could be interpreted through mechanisms of motor learning and neuroplasticity, whereby repeated performance of meaningful motor tasks promotes experience-driven cortical reorganization, improved motor planning, and enhanced sensorimotor integration (12,13). From a systems perspective, the intervention addressed multiple determinants of movement simultaneously, consistent with dynamic systems theory, which proposes that motor performance emerges from interactions among musculoskeletal capacity, neural control, environmental context, and task demands (14). Physiologically, progressive resistance training was likely to have enhanced motor unit recruitment, neuromuscular activation efficiency, and force generation, thereby improving joint stability and postural alignment necessary for efficient mobility (15). Importantly, the absence of adverse effects supported evidence that appropriately dosed strengthening does not exacerbate spasticity in children with cerebral palsy (16). The functional component of the intervention ensured that strength gains were embedded within purposeful activities, facilitating transfer of improvements to real-world tasks, which is essential because isolated strength gains may not automatically translate into functional performance without task-specific practice (17). Collectively, these mechanisms provided a coherent explanation for the multidimensional functional improvements observed in the study cohort.

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The findings were consistent with previous reports demonstrating that strengthening interventions can improve motor performance in children with cerebral palsy, particularly when combined with activity-based training approaches (18,19). Task-oriented rehabilitation has been shown to enhance balance, mobility, and postural control through repetitive goal-directed practice and contextual learning (20). Recent clinical evidence also indicated that structured functional programs improve mobility outcomes and participation in children with spastic diplegia, reinforcing the relevance of combining impairment-focused and activity-focused strategies (21). Moreover, emerging syntheses of pediatric neurorehabilitation trials suggested that multimodal interventions integrating strength and functional training yield superior outcomes compared with single-component therapies, as they simultaneously address muscle weakness, motor coordination, and task execution (22). Within the Pakistani rehabilitation context, these findings were particularly relevant because structured progressive training protocols were not routinely implemented in many hospital settings, where therapy often remained impairment-oriented or non-standardized. Demonstrating that a structured yet resource-feasible intervention produced measurable functional gains supported the feasibility of implementing evidence-informed programs even in constrained clinical environments. The magnitude of improvement observed in mobility and balance measures also suggested potential real-world benefits, including improved independence in transfers and walking, enhanced safety during mobility, and reduced caregiver burden. Such outcomes reflected the principles of the International Classification of Functioning framework, in which improvements in body functions translated into gains in activity performance and participation (23).

Despite these encouraging findings, several methodological considerations tempered the interpretation of results. The absence of a control group limited causal inference because developmental maturation, repeated testing effects, or increased therapeutic attention could have contributed partially to the improvements. The use of purposive sampling and recruitment from a single hospital reduced external validity, as the findings primarily reflected ambulatory children with mild-to-moderate functional limitations and might not extend to those with severe impairments or different cerebral palsy subtypes. The relatively short intervention period restricted evaluation of long-term sustainability of functional gains, and follow-up assessments were not performed to determine whether improvements were retained beyond the training phase. In addition, environmental and home-based activity factors were not monitored, and variations in daily practice or caregiver engagement could have influenced outcomes. Nevertheless, the study possessed several strengths, including the use of validated functional outcome measures, a structured progression protocol grounded in physiological and motor-learning principles, and consistent therapist supervision that enhanced treatment fidelity. Taken together, the findings supported the clinical value of integrating progressive strengthening with task-oriented training in pediatric neurorehabilitation while underscoring the need for larger controlled trials, longer follow-up periods, and broader population sampling to confirm effectiveness and generalizability (24, 25).

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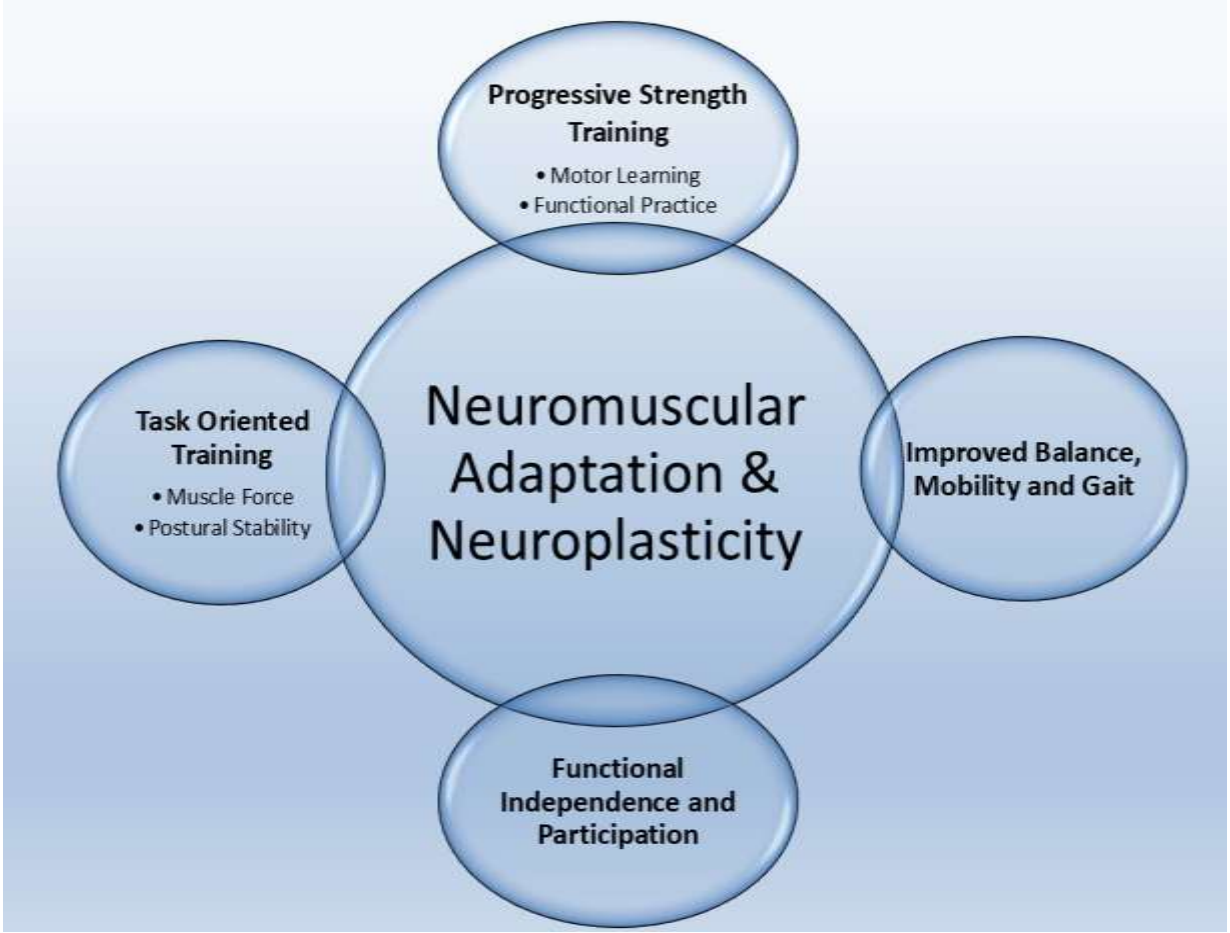

Figure 3 Conceptual model illustrating mechanisms through which combined progressive strength and task-oriented training improves neuromuscular function, mobility, and participation in children with spastic diplegic cerebral palsy

CONCLUSION

The results of this study show that children with spastic diplegic cerebral palsy benefit significantly and clinically effective from an 8-week program that combines progressive strength training with functional task-oriented rehabilitation in terms of gross motor function, balance, mobility, and gait speed. The extent of progress seen in outcome measures reflects greater functional independence and better movement efficiency, both of which are crucial for safe mobility and involvement in everyday tasks. The combined intervention method targets both neuromuscular deficits and limitations in functional performance. Progressive strengthening improves muscle force generation and postural stability, whereas task-oriented training promotes motor learning, functional skill development, and the application of therapeutic benefits to everyday activities. This integrated approach adheres to the principles of neuroplasticity, dynamic systems theory, and the International Classification of Functioning framework by focusing on body function, activity execution, and involvement. From a clinical viewpoint, the intervention is effective, secure, and workable for pediatric rehabilitation in hospital contexts, even in resource-constrained settings. Enhanced mobility and stability can lower the risk of falls, boost independence, encourage school involvement, and lessen caregiver stress, leading to a better quality of life for children and their families.

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AUTHOR CONTRIBUTIONS

Author	Contribution
Muhammad Uzair Khan	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Chidebe Nkem Onyeogulu	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Malije Henry Ezepue	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Shumaila Tahreem	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Tanzila Rashid	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Abdullah*	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Shaheen Abdullah	Contributed to study concept and Data collection Has given Final Approval of the version to be published
Etisam Wahid	Writing - Review & Editing, Assistance with Data Curation
Shahzad Ahmad	Writing - Review & Editing, Assistance with Data Curation

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