

Original Article

Effects of High-Intensity Circuit Training Combined with Conventional Rehabilitation on Functional Outcomes in Children with Cerebral Palsy: A Randomized Controlled Trial

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ABSTRACT

Background: Children with cerebral palsy frequently experience impaired muscle strength, mobility, and functional independence. High-intensity circuit training (HICT) may complement conventional rehabilitation, although its additional benefits remain uncertain. **Objective:** To compare the effects of HICT combined with conventional rehabilitation versus conventional rehabilitation alone on functional outcomes in children with spastic cerebral palsy. **Methods:** A two-group randomized controlled trial was conducted at the National Special Education Center, Peshawar, Pakistan, from March 2022 to March 2023. Forty-six children aged 7–15 years were allocated equally to experimental and control groups (n=23 each). Interventions were delivered three times weekly for eight weeks. Outcomes included GMFM-88, 6MWT, TUG, TUDS, MAS, and MMT. Descriptive statistics and parametric or non-parametric comparisons were reported. **Results:** GMFM-88 scores increased by 3.57 and 3.30 percentage points in the experimental and control groups, respectively. Walking distance increased by 17.18 and 18.52 m, while TUG time decreased by 0.57 and 0.80 s, respectively. TUDS time decreased by 1.90 and 1.63 s. The descriptive between-group differences were small and varied across outcomes. **Conclusion:** Both rehabilitation approaches were associated with improved functional performance. The additional effectiveness of HICT over conventional rehabilitation alone could not be established from the available comparative results. **Keywords:** Cerebral palsy; high-intensity circuit training; conventional rehabilitation; gross motor function; functional mobility; randomized controlled trial.

INTRODUCTION

Cerebral palsy (CP) is a group of permanent disorders affecting the development of movement and posture, resulting in limitations in physical activity and functional performance. These disorders arise from non-progressive disturbances in the developing fetal or infant brain, although their clinical manifestations and associated functional limitations may change with growth and development. Children with CP frequently experience muscle weakness, abnormal muscle tone, impaired motor coordination, reduced postural control, balance deficits, and restrictions in

functional mobility. These impairments can adversely affect walking ability, performance of daily activities, independence, and participation in educational and community environments (1,2). Spastic cerebral palsy is the most common motor presentation and is characterized by increased resistance to passive movement, impaired selective motor control, and difficulties performing coordinated movements. These limitations may interfere with activities such as standing, walking, transferring, and negotiating stairs, thereby increasing the need for rehabilitation interventions directed toward improving functional abilities (3).

Physiotherapy plays an essential role in the multidisciplinary management of children with cerebral palsy by addressing impairments in muscle strength, flexibility, balance, mobility, and functional independence. Conventional rehabilitation generally includes stretching, strengthening exercises, postural control activities, balance training, gait exercises, and task-specific movement practice. However, rehabilitation outcomes may vary according to the child's age, severity of motor impairment, functional classification, baseline physical capacity, and the intensity and specificity of the prescribed intervention. Damiano et al. emphasized the importance of targeted rehabilitation approaches for managing lower-extremity dysfunction in ambulatory children with CP, highlighting the need to address functional limitations through appropriately selected therapeutic interventions (4). Similarly, Moreau et al., in a systematic review and meta-analysis, investigated the effectiveness of rehabilitation interventions for improving gait speed in children with CP, demonstrating the importance of evaluating functional mobility as an outcome of rehabilitation (5). Although conventional physiotherapy addresses several motor impairments, the additional benefits of incorporating more structured and intensive functional exercise programs require further investigation.

Muscle weakness is an important contributor to reduced physical performance in children with spastic cerebral palsy. Impaired muscle activation, reduced force production, and difficulty generating adequate muscular power may compromise walking efficiency, postural stability, endurance, and the ability to perform functional movements. These limitations are particularly relevant to activities such as rising from a seated position, maintaining balance during movement, climbing stairs, and walking over longer distances. Dodd et al., in a systematic review, examined the effectiveness of strength-training programs in individuals with cerebral palsy and highlighted the potential role of strengthening interventions in rehabilitation (6). Scholtes et al. subsequently evaluated functional progressive resistance exercise training in children with CP through a randomized controlled trial, contributing evidence regarding the relationship between strengthening exercises and walking ability (7). Furthermore, Van Vulpen et al. investigated functional power training in young children with CP and reported improvements in walking capacity and muscle strength following structured exercise (8). These investigations support the therapeutic relevance of progressive strengthening and functional training. Nevertheless, improvements in muscle performance do not necessarily produce equivalent improvements in functional mobility, endurance, or participation, emphasizing the importance of evaluating outcomes that directly reflect everyday physical activities.

High-intensity circuit training (HICT) represents a structured exercise approach in which multiple activities are performed sequentially over prescribed periods of exercise and recovery. Depending on the training protocol, circuit-based rehabilitation may incorporate strengthening exercises, aerobic activities, balance challenges, and functional movement tasks within a single intervention session. Its potential relevance to pediatric neurorehabilitation lies in providing repeated opportunities to perform goal-directed movements while challenging muscular performance, coordination, and physical endurance. Unlike isolated strengthening exercises, functional circuit activities may involve movements resembling everyday tasks, including standing, stepping, stair negotiation, reaching, and object manipulation. Blundell et al. investigated functional strength training through a group circuit-training program among children with CP aged 4–8 years, reporting improvements in lower-limb strength and selected functional performance measures (9). Their findings provided an early rationale for integrating task-specific activities into circuit-based rehabilitation. However, differences in exercise content, participant characteristics, and training dosage limit the extent to which these findings can be generalized to other pediatric CP populations.

Further research has examined the potential benefits of higher-intensity exercise and progressive resistance training among children with cerebral palsy. Schranz et al. compared home-based progressive resistance training with high-intensity circuit training and evaluated outcomes related to muscle strength, function, physical activity, and participation (10). Their investigation is particularly relevant because it directly considered high-intensity circuit training as a rehabilitation strategy for children with CP. In addition, Lauglo et al. investigated high-intensity

interval training and reported improvements in aerobic fitness, supporting the potential value of structured exercise programs that challenge cardiorespiratory capacity in this population (11). Although high-intensity interval training and high-intensity circuit training share certain principles, including repeated periods of physical exertion and recovery, they differ in exercise organization, training objectives, and the physical demands imposed on participants. Consequently, improvements in aerobic fitness or muscle strength cannot automatically be interpreted as evidence of improved gross motor function or functional mobility. Direct assessment of activity-related outcomes is therefore necessary to determine the clinical relevance of circuit-based exercise interventions.

Task-oriented circuit training has also been investigated as an approach to improving mobility and balance in children with cerebral palsy. Kumar and Kataria examined the effectiveness of task-oriented circuit training on functional mobility and balance, highlighting the relevance of structured movement practice in pediatric rehabilitation (12). Similarly, Nasiri et al. investigated the effects of high-intensity circuit training on balance and activities of daily living in children with CP, contributing further evidence concerning circuit-based rehabilitation approaches (13). These studies suggest that integrating functional activities within structured exercise programs may offer benefits across multiple domains of motor performance. However, differences in participant characteristics, motor severity, intervention protocols, exercise intensity, assessment tools, and treatment duration complicate direct comparisons across studies. Moreover, the extent to which such interventions provide additional functional improvement when combined with conventional rehabilitation, rather than delivered as an alternative exercise approach, remains an important clinical question.

The evaluation of functional rehabilitation in children with cerebral palsy requires outcome measures that capture both activity-level performance and impairment-related changes. The Gross Motor Function Measure-88 (GMFM-88) evaluates gross motor abilities across functional activities, whereas the Six-Minute Walk Test (6MWT) provides an assessment of walking capacity. The Timed Up and Go (TUG) test evaluates functional mobility through standing, walking, turning, and returning to a seated position, while the Timed Up and Down Stairs (TUDS) test measures performance during stair negotiation. In addition, Manual Muscle Testing (MMT) provides an ordinal assessment of selected muscle strength, and the Modified Ashworth Scale (MAS) assesses resistance to passive movement. Together, these measures provide complementary information regarding functional performance and selected neuromuscular impairments. Their combined use is particularly relevant when evaluating an intervention that incorporates strengthening, repetitive functional movements, and mobility-related activities.

Despite previous investigations into progressive resistance training, functional strengthening, aerobic conditioning, and circuit-based rehabilitation, uncertainty remains regarding the additional functional benefits of incorporating high-intensity circuit training into conventional physiotherapy for ambulatory children with spastic cerebral palsy. Existing studies have examined different exercise protocols and outcomes, making it difficult to determine whether findings from one intervention approach can be directly applied to another (7–13). Furthermore, the applicability of these approaches to children receiving rehabilitation in Pakistani special education and clinical settings requires further investigation. Children with spastic CP classified at Gross Motor Function Classification System (GMFCS) levels I and II generally possess ambulatory abilities that permit participation in structured functional exercises, making this population relevant for evaluating circuit-based rehabilitation. Examining the combination of HICT and conventional rehabilitation may therefore provide clinically useful information regarding changes in gross motor function, walking capacity, functional mobility, stair-climbing performance, muscle strength, and resistance to passive movement.

Therefore, the present randomized controlled trial was designed to compare high-intensity circuit training combined with conventional rehabilitation against conventional rehabilitation alone in children aged 7–15 years with spastic cerebral palsy classified at GMFCS levels I and II. The study aimed to evaluate changes in gross motor function using the GMFM-88, walking capacity using the 6MWT, functional mobility using the TUG test, stair-climbing performance using the TUDS test, muscle strength using MMT, and resistance to passive movement using the MAS following an eight-week intervention. It was hypothesized that changes in these functional and impairment-related outcomes would differ between children receiving HICT combined with conventional rehabilitation and those receiving conventional rehabilitation alone.

MATERIAL AND METHODS

A two-arm, parallel-group randomized controlled trial was conducted to compare the effects of high-intensity circuit training (HICT) combined with conventional rehabilitation versus conventional rehabilitation alone on functional outcomes in children with spastic cerebral palsy. The study was carried out at the National Special Education Center, Hayatabad, Peshawar, Pakistan, between March 2022 and March 2023.

The intervention was designed to evaluate whether incorporating structured, repetitive, functional circuit exercises into conventional rehabilitation was associated with additional improvements in gross motor function, walking capacity, functional mobility, stair-climbing performance, muscle strength, and resistance to passive movement. Participants were allocated to an experimental group receiving HICT alongside conventional rehabilitation or a control group receiving conventional rehabilitation alone. The intervention period was eight weeks, with treatment sessions scheduled three times weekly for both groups.

The target population comprised children diagnosed with spastic cerebral palsy who were receiving services at the study setting. Eligible participants were children aged 7–15 years with a Modified Ashworth Scale (MAS) score of 1–3 and a Gross Motor Function Classification System (GMFCS) level of I or II, indicating ambulatory functional abilities appropriate for participation in the prescribed rehabilitation activities.

Children with cognitive impairment, visual impairment, hearing impairment, or additional comorbidities or metabolic disorders were excluded. Eligibility assessment involved reviewing available school records and evaluating participants using the GMFCS, MAS, and Wechsler Intelligence Scale for Children–Fourth Edition (WISC-IV). The GMFCS was used to determine gross motor functional classification, the MAS to assess resistance to passive movement, and the WISC-IV as part of the assessment of cognitive eligibility. These procedures were used to identify children who fulfilled the study's predefined selection criteria.

Participants were recruited using a non-probability convenience sampling technique. During the recruitment process, 80 children were identified as fulfilling the eligibility criteria, from whom 46 were selected for participation. The sample size was determined using G*Power software, yielding a total of 46 participants. These participants were allocated equally into two groups, comprising 23 children in the experimental group and 23 in the control group.

Group allocation was carried out using a lottery-based procedure in which the names of eligible participants were written on separate pieces of paper, mixed in a drawer, and selected to form the two intervention groups. The experimental group received high-intensity circuit training combined with conventional rehabilitation, whereas the control group received conventional rehabilitation alone.

Participants in both groups underwent an eight-week rehabilitation program consisting of three treatment sessions per week. Conventional rehabilitation was provided in both groups and included passive stretching of tight upper- and lower-extremity muscles, supportive bridging exercises, ball-based activities for motor control, abdominal muscle co-activation exercises, and therapeutic positioning.

The conventional rehabilitation program also incorporated knee-to-chest movements and half-rolling exercises as components of abdominal co-activation. Passive stretching and supportive bridging exercises were described as involving 10 repetitions. These activities were intended to address limitations in flexibility, postural control, trunk stability, and functional movement associated with spastic cerebral palsy. Conventional rehabilitation constituted the sole intervention for participants assigned to the control group.

In addition to conventional rehabilitation, participants in the experimental group performed a structured high-intensity circuit-training program incorporating functional exercises involving the upper and lower extremities. The circuit consisted of three rounds of prescribed exercises, with each activity performed for 30 seconds followed by a 30-second rest interval.

The program included forward lunges, standing marching, knee-ups, butt kicks, stair ascending and descending, ball throwing, lifting objects from the ground to a table, and hanging activities performed for 30 seconds. Warm-up and cool-down activities were also incorporated into the experimental intervention. The exercises were organized to provide repeated practice of movements involving lower-limb activity, postural control, balance, coordination,

and functional mobility. The circuit-training component was delivered alongside the conventional rehabilitation program throughout the eight-week intervention period.

Functional outcomes were evaluated before the commencement of treatment and following completion of the eight-week intervention. The assessment battery included the Gross Motor Function Measure-88 (GMFM-88), Six-Minute Walk Test (6MWT), Timed Up and Go (TUG) test, Timed Up and Down Stairs (TUDS) test, Modified Ashworth Scale (MAS), and Manual Muscle Testing (MMT). These instruments were selected to evaluate different dimensions of gross motor performance, walking capacity, functional mobility, stair-climbing ability, muscle strength, and resistance to passive movement. The same outcome domains were assessed at baseline and after intervention to examine changes in functional performance over the treatment period.

Gross motor function was assessed using the GMFM-88, which evaluates motor abilities through 88 items distributed across five dimensions: lying and rolling, sitting, crawling and kneeling, standing, and walking, running, and jumping. The measure was used to evaluate functional motor performance, with the reported GMFM-88 outcomes expressed as percentages.

Walking capacity was assessed using the 6MWT, in which the distance covered during a six-minute walking period was recorded in meters. Functional mobility was assessed using the TUG test, which involves standing from a seated position, walking a specified distance, turning, returning, and sitting down, with completion time recorded in seconds. Stair-climbing performance was evaluated using the TUDS test, which measures the time required to ascend and descend stairs. Lower completion times on the TUG and TUDS tests represented better performance on the respective timed tasks.

Muscle tone-related impairment was assessed using the MAS, which grades resistance encountered during passive movement. The assessment included selected upper- and lower-limb muscle groups, with right upper- and lower-limb measurements reported among the study outcomes. Muscle strength was evaluated using MMT, an ordinal clinical grading system used to assess the ability of selected muscle groups to generate movement against gravity and resistance. The reported assessments included right upper-limb flexors and right lower-limb flexor muscle groups. Changes in MAS and MMT scores were used to evaluate selected impairment-level outcomes alongside the functional mobility and gross motor assessments. Pre-intervention and post-intervention assessments were performed by a lecturer from Khyber Medical College who was not involved in delivering the rehabilitation interventions. The assessor was unaware of participants' group assignments during outcome evaluation.

This assessor-blinded approach was used to reduce the potential influence of knowledge of treatment allocation on outcome assessment. Participants in both groups were evaluated using the study's selected outcome measures at the corresponding assessment points, allowing examination of changes within each group and comparison of outcomes between the two rehabilitation approaches.

Statistical analysis was performed using IBM SPSS Statistics, version 27. Continuous outcome variables were summarized using descriptive statistics, including means and standard deviations, while selected ordinal outcomes were summarized using medians and interquartile ranges. The Shapiro-Wilk test was used to assess the normality of data distributions. Parametric tests were applied to variables meeting the relevant distributional assumptions, whereas non-parametric tests were used for variables that did not satisfy those assumptions or were evaluated on an ordinal scale. Within-group pre-intervention and post-intervention comparisons were performed using paired-samples t-tests or Wilcoxon signed-rank tests, as appropriate.

Between-group comparisons were evaluated using independent-samples t-tests or Mann-Whitney U tests, according to the characteristics and distribution of the outcome data. Statistical significance was assessed at a two-sided threshold of $p < 0.05$. The analyses were intended to evaluate changes in gross motor function, walking capacity, functional mobility, stair-climbing performance, muscle strength, and resistance to passive movement following the prescribed rehabilitation interventions.

RESULTS

A total of 46 children with spastic cerebral palsy participated in the randomized controlled trial. Participants were allocated equally to the experimental group, which received high-intensity circuit training in addition to conventional rehabilitation, and the control group, which received conventional rehabilitation alone. Each group is

comprised of 23 participants (Figure 1). The mean age of the study population was 10.76 ± 2.83 years. The sample included 25 male and 21 female participants. Participant characteristics are summarized in Table 1.

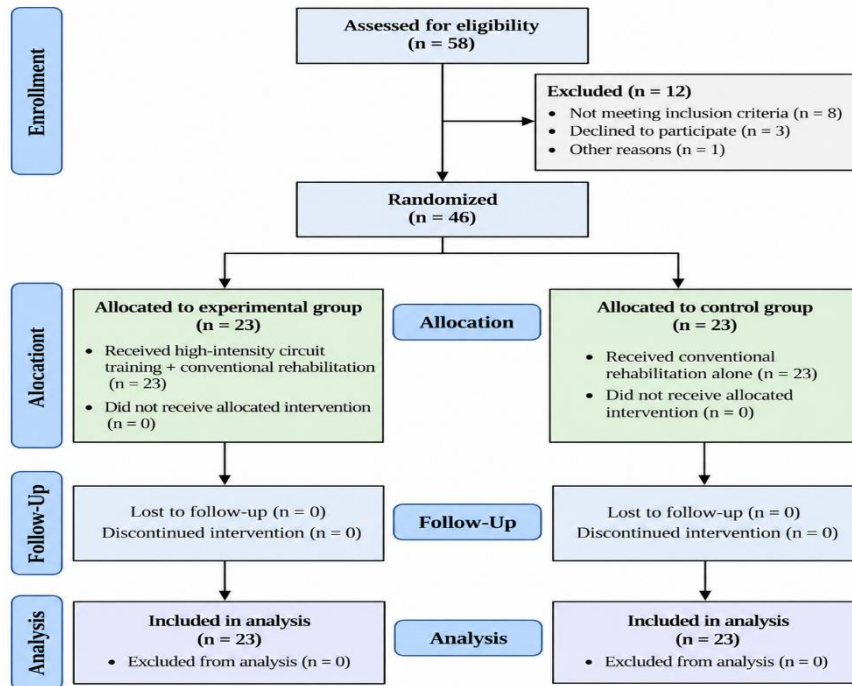


Figure 1. CONSORT participant flow diagram

At the end of the eight-week intervention period, increases in Gross Motor Function Measure-88 (GMFM-88) scores were reported in both groups. In the experimental group, mean GMFM-88 scores increased from $79.55 \pm 3.08\%$ at baseline to $83.12 \pm 3.03\%$ after intervention, representing an absolute increase of 3.57 percentage points. In the control group, scores increased from $79.15 \pm 3.57\%$ to $82.45 \pm 3.14\%$, representing an increase of 3.30 percentage points. The unadjusted difference in mean changes between the experimental and control groups was 0.27 percentage points.

Walking capacity, assessed using the Six-Minute Walk Test (6MWT), increased in both groups. The experimental group demonstrated an increase in mean walking distance from 387.82 ± 5.32 m to 405.00 ± 23.10 m, corresponding to a mean increase of 17.18 m. The control group demonstrated an increase from 381.08 ± 29.27 m to 399.60 ± 27.31 m, corresponding to a mean increase of 18.52 m. The unadjusted difference in changes was -1.34 m.

Table 1. Demographic and baseline characteristics of children with spastic cerebral palsy (N = 46)

Characteristic	Total (N = 46)
Age (years), mean $\pm$ SD	10.76 ± 2.83
Male, n (%)	25 (54.3)
Female, n (%)	21 (45.7)
Experimental group, n (%)	23 (50.0)
Control group, n (%)	23 (50.0)

Abbreviations: SD, standard deviation. Percentages were calculated using the total sample of 46 children.

Table 2. Functional outcomes at baseline and after eight weeks of rehabilitation

Outcome	Group	Baseline, mean $\pm$ SD	Week 8, mean $\pm$ SD	Change in mean
GMFM-88 (%)	Experimental	79.55 ± 3.08	83.12 ± 3.03	+3.57
	Control	79.15 ± 3.57	82.45 ± 3.14	+3.30
6MWT (m)	Experimental	387.82 ± 5.32	405.00 ± 23.10	+17.18
	Control	381.08 ± 29.27	399.60 ± 27.31	+18.52
TUG (s)	Experimental	9.70 ± 1.51	9.13 ± 1.37	-0.57
	Control	10.10 ± 1.72	9.30 ± 1.58	-0.80
TUDS (s)	Experimental	14.70 ± 1.32	12.80 ± 1.26	-1.90
	Control	15.43 ± 1.04	13.80 ± 1.31	-1.63

Abbreviations: GMFM-88, Gross Motor Function Measure-88; 6MWT, Six-Minute Walk Test; TUG, Timed Up and Go; TUDS, Timed Up and Down Stairs; SD, standard deviation. Change in mean = week-eight mean minus baseline mean. Group allocation was 23 children per group.

Table 3. Selected muscle tone and muscle strength measurements in the experimental group

Outcome	Baseline, median (IQR)	Week 8, median (IQR)	Reported p-value
MAS, right upper limb	2 (2)	1 (1)	<0.001
MMT, right upper-limb flexors	3 (0)	4 (1)	<0.001
MMT, right lower-limb flexors	3 (1)	4 (1)	<0.001
MAS, right lower limb	2 (2)	1 (1)	<0.001

Abbreviations: MAS, Modified Ashworth Scale; MMT, Manual Muscle Testing; IQR, interquartile range. P-values are transcribed from the manuscript's within-group table; the specific test used for each outcome requires verification.

Functional mobility, measured using the Timed Up and Go (TUG) test, demonstrated reductions in completion time over the intervention period. Mean TUG time decreased from 9.70 ± 1.51 s to 9.13 ± 1.37 s in the experimental group and from 10.10 ± 1.72 s to 9.30 ± 1.58 s in the control group. These values corresponded to reductions of 0.57 s and 0.80 s, respectively, with an unadjusted between-group difference in changes of 0.23 s.

Stair-climbing performance, assessed using the Timed Up and Down Stairs (TUDS) test, also demonstrated reductions in completion time. In the experimental group, mean TUDS time decreased from 14.70 ± 1.32 s to 12.80 ± 1.26 s, corresponding to a reduction of 1.90 s. In the control group, mean TUDS time decreased from 15.43 ± 1.04 s to 13.80 ± 1.31 s, representing a reduction of 1.63 s. The unadjusted difference in changes between groups was -0.27 s. The descriptive findings for gross motor function, walking capacity, functional mobility, and stair-climbing performance are presented in Table 2.

Selected muscle tone and muscle strength assessments in the experimental group are presented in Table 3. The median Modified Ashworth Scale (MAS) score for the right upper limb decreased from 2 (IQR 2) at baseline to 1 (IQR 1) following intervention. A corresponding reduction from 2 (IQR 2) to 1 (IQR 1) was reported for the right lower limb. Manual Muscle Testing (MMT) scores increased from a median of 3 (IQR 0) to 4 (IQR 1) for the right upper-limb flexors and from 3 (IQR 1) to 4 (IQR 1) for the right lower-limb flexors. The manuscript reported $p < 0.001$ for each of these experimental-group comparisons.

DISCUSSION

The present randomized controlled trial investigated the effects of high-intensity circuit training (HICT) combined with conventional rehabilitation compared with conventional rehabilitation alone on functional outcomes in children with spastic cerebral palsy. The findings demonstrated improvements in gross motor function, walking capacity, functional mobility, and stair-climbing performance over the eight-week intervention period in both groups. However, the magnitude of improvement differed across outcome measures, and the descriptive between-group differences did not consistently favor the addition of HICT. Although selected muscle strength and muscle tone measurements also showed changes following the combined intervention, the available results do not establish whether these changes were greater than those achieved through conventional rehabilitation alone. Overall, the findings suggest that structured rehabilitation incorporating functional exercises may support improvements in physical performance among ambulatory children with cerebral palsy, while the additional effectiveness of HICT remains uncertain.

Gross motor function improved in both intervention groups, as reflected by increases in Gross Motor Function Measure-88 (GMFM-88) scores. The experimental group demonstrated a mean increase of 3.57 percentage points, compared with 3.30 percentage points in the control group, resulting in a descriptive between-group difference in change of 0.27 percentage points. Although this difference numerically favored the combined intervention, its magnitude was small, and the available results do not establish whether it represents a statistically reliable or clinically meaningful treatment effect. Gross motor performance in children with cerebral palsy depends on several interrelated factors, including muscle strength, postural control, motor coordination, and the ability to perform purposeful movements. Repeated practice of functional tasks may contribute to improvements in movement execution and motor performance, particularly when exercises are incorporated into structured rehabilitation programs. Blundell et al. investigated a group circuit-training program involving functional strength exercises in children with cerebral palsy and reported improvements in selected strength and functional outcomes (9). Similarly, Scholtes et al. evaluated functional progressive resistance training in children with cerebral palsy, providing evidence relevant to the relationship between strengthening interventions and walking-related functional performance (7). These studies support the rationale for task-specific rehabilitation, although differences in

participant characteristics, intervention content, and training duration limit direct comparison with the present findings.

The improvement in gross motor function observed in both groups may also reflect the functional components incorporated into conventional rehabilitation. Stretching, supportive bridging, abdominal co-activation, positioning, and ball-based activities were included in the treatment received by both groups, while the experimental intervention additionally incorporated repeated functional movements such as lunges, marching, stair negotiation, and object lifting. These activities may provide opportunities to practice movements requiring coordinated activation of multiple muscle groups. Damiano et al. emphasized the importance of targeted interventions in the management of lower-extremity dysfunction among ambulatory children with cerebral palsy, supporting the use of rehabilitation approaches directed toward specific motor impairments and functional activities (4). However, because both groups received active treatment and demonstrated improvements, the present findings cannot isolate the contribution of individual exercise components or establish that circuit training independently enhanced gross motor performance. Furthermore, the small descriptive difference between groups suggests that the additional functional benefit of HICT should be interpreted cautiously.

Walking capacity, assessed using the Six-Minute Walk Test (6MWT), increased in both groups following rehabilitation. The experimental group demonstrated a mean increase of 17.18 m, whereas the control group showed an increase of 18.52 m, producing an unadjusted between-group difference in change of -1.34 m. This descriptive pattern did not favor the addition of HICT for walking distance. Walking performance in children with spastic cerebral palsy may be influenced by lower-limb strength, postural stability, movement efficiency, and physical endurance. The circuit-training intervention included repeated standing and lower-limb activities that could plausibly contribute to walking-related physical conditioning. Van Vulpen et al. reported improvements in walking capacity and muscle strength following functional power training among young children with cerebral palsy, suggesting that structured exercise directed toward functional muscle performance may have relevance to walking-related outcomes (8). Similarly, Moreau et al. examined rehabilitation interventions aimed at improving gait speed in children with cerebral palsy and highlighted the importance of evaluating walking performance when assessing therapeutic effectiveness (5). Nevertheless, the present findings suggest that additional circuit-based exercise was not accompanied by a larger descriptive improvement in six-minute walking distance than conventional rehabilitation alone.

Previous investigations of higher-intensity exercise provide further context for interpreting the walking results. Lauglo et al. examined high-intensity interval training among children with cerebral palsy and reported improvements in aerobic fitness, indicating that appropriately prescribed intensive exercise may enhance cardiorespiratory capacity in this population (11). Schranz et al. investigated home-based progressive resistance training and high-intensity circuit training in children with cerebral palsy, evaluating strength, function, activity, and participation outcomes (10). Although these studies support the clinical relevance of structured exercise, improvements in aerobic fitness, muscular capacity, or physical activity do not necessarily translate into equivalent improvements in six-minute walking performance. Differences in exercise intensity, training progression, baseline functional ability, and intervention specificity may contribute to variation in outcomes across studies. In the present trial, the circuit incorporated functional activities performed during repeated 30-second exercise intervals; however, the degree of physiological exertion achieved during these activities was not quantified in the reported protocol. Consequently, the relationship between prescribed circuit structure, actual exercise intensity, and walking capacity cannot be determined.

Functional mobility, assessed using the Timed Up and Go (TUG) test, demonstrated reductions in completion time in both groups. The mean reduction was 0.57 s in the experimental group and 0.80 s in the control group, resulting in a descriptive between-group difference in change of 0.23 s. Because lower TUG completion times represent better performance, the observed numerical difference in change favored conventional rehabilitation alone, although its statistical and clinical importance remains undetermined. The TUG test involves multiple coordinated activities, including transitioning from sitting to standing, initiating walking, turning, and returning to a seated position. These tasks depend on postural stability, lower-limb muscle activation, movement coordination, and functional mobility. Conventional rehabilitation and circuit-based exercise both incorporated activities relevant to these motor demands. Kumar and Kataria examined task-oriented circuit training in relation to functional mobility and balance in children with cerebral palsy, supporting the rationale for using repetitive functional activities in

rehabilitation (12). However, the present findings do not demonstrate that the addition of HICT produced a greater improvement in TUG performance than conventional treatment alone.

Stair-climbing performance showed a different descriptive pattern. The experimental group demonstrated a mean reduction of 1.90 s in Timed Up and Down Stairs (TUDS) completion time, compared with 1.63 s in the control group, corresponding to a between-group difference in change of -0.27 s. Although the numerical difference favored the experimental intervention, the magnitude was modest, and its clinical significance cannot be established from the available summary statistics. Stair negotiation requires coordinated lower-limb muscle activation, dynamic postural control, balance, and the ability to transfer body weight during ascending and descending movements. The experimental circuit incorporated stair ascending and descending as a specific training component, potentially increasing participants' opportunities to practice a task directly related to the outcome assessment. Task-specific repetition may help explain the descriptive improvement observed in stair performance, although the study did not directly investigate the mechanisms responsible for this change. Blundell et al. demonstrated the relevance of functional strength exercises within circuit-based rehabilitation for children with cerebral palsy, while Kumar and Kataria examined circuit training in relation to balance and mobility outcomes (9,12). These investigations provide a rationale for further exploration of task-oriented training, but the present results do not establish a definitive additional treatment effect.

The differences observed across functional outcomes may be related to the multidimensional nature of motor impairment in spastic cerebral palsy. Functional activities such as walking, rising from a chair, and negotiating stairs require different combinations of strength, coordination, balance, endurance, and motor control. Consequently, an exercise program may produce measurable changes in certain tasks without generating comparable changes across all functional domains. Previous investigations of progressive resistance exercise, functional power training, and circuit-based rehabilitation have similarly assessed multiple dimensions of motor performance, reflecting the complexity of rehabilitation outcomes in children with cerebral palsy (6–10). The relatively small descriptive between-group differences in the present study may also reflect the active nature of the comparator intervention, which incorporated therapeutic activities directed toward flexibility, postural control, muscle activation, and functional movement. Nevertheless, these explanations remain hypotheses because the study did not directly measure the physiological mechanisms or individual exercise contributions responsible for the observed changes.

Selected muscle strength and muscle tone-related outcomes were also assessed using Manual Muscle Testing (MMT) and the Modified Ashworth Scale (MAS). In the experimental group, median MMT scores for selected right upper- and lower-limb muscle groups increased from grade 3 to grade 4, while median MAS scores for the assessed upper and lower limbs decreased from 2 to 1. These findings indicate favorable changes in the reported ordinal clinical measurements following the combined rehabilitation program. Muscle weakness is a recognized component of functional impairment in children with cerebral palsy, and previous studies have investigated the effects of strengthening interventions on muscle performance and mobility-related outcomes (6–8). Nasiri et al. examined high-intensity circuit training in relation to balance and activities of daily living among children with cerebral palsy, providing additional context for evaluating the possible functional relevance of circuit-based rehabilitation (13). However, MMT scores represent ordinal estimates of muscle performance, while MAS scores reflect resistance encountered during passive movement rather than a direct physiological measurement of spasticity. Moreover, corresponding control-group results were not adequately presented, preventing determination of whether the observed changes were specifically attributable to the addition of HICT.

From a clinical perspective, the findings highlight the relevance of structured functional exercise within pediatric rehabilitation programs. Activities such as marching, lunges, stair negotiation, ball throwing, and object lifting are related to movement demands encountered during daily activities and may be incorporated into supervised rehabilitation according to individual functional abilities. Children classified at GMFCS levels I and II generally retain ambulatory capacity, making functional exercise approaches particularly relevant to their rehabilitation needs. Previous research has emphasized the potential value of strengthening, task-oriented training, and appropriately prescribed higher-intensity exercise in children with cerebral palsy (4,7–13). Nevertheless, the present study does not provide sufficient evidence to recommend HICT as superior to conventional rehabilitation. Decisions regarding rehabilitation intensity, exercise selection, and treatment progression should therefore continue to consider each child's motor abilities, physical tolerance, safety, and individual functional goals. The findings are most directly

applicable to ambulatory children with spastic cerebral palsy receiving supervised rehabilitation in settings comparable to the study center (14,15).

An important strength of the study was its two-group controlled intervention design, which allowed the addition of HICT to be examined against an active conventional rehabilitation comparator. The use of multiple functional outcome measures provided information across gross motor function, walking capacity, functional mobility, stair-climbing performance, muscle strength, and resistance to passive movement. The study also incorporated baseline and post-intervention assessments and reported the use of an outcome assessor who was unaware of treatment allocation. Conducting the intervention within a special education setting in Pakistan further provides context-specific information concerning the delivery of structured functional rehabilitation among children with spastic cerebral palsy. These features strengthen the clinical relevance of the investigation, although they do not eliminate uncertainties associated with trial execution and outcome reporting (16-19).

Several limitations should be considered when interpreting the findings. First, the sample included only 46 children recruited from a single center through convenience sampling, limiting the precision and broader applicability of the observations. Second, the intervention lasted eight weeks, and the absence of longer-term follow-up prevents assessment of whether changes in functional performance were maintained after supervised rehabilitation ended. Third, although the study described lottery-based group allocation and assessor blinding, the procedures used to conceal treatment assignment and maintain assessor masking were insufficiently detailed. Fourth, exercise intensity, progression, adherence, and total intervention dosage were not comprehensively quantified, limiting assessment of the delivered training stimulus and reproducibility of the intervention. Fifth, the available results did not provide adjusted between-group treatment estimates, confidence intervals, or sufficiently documented comparative statistical tests, restricting conclusions regarding the additional effectiveness of HICT. The manuscript also contained discrepancies between originally reported outcome tables, requiring verification of the source data before definitive interpretation. Finally, incomplete reporting of control-group MAS and MMT outcomes limited comparative assessment of muscle strength and resistance to passive movement. The study focused on selected physical performance measures and did not establish whether changes translated into sustained improvements in participation, independence, or quality of life (20,21).

Taken together, the findings indicate that both conventional rehabilitation and conventional rehabilitation supplemented with HICT were associated with favorable changes in several functional outcomes among ambulatory children with spastic cerebral palsy. However, the descriptive differences between groups were small and varied in direction across outcome measures, providing no consistent evidence of additional benefit from the combined intervention (22). The findings should therefore be interpreted as preliminary rather than definitive evidence of comparative effectiveness. Further evaluation using clearly documented allocation procedures, standardized and monitored exercise intensity, complete outcome reporting, appropriate between-group statistical analyses, and longer follow-up would help clarify the clinical contribution of HICT within pediatric cerebral palsy rehabilitation (23).

CONCLUSION

The present study demonstrated improvements in gross motor function, walking capacity, functional mobility, and stair-climbing performance over eight weeks in children with spastic cerebral palsy receiving either high-intensity circuit training combined with conventional rehabilitation or conventional rehabilitation alone. Although selected muscle strength and resistance-to-passive-movement measurements also showed favorable changes in the combined-intervention group, the descriptive differences in functional outcomes between groups were small and inconsistent. The available findings therefore do not establish that adding high-intensity circuit training provides greater functional benefits than conventional rehabilitation alone. Structured rehabilitation was associated with improvements in physical performance in both groups, while the additional clinical effectiveness of high-intensity circuit training requires confirmation through reliable comparative analyses.

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