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Original article

The influence of selective movements, strength training and emotional well-being on balance and quality of life in children with cerebral palsy: A holistic approach

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ABSTRACT

Background & Aim: Cerebral palsy (CP) is a leading cause of childhood disability, with spastic subtypes often resulting in motor impairments and reduced quality of life. While strength training and selective movement interventions show therapeutic potential, their combined effects with psychosocial support remain underexplored. This study evaluated the impact of a 12-week integrative program combining strength training, selective motor control exercises, and psychosocial support on motor function, balance, and emotional well-being in children with spastic CP.

Methods: A prospective single-arm intervention was conducted in rehabilitation centres affiliated with Mazandaran University of Medical Sciences in Iran. Sixty-one children (aged 4–12 years; Gross Motor Function Classification System [GMFCS] levels I–III) completed three 60-minute sessions per week. Primary outcomes included selective motor control (Selective Motor Control Questionnaire), balance (Timed Up-and-Go test, TUG), and strength (handheld dynamometry). Secondary outcomes were gross motor function (Gross Motor Function Measure-88, GMFM-88), quality of life (Paediatric Quality of Life Inventory, PedsQL), and emotional well-being (Strengths and Difficulties Questionnaire, SDQ). Psychosocial support included mood check-ins, positive reinforcement, and emotion-regulation techniques.

Results: The study included 61 children with spastic CP [mean age 7.8 (SD=2.1) years; 31 male, 30 female], distributed across GMFCS levels I (n=22), II (n=27), and III (n=12). Subtypes included hemiplegic (n=27), diplegic (n=29), and quadriplegic (n=5). Significant improvements were observed in selective motor control (51.2% increase, p<0.001), balance (27.3% faster TUG times, p<0.001), and knee extensor strength (35.6% increase, p<0.001). Secondary outcomes showed clinically meaningful gains in gross motor function (GMFM-D section +12.8% E section +13.7%), quality of life (PedsQL physical/emotional: +18.3/+16.2 points), and reduced emotional difficulties (SDQ: −5.3 points, p<0.001).

Conclusions & Recommendations: The integrated program improved motor and psychosocial outcomes in children with spastic CP, advocating for holistic rehabilitation. Future research should explore long-term sustainability and controlled trials.

Keywords: *cerebral palsy, strength training, selective motor control, quality of life, emotional well-being*

Introduction

Cerebral palsy (CP) is a group of lifelong movement disorders that originate from early brain developmental abnormalities, leading to varying degrees of motor dysfunction, spasticity, and impairments in balance and coordination (1,2). These motor deficits not only restrict mobility but also profoundly impact the quality of life of affected children, limiting their ability to perform daily activities, engage in play, and participate in social and educational settings (3-5). Spastic cerebral palsy (CP), representing 70-80% of all CP cases, is characterised by impaired selective motor control, muscular weakness, and postural dysfunction (6,7). These motor impairments frequently co-occur with psychological comorbidities, including anxiety, diminished self-esteem, and social withdrawal, collectively contributing to reduced quality of life (8,4).

CP rehabilitation has classically been focused on isolated physical interventions with an emerging evidence base supporting the effectiveness of strength training and selective movement exercises (9,10). Contemporary research refutes the historical concern about the worsening of spasticity with resistance training by demonstrating that progressive strength training improves muscle function without adverse effects (11,12). Similarly, selective motor control interventions explicitly address enhanced movement accuracy and functional mobility (13,14). However, they are rarely combined with psychosocial intervention despite growing awareness of the mind-body interface in neurorehabilitation (15,16).

While the physical benefits of such interventions are well-documented, the role of emotional well-being in the rehabilitation process remains equally critical yet often underemphasized. Children with CP frequently experience psychological challenges, including reduced self-esteem, social withdrawal, and anxiety, all of which can further limit their participation in physical and social activities (17). The interplay between physical functionality and emotional health can lead to profound enhancements in motor skills can lead to increased confidence, greater autonomy, and improved mental well-being. Studies have shown that structured exercise programs not only foster physical improvements but also contribute to higher levels of self-efficacy, resilience, and life satisfaction in children with CP (17,18). Current evidence in cerebral palsy rehabilitation reveals three critical limitations: integration of psychosocial support with physical therapies (17), insufficient evidence on motor-emotional combined interventions (18) and lack of holistic approaches.

In order to fill these gaps, this study evaluates a 12-week multimodal program integrating progressive strength training, selective movement exercises, and psychosocial support with mindfulness. Consistent with international guidelines (9) and the Cerebral Palsy-Functional Unification (CPFUN) framework (7), this combined intervention simultaneously targets physical and psychological outcomes, offering a multimodal alternative to conventional unimodal treatments.

Methods

Study design

This prospective single-arm intervention study evaluated a 12-week multimodal rehabilitation program in clinics of Mazandaran University of Medical Sciences, Iran (Ethical Code: IR.MAZUMS.IMAMHOSPITAL.REC.1403.102). The single-arm design was selected to establish preliminary effect sizes and feasibility for future randomised controlled trials, given the novel integration of physical and psychosocial components. Outcome measures were assessed at baseline and post-intervention by blinded evaluators to minimise measurement bias.

Study participants

A total of 61 ambulatory children diagnosed with spastic CP (Gross Motor Function Classification System [GMFCS] levels I–III) were recruited, comprising hemiplegic (n=27), diplegic (n=29), and quadriplegic (n=5) subtypes. The study was conducted in rehabilitation centres affiliated with Mazandaran University of Medical Sciences in Iran. Participants were eligible if they had a confirmed diagnosis of spastic CP, were between 4 and 12 years of age, were able to follow simple instructions, and could ambulate independently or with assistive devices. Exclusion criteria included a history of orthopaedic surgery within the past six months, botulinum toxin injections within the last three months, uncontrolled seizures, or fixed contractures that prevent participation in the intervention.

Outcome measures

Assessments were conducted at baseline and after the 12-week intervention to evaluate improvements in motor function, quality of life, and psychosocial well-being. Selective motor control was measured using the Selective Motor Control Questionnaire (SMCQ), a 10-item scale with a total score ranging from 0 to 20(19). Functional balance was assessed using the Timed Up-and-Go (TUG) test (20), which records the time required for a child to rise from a seated position, walk three meters, turn, and return to the chair. Muscle strength was evaluated through handheld dynamometry, specifically measuring knee extensor strength in kilograms.

Gross motor function was assessed using the Gross Motor Function Measure-88 (GMFM-88), focusing on Dimensions D and E, which assess standing and walking abilities (21). Quality of life was measured using the Paediatric Quality of Life Inventory (PedsQL 4.0) (22), and psychosocial well-being was assessed with the Strengths and Difficulties Questionnaire (SDQ) (23).

Intervention protocol

The intervention consisted of three weekly sessions, each lasting 60 minutes, over 12 weeks. The program incorporated three core components: strength training, selective movement training, and emotional well-being support.

The strength training component, lasting 25 minutes per session, focused on progressive resistance exercises targeting key muscle groups. Exercises included seated leg extensions to strengthen knee extensors, weighted calf raises to improve plantar flexor strength, and side-lying leg lifts to enhance hip abductor strength. Training was structured in three sets of 8 to 12 repetitions, with resistance progressively increased once participants could complete 12 repetitions with proper form.

The selective movement training component, lasting 20 minutes per session, consisted of targeted exercises designed to improve voluntary motor control, balance, and coordination. Exercises included toe tapping on numbered targets to enhance ankle dorsiflexion control, slow, controlled step-downs from a four-inch block to improve knee control, and ball tossing in a single-leg stance to promote weight shifting and postural stability. These exercises were further integrated into functional activities such as precision obstacle courses and sit-to-stand transitions with controlled descent, aimed at reinforcing motor skills in daily life.

The program's final component, emotional well-being support, was integrated into the final 15 minutes of each session under the guidance of a licensed paediatric psychologist. Each session began with mood check-ins using visual scales to help children express their emotional states. Positive reinforcement strategies, including verbal praise and goal-tracking charts, were used to encourage engagement and motivation. Emotion regulation techniques such as diaphragmatic breathing exercises, basic mindfulness practices, and gratitude reflection exercises were also introduced to promote self-regulation and emotional resilience. In addition, parent education modules were provided, focusing on recognising emotional cues in their children and encouraging continued participation in physical activities at home.

Session structure

Each session followed a standardised structure to ensure consistency and maximise therapeutic benefits. The sessions began with a 10-minute warm-up, consisting of dynamic stretching and light aerobic exercises to prepare the body for movement. This was followed by 25 minutes of strength training, targeting key muscle groups essential for functional mobility. Next, participants engaged in 20 minutes of selective movement training, focusing on exercises designed to enhance motor control and balance. Finally, each session concluded with a 5-minute cool-down, incorporating static stretching and mindfulness exercises to promote relaxation and recovery.

Safety and monitoring

To ensure participant safety, the intervention was conducted under continuous supervision by trained physiotherapists. Pain levels were assessed at every session using the Faces Pain Scale-Revised (FPS-R), and spasticity was monitored using the modified Ashworth scale. Adjustments to the training regimen were made in response to signs of fatigue, defined as a noticeable decline in movement quality, or when self-reported pain exceeded 3 out of 10 on the FPS-R. Any adverse events, including their nature, duration, and resolution, were systematically documented. This rigorous monitoring protocol ensured that all interventions remained within safe physiological limits while providing an appropriate therapeutic challenge for each participant.

Statistical analysis

Data were analysed using SPSS Statistics 26 (IBM Corp.). Normality of data distribution was assessed using the Shapiro-Wilk test. For normally distributed data, paired t-tests were conducted to compare pre- and post-intervention scores, while Wilcoxon signed-rank tests were used for non-parametric data. Effect sizes were calculated using Cohen's d, where values of 0.2, 0.5, and 0.8 were interpreted as small, medium, and large effects, respectively. Statistical significance was set at $p<0.05$ (two-tailed).

Ethical considerations

Informed written consent was obtained from the parents or legal guardians of all participants, and child assent was secured for children aged 7 years and older. Participation in the study was entirely voluntary, and participants had the right to withdraw at any time without facing any consequences. Confidentiality was strictly maintained through anonymized data collection and secure storage of all participant information in accordance with ethical guidelines.

Results

The study enrolled 61 children with spastic cerebral palsy [mean age 7.8 (SD=2.1) years; 31 male, 30 female] classified across Gross Motor Function Classification System (GMFCS) levels I (n=22), II (n=27), and III (n=12). Subtype distribution included hemiplegic (n=27), diplegic (n=29) and quadriplegic (n=5) variants.

Primary outcomes

As summarized in Table 1, participants exhibited significant improvements across all primary outcome measures. Selective motor control showed a 51.2% increase ($p<0.001$, $d=1.42$), reflecting a notable enhancement in movement precision and voluntary motor control. Functional balance also improved markedly, as indicated by a 27.3% reduction in TUG test times ($p<0.001$, $d=1.51$), demonstrating enhanced mobility and postural stability. Additionally, knee extensor strength increased by 35.6% (p<0.001, d=1.48), signifying meaningful gains in lower limb muscular function.

Secondary outcomes

Improvements extended beyond primary motor functions with gross motor function enhancements most pronounced in standing and walking abilities. Scores on the GMFM-88 increased by 12.8% in dimension D (standing) and 13.7% in dimension E (walking) (p<0.001), highlighting functional gains critical for independent mobility (Table 2). Additionally, quality of life showed notable improvements, particularly in physical (+18.3 points) and emotional (+16.2 points) well-being domains, reinforcing the holistic benefits of the intervention. Emotional and behavioural difficulties showed a significant reduction in total problem scores (-5.3 points, p<0.001) suggesting a positive impact on psychosocial well-being.

Table 1. Changes in primary outcomes (N=61)

Measure	Baseline Mean (SD)	Post intervention Mean (SD)	Mean difference (95% CI)	% change	*p* value
Boyd score (0-20)	8.4 (3.2)	12.7 (2.9)	4.3 (3.7, 4.9)	+51.2%	<0.001
TUG score (seconds)	13.2 (2.8)	9.6 (1.9)	-3.6 (-4.1, -3.1)	-27.3%	<0.001
Knee strength (kg)	14.6 (3.4)	19.8 (3.7)	5.2 (4.6, 5.8)	+35.6%	<0.001

SD: standard deviation, CI: confidence interval, TUG: Timed-up-and-go test

Table 2. Secondary outcome improvements (N=61)

Domain	Measure	Baseline mean (SD)	Post intervention mean (SD)	change (%)	*p* value
Motor function	GMFM-D (%)	52.3 (11.2)	65.1 (10.5)	+12.8	<0.001
	GMFM-E (%)	48.7 (10.8)	62.4 (9.7)	+13.7	<0.001
Quality of life	PedsQL Physical	58.2 (12.4)	76.5 (10.8)	+18.3	<0.001
	PedsQL Emotional	62.7 (14.1)	78.9 (11.3)	+16.2	<0.001
Emotional wellbeing	SDQ Total	14.8 (4.2)	9.5 (3.7)	-5.3	<0.001

SD: standard deviation, GMFM: Gross Motor Function Measure, PedsQL: Paediatric Quality of Life Inventory, SDQ: Strengths and Difficulties Questionnaire

Table 3. Selective motor control questionnaire item analysis

Task	Baseline Mean (SD)	Post intervention Mean (SD)	Improvement (95% CI)	*p* value
Heel walking	0.5 (0.3)	1.1 (0.3)	+120% (98, 142)	<0.001
Single-leg stance	0.7 (0.4)	1.4 (0.3)	+100% (82, 118)	<0.001
Ankle dorsiflexion	0.8 (0.4)	1.5 (0.3)	+87.5% (72, 103)	<0.001

SD: standard deviation, CI: confidence interval, TUG:

Selective motor improvements

Further analysis of selective motor control (Table 3) revealed that specific motor tasks exhibited even greater improvements. Performance in heel walking improved by 120%, while single-leg stance demonstrated a 100% increase, reflecting enhanced postural control and balance. Additionally, control over ankle dorsiflexion improved by 87.5%, underscoring the effectiveness of the intervention in enhancing distal lower extremity motor control, which is critical for gait and mobility.

Progressive training outcomes

The progressive resistance training protocol resulted in marked increases in training loads over the intervention period (Table 4). By the 12th week, participants performed knee extensions at 82% of their maximum resistance (equivalent to a red Thera Band®, plus an additional 2 kg), while calf raises were executed at 76% of maximum resistance (using a 6 kg weighted vest). Moreover, strength gains demonstrated a strong dose-response relationship, with training intensity positively correlated with improvements in muscle strength ($r=0.72$, $p<0.001$), suggesting that progressive overload played a crucial role in functional enhancements.

Predictors of treatment response

Exploratory analyses identified key predictors of greater treatment response (Table 5). Younger age (<8 years) and milder baseline impairment (GMFCS I) were associated with more pronounced improvements across multiple outcomes. Furthermore, children who demonstrated faster baseline mobility (TUG <12s) experienced greater selective motor control gains, with a mean Boyd score improvement of 5.1 compared to 3.2 in those with TUG≥12s ($p=0.01$). However, no significant correlations were observed between gender or baseline strength levels and treatment response, indicating that improvements were independent of these factors.

Safety and tolerability

The intervention was well tolerated, with no major adverse effects reported. Mild transient muscle soreness, resolving within 48 hours, was noted in three participants (8.6%), but no increases in spasticity or other safety concerns were observed. These findings underscore the safety and feasibility of integrating multimodal rehabilitation strategies in children with CP, reinforcing the potential for widespread clinical application.

Table 4. Training progression outcomes

Exercise	Initial load	Final load	% Achieving final load	Strength gain (kg) mean (SD)
Knee extensions	Yellow band	Red+2kg	82	5.8 (1.4)
Calf raises	Bodyweight	+6kg vest	76	4.9 (1.2)
Hip abductions	Bodyweight	1.5kg ankle	68	3.7 (0.9)

SD: standard deviation

Table 5. Response predictors (n=61)

Predictor	High response (n=23)	Moderate response (n=12)	*p* value
Age <8 years	78%	42%	0.02
GMFCS I	52%	25%	0.03
Baseline TUG <12s	61%	25%	0.01

GMFCS: Gross Motor Function Classification System, TUG: Timed-up-and-go test

Discussion

This study provides compelling evidence that a 12-week multimodal intervention—encompassing strength training, selective movement exercises, and psychosocial support—induces clinically significant improvements in motor function, quality of life, and emotional well-being among children with spastic cerebral palsy (CP). Our findings highlight three key takeaways: (1) substantial gains in selective motor control (d = 1.42) and functional mobility (d = 1.51), (2) noteworthy enhancements in psychosocial well-being, particularly a 16-point increase in emotional quality of life scores, and (3) a dose-response relationship between training intensity and functional outcomes. These results refine existing rehabilitation paradigms by reinforcing the synergistic benefits of integrating physical and psychosocial interventions.

The 51% improvement in selective motor control questionnaire scores observed in this study exceeds the 20–30% improvements typically reported with conventional selective movement therapies (13, 19). Several factors likely contributed to these superior outcomes. First, our focused ankle dorsiflexion training, which led to an 87.5% improvement in dorsiflexion control, targeted distal impairments often neglected in traditional protocols, which tend to emphasise proximal stability. Second, integrating resistance training alongside selective motor exercises may have enhanced neuromuscular recruitment patterns, supporting recent neuroplasticity models (15, 24). Notably, heel walking performance improved, which is similar to comparable intervention studies by Novak et al. (2020), suggesting that our dual-focused approach more effectively addresses key motor deficits in children with CP (25).

Functional mobility gains were equally remarkable. The 27% reduction in TUG test times surpassed the 15–20% reductions reported in studies focusing solely on strength training (12), suggesting that combining selective motor control training with progressive resistance exercises yields additive benefits (11). Additionally, our progressive resistance protocol led to a 35.6% increase in knee extensor strength, outperforming traditional fixed-load regimens (which typically yield 20–25% strength gains). This aligns with emerging evidence supporting the safety and efficacy of progressive resistance training in paediatric CP populations (26). Moreover, the strong correlation between strength gains and improvements in GMFM scores (r=0.71) underscores the functional relevance of resistance training in CP rehabilitation.

Beyond motor function, our findings emphasise the profound psychosocial impact of incorporating structured well-being components into rehabilitation. The 16-point increase in emotional quality of life far exceeds the 8–10-point improvements typically observed in strictly physical rehabilitation programs (7). This suggests that integrating goal setting, mindfulness, and positive reinforcement strategies amplifies the psychological benefits of physical rehabilitation. Moreover, our -5.3-point reduction in SDQ total problem scores is comparable to outcomes achieved with specialised psychological interventions (27), reinforcing the necessity of a biopsychosocial model of CP care. These findings align with the CPFUN model (16), which underscores the interdependence of mental and physical health outcomes in CP management.

While the single-arm study design provides critical preliminary evidence of the intervention's efficacy, various study design flaws in this instance are of note. First, the absence of a control condition prevents final conclusions about specific intervention effects over natural growth or placebo responses. Placebo effects may be particularly relevant to paediatric rehabilitation research, where child-therapist interaction and parental expectations influence outcomes (20). But a few considerations suggest our findings are true intervention effects and not placebo alone: (1) magnitude of change (51.2% improvement in selective motor control); (2) objective measures of biomechanics (dynamometry, timed test performance) accounted for 70% of our outcome variables; and (3) we observed a clear dose-response relation between dose of intervention and clinical change ($r=0.72$, $p<0.001$). Future randomised controlled trials need to have blinded assessors and active control groups to distinguish other specific treatment effects from such potential confounders. Despite the robust effect sizes observed ($d>1.4$ for primary outcomes), certain limitations must be acknowledged. The single-arm design limits direct comparison to control groups, though the magnitude of improvements suggests that findings remain clinically meaningful. Additionally, the 12-week duration does not allow for long-term follow-up, making it unclear whether these functional and psychological gains are sustained over time. Future research should explore optimal intervention dosing, strategies for long-term retention, technology-assisted rehabilitation models, and cost-effectiveness analyses to further refine evidence-based CP rehabilitation protocols.

Conclusions

This study demonstrates that a 12-week multimodal rehabilitation program has a significant effect on motor function and psychosocial adaptation in children with spastic CP. Responses to treatment, however, varied strongly by age, initial function (level of GMFCS), and extent of impairment, highlighting the need to modify individualised treatment. Treatment must be individualised in intensity and psychosocial support based on initial assessment and ongoing monitoring of response.

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Author Declarations

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