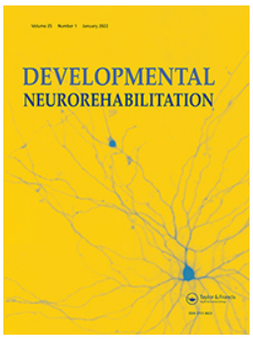

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Effects of Inspiratory Muscle and Balance Training in Children with Hemiplegic Cerebral Palsy: A Randomized Controlled Trial

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ABSTRACT

The aim of the study was to investigate the effects of inspiratory muscle and balance training on pulmonary function, respiratory muscle strength (RMS), functional capacity, and balance in children with hemiplegic cerebral palsy (CP). Thirty children with hemiplegic CP (Gross Motor Function Classification System I–II) included in this study. The control group (n = 15) underwent conventional physiotherapy rehabilitation program (CPRP) that included balance exercises, and the training group's (n = 15) program included inspiratory muscle training (IMT) in addition to CPRP for 8 weeks. The outcome measures were pulmonary function test, RMS measurement, the six-minute walk test (6MWT), and balance tests. There were no significant differences in the score changes of pulmonary function, balance, and 6MWT distance between groups ($p > .05$), whereas maximum inspiratory and expiratory pressure further increased in the training group ($p > .05$). RMS assessment and the identification of children who need it, and adding IMT to CPRP will contribute greatly to the rehabilitative approach of children with CP.

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Cerebral palsy; respiratory muscle strength; inspiratory muscle training; pulmonary function; balance

Introduction

Cerebral palsy (CP) has been described as a group of disorders of abnormal tone of muscles, movement, and posture that occurred as a result of brain injury during the prenatal, perinatal or early postnatal period.[1] Damage to the central nervous system causes disturbances in musculoskeletal, nervous, and sensory systems, leading to posture, movement, postural control, and balance problems in children with CP. The motor disorders of CP are often accompanied by cognitive, perceptional, sensorial, and behavioral problems, associated impairments (such as visual or hearing impairment, intellectual disability, oral-motor problems), epilepsy, and secondary musculoskeletal problems.[1,2] One of the most important problems in children with CP is postural control. Providing the postural control necessary for carrying out daily life activities is often a major problem for children with CP. The affected postural control may cause problems in gross motor skills that require balance in children with CP such as walking or reaching.[3,4]

Motor dysfunction in CP causes activity limitations, and because of its clinical importance, most treatment approaches focus on improving motor function and physical capacity.[5] However, children with CP are at risk for respiratory impairments, besides the motor problems. Respiratory problems, which are common in CP, contribute to increased morbidity and mortality, and a variety of factors such as deformity of the spine and chest wall, impaired airway clearance, recurrent aspiration, a poor cough mechanism, and nutritional status affect respiratory status in CP.[6] Abnormality of pulmonary function such as poor airway clearance, respiratory muscle weakness, and decreased chest mobility can be observed in children with CP.[7,8] Past research suggests that the pulmonary function of children with CP is decreased when compared to typically developing children,[9] and in a few limited studies, respiratory muscle weakness was reported in children with CP.[9–11] Respiratory muscle strength is related to the severity of motor impairment and decreases with the severity of motor function in children with CP.[8,12] According to Kwon et al.,[13] children with diplegic CP have lower respiratory muscle strength than children with hemiplegic CP.

Inspiratory muscle training (IMT) is widely used to improve respiratory muscle strength and pulmonary function in different diseases. Some studies have mentioned that there is a relationship between respiratory muscle strength and balance, and IMT can improve balance in different diseases.[14–17] To the best of our knowledge, three studies have examined the effects of respiratory muscle training via different devices and different techniques in children with CP,[10,11,18] and only one study by Keleş et al.[10] investigated the effects of IMT on trunk control. When the relationship between inspiratory muscle strength and balance is considered, improvement in balance can be achieved by increasing the respiratory muscle strength by IMT. Based on this evidence, it is hypothesized that postural stability and balance may be improved by IMT in children with hemiplegic CP. Therefore, the aim of this study was to assess the effects of IMT and balance training on pulmonary function, respiratory muscle strength, functional capacity, postural control, and balance in children with hemiplegic CP.

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Materials and Methods

Trial Design and Ethical Concerns

This prospective study was conducted as a randomized-controlled trial with a pretest/posttest design for a period of 8 weeks. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Bezmialem Vakif University (Protocol number: 54022451-050.01.04-9/90), and registered to the ClinicalTrials.gov website (Registration Number: NCT03396289). Written informed consents were received from all parents.

Subject and Settings

Figure 1 shows the flow chart and illustrates the recruitment procedure and the number of potential participants screened. Two hundred and twenty-five patients who were diagnosed as having CP were screened for this study. The inclusion criteria were being diagnosed as having hemiplegic CP (one side of the body is affected, addressed at the levels of "body function and structure" according to ICF) by a specialist of child neurology, aged 7–16 years old, classified as Gross Motor Function Classification System (GMFCS) level I or level II (was used to define the key points "activity and participation" according to ICF[19]) and having sufficient communication skills for understanding of spoken or written language. The exclusion criteria were orthopedic surgery and/or botulinum toxin – an injection in the lower extremity within the past 6 months, severe convulsions that could not be controlled by drugs, and congenital malformations accompanying CP.

Sample Size

The sample size was calculated using G*Power 3.1 (Universitaet Dusseldorf, Germany)[20] based on the variable

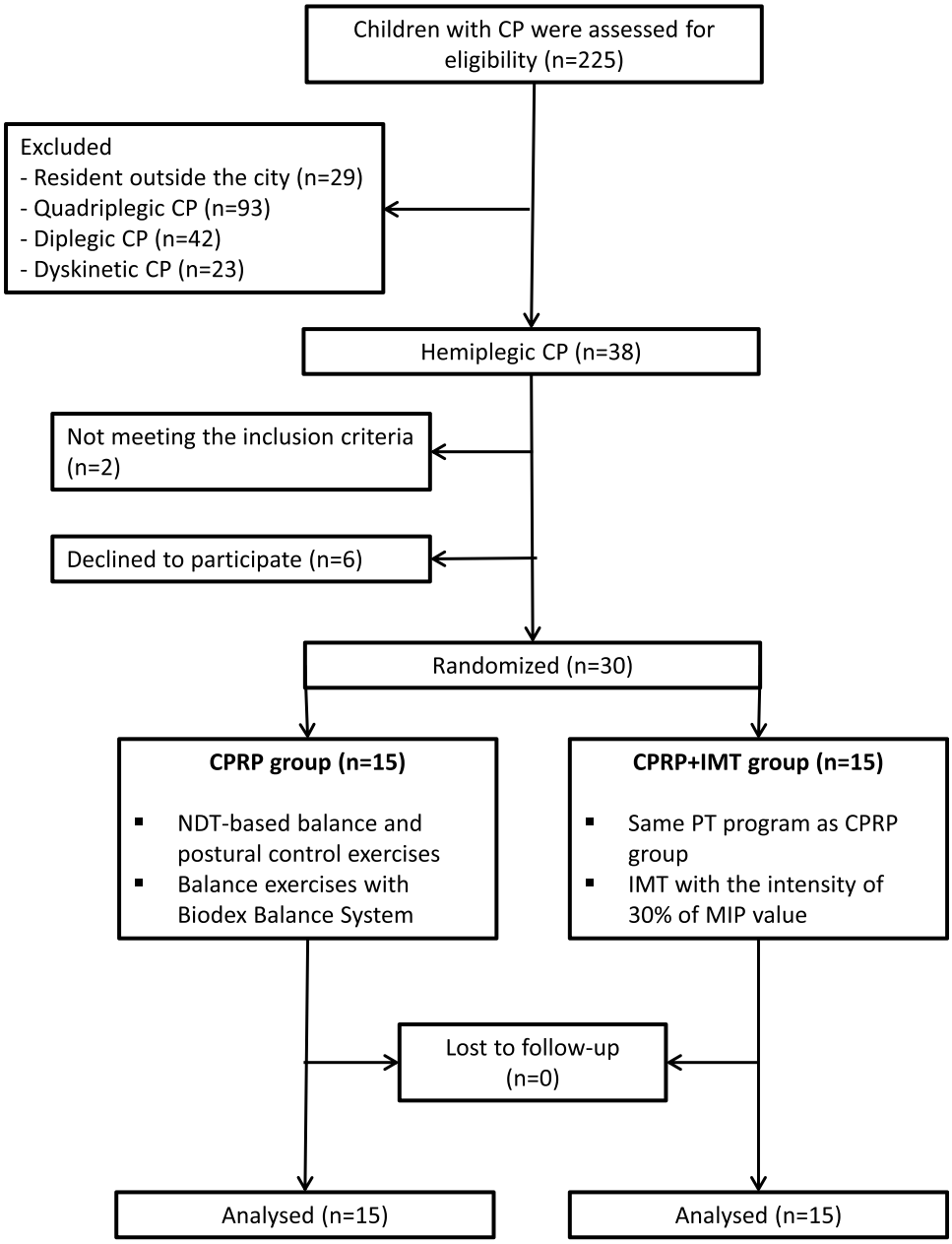

Figure 1. Flow chart. CP: cerebral palsy; CPRP: conventional physiotherapy rehabilitation program; IMT: inspiratory muscle training; NDT: neurodevelopmental therapy.

with the highest standard deviation among all variables in our study, which was the 6MWT. Keleş et al.[10] report that an increase of 66 m was achieved via IMT in 6MWT of children with CP (500 ± 60 m), which indicates an effect size of 1.1. We calculated that a minimum of 15 participants should be included in each group to detect such an improvement in 6MWT via IMT with 95% confidence level and 80% power (1-β) in our study.

Randomization

The children participating in the study were randomly divided into a control (n = 15) and a training (n = 15) group using a numbered series of 30 prefilled envelopes constituted by a computer-based randomization program. Children in the control group underwent a neurodevelopmental therapy (NDT)-based conventional physiotherapy rehabilitation program (CPRP) including balance exercises. Patients in the training group received IMT in addition to CPRP. The assessor completed pre- and posttest assessments for both groups and was not blinded to group allocation.

Assessment and Outcome Measures

Demographic Variables

The demographic and clinical characteristics of the children were recorded including age, sex, topographic classification (right or left affected side), birth weight, type of birth, gestational age, auxiliary equipment (if any), and medication taken (if any). Body mass index (BMI) was calculated by measuring the height and weight of each child. The gross motor function levels of the children were determined according to the GMFCS. All assessments described below were performed on children in both groups before the treatment and at the end of the 8-week physiotherapy program by the same investigator.

Pulmonary Function Test (PFT)

PFTs were performed using a COSMED Pony FX (COSMED; Italy) spirometer according to the American Thoracic Society (ATS) and European Respiratory Society (ERS) guidelines.[21] Forced vital capacity (FVC), forced expiratory volume at 1 s (FEV_1), and FEV_1/FVC and peak expiratory flow (PEF) were measured and expressed as percentages of the predicted values. Before the test, the physiotherapist who conducted the test explained and visually demonstrated the maneuver to each child. The children rested for 10 min before the test and the best performance of the three tests was accepted as the result. During the test, the device was held with the unaffected hand of the child.

Assessment of Respiratory Muscle Strength

Respiratory muscle strength assessments were conducted in accordance with the ATS/ERS criteria[22] using a portable, electronic pressure transducer (MicroRPM, Micro Medical, UK) using a rigid, plastic, flanged mouthpiece. The maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were measured after maximal expiration and inspiration, respectively. Before the measurement, the physiotherapist explained and visually demonstrated the maneuver to each child. The device was held with the unaffected hand of the child during the assessment. In this study, respiratory muscle strength was measured each week in children in both groups. The best of the three assessments was accepted as a result for both MIP and MEP.

Balance and Postural Stability

The Biodex Balance System (BBS; Biodex Medical Systems, Shirley, NY, USA) was used as a valid and a reliable device to quantify balance and postural stability.[23] The BBS consists of a support handle, a display, a printer and a platform, which has a static mode or dynamic modes (12 levels). Descriptive information about the test steps were given to all children in both groups before the evaluation. Children underwent three tests for BBS: the Postural Stability Test (PST), Limits of Stability Test (LoST), and the Test of Sensory Integration and Balance (TSIB).

The Six-minute Walk Test (6MWT)

6MWT was used to evaluate the functional capacity of children with CP. The 6MWT is an inexpensive, standardized test performed with submaximal clinical effort, which is commonly used to assess functional exercise capacity in children with CP.[24,25] The test does not require complex equipment, and is easy to administer in a clinical setting.[24] The ATS developed and published a guideline for performing the 6MWT in clinical settings.[26] The guideline recommends specific standardized instructions, encouragement, and corridor length. The 6MWT was administered according to the ATS guidelines,[26] using an indoor straight hard surface of 30 m marked with 3-m intervals. Before the test, the children were instructed to walk up and down as many laps as they could during the 6 min without running. The children rested in a chair near the starting position for 10 min before the test, and oxygen saturation, blood pressure, and heart rate were measured during this period and immediately after the test was completed. Dyspnea and fatigue levels were determined using the Modified Borg Scale before and after the test. At the end of 6 min, the distance in meters was recorded. The test was performed during the day with the children using orthotics if required.

Intervention Programs

Children in both groups underwent a CPRP including NDT-based balance and postural control exercises, and balance exercises with the BBS for 8 weeks with three training sessions of 45 minutes per week. In addition to CPRP, the training group also received IMT. One physiotherapy session per week was performed under the supervision of a physiotherapist, the other two sessions were performed as a home program for eight successive weeks. All physiotherapy sessions were conducted by the same physiotherapist experienced in pediatric physiotherapy.

CPRP was planned by individualizing each child after the first assessments. The general goals of this NDT-based treatment were inhibiting abnormal muscle tone, supporting sensorymotor development and the regulation of the agonist-antagonist muscles, and also facilitating normal movement patterns using proximal and distal key points on the child. NDT-based interventions were conducted as follows: weight-shifting

exercises (especially on the affected side) with and without reaching activities, reaching and elongation on the weight-shifted side, facilitating righting, equilibrium, and protective reactions to improve postural mechanisms, stretching exercises of the upper and lower limbs, and using sensory inputs (proprioceptive, tactile, vestibular, visual and auditory) to gain body control. A balance board, mats, trampoline, different sizes of exercise balls and suitable toys for the child's dexterity were used during the specific exercises.

Following the CPRP session, both groups received 15-min balance training with the BBS under the supervision of the same physiotherapist. Balance training with the BBS was conducted using only the static platform of the device. The training program was conducted while the child was in the standing position, with the feet in the same position as used during the test without any hand support. The Limits of Stability (5 min), Random Control (5 min) and Maze Control (5 min) training programs were performed, respectively. The children rested for 2 min after every 5 min of training.

The children in the CPRP+IMT group received IMT using a Threshold IMT (Threshold IMT, Philips-Respironics, Pittsburgh, USA) device, which has a spring-loaded valve that can adjust the inspiratory resistance during the inspiration period. Initial training workloads were determined as 30% MIP. The MIP was measured by the physiotherapist physiotherapist each week, 30% if MIP was determined as a new training workload, and the new training workload of Threshold IMT was adjusted by the same physiotherapist each week. The children in the CPRP+IMT group trained for 15 min twice daily, 7 days a week, one session per week under the supervision of the physiotherapist, for 8 weeks. The children's parents were advised to keep a diary in both groups. The exercise diaries were checked once per week by the physiotherapist.

Statistical Analysis

Qualitative variables are presented as percentages and quantitative variables as means with standard deviations. Statistical analyses were conducted using the SPSS V.20 (SPSS Inc., USA) program. The Kolmogorov–Smirnov test was used in order to evaluate whether the data had normal distribution. Analysis of qualitative variables of the two groups was interpreted using the chi-square test. The paired sample t-test was used for the comparison of pre- and posttest conditions within each group. Independent samples t-tests were executed in order to compare group differences for the results of BBS, 6MWT, PFT, and respiratory muscle strength. The significance level was accepted as $p < .05$ for all analyses. The effect size (Cohen's d) and 95% confidence interval (lower and upper) were calculated, and Cohen's d results represent 0.8 large, 0.5 medium, and 0.2 small effect.[27]

Results

Out of the 225 who were diagnosed as having CP were screened for this study (Figure 1). From participants screened only 38 were hemiplegic CP, 36 children who met the inclusion and exclusion criteria were selected, but 30 (16 girls and 14 boys) consented to participate, were randomized, and assessed. The demographic and clinical characteristics of the two groups, and the comparisons between the groups are presented in Table 1. There was no significant difference between the two groups in terms of the baseline characteristics of the children ($p > .05$). When the pregnancy process of the mothers of the participants was questioned, it was found that all children were born from spontaneous pregnancy and no mothers used assisted reproductive techniques. Five children in the CPRP+IMT group used regular anticonvulsant drugs, and three children had regular anticonvulsive drugs in the CPRP group; there were no significant differences between the groups ($p > .05$). In addition, none of the children had a history of epileptic seizures in the last year. There were six preterm and nine term children in the CPRP+IMT group and five preterm and ten term children in the CPRP group; there were no significant differences between the groups ($p > .05$).

There was no adverse effect during the study in both groups due to the intervention programs, and the training sessions were well tolerated. The pre- and post-training values of the pulmonary function, respiratory muscle strength and functional capacity of the two groups, and the training effects are given in Table 2. At the beginning of the study, there was no difference between them in terms of pulmonary function, respiratory muscle strength, functional capacity, postural stability, and balance evaluations. There were no significant changes in the FVC (% predicted), FEV1 (% predicted) and FEV1/FCV % values in both groups ($p > .05$), while MIP, MEP, PEF (% predicted) and 6MWT values were significantly increased ($p < .001$) after the training. The improvements in MIP and MEP values were significantly greater in the CPRP +IMT group compared with the CPRP group ($p < .001$). The effect sizes in MIP and MEP were very large (Cohen's $d = 3.154$; Cohen's $d = 2.714$ respectively).[27] There were no significant

Table 1. The baseline characteristics of children.

	CPRP+IMT group (n = 15)	CPRP group (n = 15)	p
Age, years (mean ± SD)	10.80 ± 1.76	11.20 ± 2.43	0.051
Gender (girls/boys), n (%)	9/6 (60%/40%)	7/8 (46.7%/53.3%)	0.715
Type of birth, n (%)			
Cesarean section	9 (60%)	7 (46.7%)	0.715
Vaginal	6 (40%)	8 (53.3%)	
Birth weight, g (mean ± SD)	2672.69 ± 717.34	2756.07 ± 1008.72	0.808
Gestational age, week (mean ± SD)	35.8 ± 4.42	36 ± 4.32	0.945
BMI, kg/m^2 (mean ± SD)	17.95 ± 3.17	18.38 ± 2.94	0.721
Affected body side, n (%)			
Left	7 (46.7%)	4 (26.7%)	0.450
Right	8 (53.3%)	11 (73.3%)	
GMFCS, n (%)			
Level I	10 (66.7%)	8 (53.3%)	0.710
Level II	5 (33.3%)	7 (46.7%)	
Orthotics, n (%)			
Not using	7 (46.7%)	10 (66.7%)	0.711
Night orthotics	3 (20%)	0 (0%)	
AFO/DAFO	5 (33.3%)	5 (33.3%)	

Data are presented as mean ± standard deviation or n (%)
CPRP: conventional physiotherapy rehabilitation program; IMT: inspiratory muscle training; BMI: body mass index; GMFCS: Gross Motor Function Classification System; AFO: ankle foot orthosis; DAFO: dynamic ankle foot orthosis; SD: standard deviation.

Table 2. Effects of treatment on pulmonary function, respiratory muscle strength and functional capacity.

	CPRP+IMT group				CPRP group				Between groups difference			
									95% Confidence interval			
	Before	After	In-group change (Δ)	Group difference *p*	Before	After	In-group change (Δ)	Group difference *p*	Lower	Upper	*p*	Effect size (Cohen's *d*)
Pulmonary function												
FVC, % predicted	82.07 ± 12.35	83.33 ± 12.76	1.27 ± 17	0.777	80.92 ± 12.21	82.91 ± 10.08	2 ± 9.45	0.431	−5.25	6.12	0.885	0.053
FEV_1,% predicted	86.53 ± 12.27	86.87 ± 13.65	0.33 ± 4.40	0.774	87.47 ± 7.18	87.53 ± 7.20	0.07 ± 4.15	0.951	−6.28	9.52	0.866	0.061
FEV_1/FVC, %	103.91 ± 10.21	102.37 ± 9.72	1.27 ± 12.59	0.643	101.26 ± 7.85	102.17 ± 8.96	0.93 ± 13.82	0.804	−3.61	8.40	0.652	0.026
PEF, % predicted	69.21 ± 12.63	77.16 ± 10.75	7.93 ± 11.62	**0.019**	67.55 ± 18.35	76.85 ± 14.60	9.33 ± 14.40	**0.026**	−14.70	11.08	0.772	0.107
Respiratory muscle strength												
MIP, cmH_2O	58.93 ± 13.50	87.20 ± 12.46	28.27 ± 9.59	**0.001**	64.47 ± 15.44	69.76 ± 15.90	5.27 ± 3.79	**0.001**	−37.48	−21.74	**0.001**	3.154
MEP, cmH_2O	61.93 ± 14.36	94.53 ± 12.06	32.60 ± 14.07	**0.001**	70.60 ± 16.87	74.47 ± 17.94	3.87 ± 5.11	**0.001**	−41.92	−20.80	**0.001**	2.714
6MWT distance, m	522.40 ± 51.35	572.27 ± 49.79	49.87 ± 28.13	**0.001**	518.02 ± 80.61	562.47 ± 91.75	44.44 ± 64.29	**0.001**	−42.53	31.70	0.767	0.109

Data are presented as mean ± standard deviation.
CPRP: conventional physiotherapy rehabilitation program; IMT: inspiratory muscle training; FVC: forced vital capacity; FEV_1: forced expiratory flow in 1 s; PEF: peak expiratory flow; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; 6MWT: six-minute walk test.

differences in PFT scores and 6MWT results between the groups after the treatment ($p > .05$). The pre- and post-training postural stability and balance evaluation values of both groups and the treatment effects are shown in Table 3. There was a significant improvement in the post-training postural stability and balance values in both groups, except "eyes closed firm surface" and "eyes closed foam surface" values, which were the subgroups of TSIB. There were no statistically significant differences between the two groups regarding postural stability and balance changes after treatment (Table 3). Although between-group differences were not found to be statistically significant, a medium effect was detected related to the effect sizes of the "overall" and "forward direction" scores of LoST (Cohen's d = 0.653; Cohen's d = 0.519, respectively).[27]

Discussion

This study focused on children with hemiplegic CP, and aimed to investigate the effects of IMT and balance training on pulmonary function, respiratory muscle strength, functional capacity, and balance. To our knowledge, this is the first study to investigate the effects of balance and IMT training on balance and postural control in children with CP. One of the most important findings in this study was that IMT improved respiratory muscle strength in children with hemiplegic CP. Respiratory muscle strength, functional capacity, postural stability, and balance were improved in both groups, but no significant differences in pulmonary function (except PEF) were observed after the treatment. When comparing the two groups, there was no significant difference in PFT, functional capacity, postural control, and balance parameters, whereas MIP and MEP values increased significantly in favor of the CPRP+IMT group.

Respiratory complications are the most important cause of morbidity and mortality in CP.[28] However, the limitation of functional activities due to motor dysfunction and the secondary complications associated with the musculoskeletal system are common in patients with CP, and most rehabilitation approaches are focused on improving motor function and maintaining existing physical capacity. Clinical symptoms such as poor air clearance, decreased chest wall mobility, and inadequate respiratory muscle function impair the capacity of physical activity in daily life and prevent the development of the motor function in CP.[5,7] Children with CP had lower respiratory function compared with children with normal development,[9,29] and previous studies demonstrated respiratory muscle weakness in children with CP.[5,8,10,13] Lanza et al.[30] reported that the reference values of respiratory muscle strength were 85.6 cm H_2O for MIP and 84.6 cm H_2O for MEP in children with normal development. Compared with these reference values, the average MIP and MEP values of the children included in our study were lower than in healthy children at the beginning of the study (58.93 ± 13.50 and 64.47 ± 15.44 cm H_2O for MIP; 61.93 ± 14.36 and 70.60 ± 16.87 cm H_2O for MEP in CPRP+IMT and CPRP groups, respectively).

Previous studies in the literature have reported IMT results showing improvement in respiratory muscle strength in

Table 3. Effects of treatment on postural stability and balance*.

	CPRP+IMT group				CPRP group				Between groups difference			
									95% Confidence interval			
	Before	After	In-group change (Δ)	Group difference *p*	Before	After	In-group change (Δ)	Group difference *p*	Lower	Upper	*p*	Effect size (Cohen's *d*)
Postural Stability Test (SI)												
Overall	1.79 ± 1.02	1.13 ± 0.76	−0.66 ± 0.37	**0.001**	1.74 ± 1.05	1.09 ± 0.54	−0.63 ± 0.65	**0.001**	−0.37	0.42	0.896	0.057
Anterior/posterior	1.26 ± 0.61	0.82 ± 0.52	−0.44 ± 0.31	**0.001**	1.35 ± 0.76	0.80 ± 0.44	−0.56 ± 0.43	**0.001**	−0.39	0.17	0.417	0.320
Medial/lateral	1.23 ± 0.86	0.76 ± 0.71	−0.46 ± 0.26	**0.001**	1.29 ± 1.04	0.75 ± 0.58	−0.55 ± 0.66	**0.006**	−0.46	0.29	0.649	0.179
Limits of Stability Test (0–100)												
Overall score	25.06 ± 7.00	53.85 ± 12.25	28.79 ± 10.75	**0.001**	28.40 ± 7.99	50.98 ± 11.08	22.57 ± 8.10	**0.001**	−13.35	0.90	0.084	0.653
Forward DS	33.54 ± 13.38	61.43 ± 16.05	27.90 ± 22.95	**0.001**	39.53 ± 16.82	58.25 ± 17.30	18.72 ± 9.98	**0.001**	−22.41	4.06	0.166	0.519
Backward DS	33.20 ± 11.76	55.97 ± 10.03	22.77 ± 13.92	**0.001**	37.45 ± 20.06	58.19 ± 17.42	20.74 ± 12.19	**0.001**	−11.82	7.76	0.674	0.155
Left DS	30.58 ± 9.80	57.93 ± 13.17	27.34 ± 15.47	**0.001**	33.70 ± 10.09	61.49 ± 11.41	27.78 ± 9.30	**0.001**	−9.10	9.99	0.925	0.034
Right DS	34.77 ± 10.31	63.67 ± 16.78	28.89 ± 15.40	**0.001**	35.62 ± 11.71	59.13 ± 15.99	23.50 ± 8.43	**0.001**	−14.68	3.89	0.244	0.434
Time to complete test (s)	70.33 ± 22.96	46.04 ± 11.60	−24.28 ± 13.01	**0.001**	60.87 ± 21.58	42.45 ± 11.45	−18.42 ± 23.28	**0.008**	−8.25	19.96	0.402	0.311
Test of Sensory Integration and Balance												
Eyes open firm surface	1.67 ± 0.53	1.04 ± 0.34	−0.63 ± 0.34	**0.001**	1.62 ± 0.53	1.11 ± 0.38	−0.51 ± 0.41	**0.001**	−0.16	0.41	0.389	0.319
Eyes closed firm surface	1.94 ± 0.67	1.77 ± 0.65	−0.16 ± 0.37	0.107	1.83 ± 0.91	1.72 ± 0.67	−0.11 ± 0.47	0.390	−0.26	0.37	0.724	0.118
Eyes open foam surface	1.90 ± 0.77	1.53 ± 0.57	−0.37 ± 0.53	**0.016**	2.14 ± 1.01	1.86 ± 0.75	−0.28 ± 0.45	**0.031**	−0.28	0.46	0.614	0.183
Eyes closed foam surface	3.52 ± 0.60	3.41 ± 0.58	−0.12 ± 0.35	0.211	3.76 ± 0.64	3.61 ± 0.68	−0.15 ± 0.43	0.206	−0.32	0.26	0.831	0.076
Composite score	2.48 ± 0.73	2.35 ± 0.74	−0.13 ± 0.37	0.191	2.54 ± 0.66	2.28 ± 0.68	−0.26 ± 0.50	0.063	−0.46	0.20	0.421	0.295

Data are presented as mean ± standard deviation.
CPRP :conventional physiotherapy rehabilitation program; IMT :inspiratory muscle training; SI: stability index; DS: direction score.
*Data provided with Biodex Balance System

various disabilities[31–33] and also in CP through different methods.[10,11,18] In our study, MIP and MEP values were increased in both the training and control group after 8 weeks of training. The IMT training loads were adjusted to 30% of MIP, weekly, and the respiratory muscle strength of all children was measured under the supervision of the physiotherapist each week. In the CPRP group not receiving IMT treatment, the increase in respiratory muscle strength may have been caused by the learning effect based on repeated assessments of respiratory muscle strength each week. The increase of the respiratory muscle strength in the CPRP group may have been due to the effect of the core muscle strength through balance training as well as the learning effect. However, the difference between MIP and MEP values of the CPRP+IMT group before and after treatment was 28.27 ± 9.59 cm H_2O (47.4%) and 32.60 ± 14.07 cm H_2O (53.2%), respectively, and the difference between MIP and MEP values of the CPRP group before and after treatment was 5.27 ± 3.79 cm H_2O (7.8%) and 3.87 ± 5.11 cm H_2O (5.6%), respectively, and the improvement in respiratory muscle strength of the CPRP+IMT group was greater than in the CPRP group, as we expected ($p < .001$). In addition to the learning effect, IMT increased muscle strength in children with CP in this study. However, there is no information about the long-term effect of IMT on respiratory muscle strength in children with CP, and further studies are needed.

In a study reported by Lee et al.[11] which used feedback respiratory training for 4 weeks in children with CP, there was a significant improvement in FEV_1 and FVC after training. However, in another study reported by Keleş et al.[10] which used the Threshold IMT for 6 weeks, no change in dynamic lung volumes was reported, similar to our results. These findings suggest that different techniques of the IMT applications and the length of the IMT treatment period may have different effects on children with CP. Further studies are needed to investigate the effects of different IMT techniques on the pulmonary function.

There is a relationship between respiratory muscle activation and the timing of contraction of the trunk muscles during extremity movements; the control of the trunk and the extremities may involve interaction with the diaphragm, which is the key respiratory muscle.[34,35] Impaired respiratory muscle activation may lead to a decrease in core stability required for normal balance and ambulation.[17] Reduced control of mediolateral stability and an increased risk of fall have been reported in individuals with chronic obstructive pulmonary disease.[36] A number of studies reported the effects of IMT on mobility and balance in heart failure,[37] multiple sclerosis,[17] and neuromuscular disease.[31] In this study, we established a hypothesis that IMT improves thoracic stability by increasing the strength of scalene muscles and diaphragm, therefore, improving balance and postural control. To our knowledge, there is only one study that demonstrated the effects of IMT for 6 weeks on postural control in children with CP.[10] According to the results of their study, IMT improved trunk control except static sitting balance, which was assessed using the Trunk Control Measurements Scale.[10] In our study, IMT was administered for 8 weeks in the CPRP+IMT group, and NDT-based balance exercises were performed in both groups. Although there are

respiratory problems and weakness in children with CP, most treatment approaches focus on motor disfunction.[5] Spasticity and decreased voluntary muscle control may cause balance and postural control problems in children with CP. Balance and postural control are important factors in maintaining daily living activities and gross motor function.[38] In light of these findings, most of the studies including conventional therapy in children with CP focused on balance and postural control.[39–41] Thus, in this study, balance exercises were performed in both groups. Balance and postural control assessed using the BBS, which is used in children with CP,[42,43] is a valid and reliable computer-aided device used to evaluate postural stability, stability limits, and fall risk.[23] After 8 weeks of treatment, the BBS values were increased and balance and postural control improved in both groups (Table 3). This is a result of the positive effects of the conventional therapy on balance and postural control in children with CP. On the other hand, no significant differences were found between the two groups in the balance parameters evaluated by BBS in our study. This may be the result of the dominant effect of spasticity on balance, which is the main disorder in spastic CP. Yang et al.[44] reported that spasticity was the most important factor affecting balance in children with CP. However, medium effect was found in the effect size between two groups in the subgroup "overall" (Cohen's $d = 0.653$) and "forward direction" (Cohen's $d = 0.519$) scores of LoST. In clinical practice, IMT may have a positive effect on balance (overall and forward direction scores) in children with hemiplegic CP. This clinically effective, but not statistically significant, differences for these two variables show us the need for further studies investigating the effects of IMT on balance and also considering the effect of spasticity on balance and postural stability, will be beneficial.

In the present study, the 6MWT was used to determine functional capacity, which is a standardized test that is commonly used in children with CP,[45,46] and also reported to be valid in children with CP.[46] Keleş et al.[10] reported that IMT significantly increased the 6MWT distance in children with CP. In our study, there was a statistically significant increase in 6MWT walking distance in both groups after the training ($p < .001$). However, the difference in the post-training 6MWT of the CPRP+IMT group (Δ walking distance = 49.87 ± 28.13 m) was higher compared with the CPRP group (Δ walking distance = 44.44 ± 64.29 m), but there was no statistically significant difference between the groups ($p > .05$). Balance and postural control problems in children with CP are among the most important causes of gait disturbances.[47] Given that there is a relationship between balance control and walking limitations in children with CP, it is beneficial to increase postural balance control to facilitate functional performance.[43] There was an increase in balance parameters in both groups, which may have had a positive effect on 6MWT. Therefore, this may explain the absence of a statistical difference in the comparison of the 6MWT between the groups.

It is not known whether anticonvulsants cause balance problems due to the adverse effects of these medications, and this may be considered as a limitation of this study. But, since there was no difference between the groups regarding the use of anticonvulsants at the beginning of the study, it did not create a bias on the effect of IMT. The most important limitation is that the study was not conducted as a blind study because the pre- and post-assessments, exercises, and IMT training were achieved at the same pulmonary rehabilitation laboratory of the department which has the BBS, spirometry, respiratory muscle strength measurement and the other assessment and various training devices in itself. For these reasons, it was not possible to provide the blindness of the study. Therefore, future blind studies investigating these effects are also needed.

In the literature, children with different types of CP or with different motor function levels of CP are included in studies investigating the involvement of balance or pulmonary function. In particular, children with hemiplegia and diplegia were investigated in the assessment of pulmonary function and respiratory muscle strength because these children's perception and oro-motor function are more sufficient than those with GMFCS IV and V. In most studies, differences in respiratory functions as well as respiratory muscles have been reported in groups with both spastic diplegic and hemiplegic children, but our study focused only on children with hemiplegia.[5,9,13] The power of the study is that this study is the only study conducted in children with hemiplegic CP. It is important to note that this study was conducted only on children with GMFCS level I and II hemiplegic CP, and the results of the study cannot be generalized to other CP types and other GMFCS levels.

Conclusion

In this study, respiratory muscle weakness was shown in children with hemiplegic CP. The results of this trial demonstrate that IMT training in addition to a CPRP could be safe and useful in improving respiratory muscle strength in children with CP. The effect of IMT on pulmonary function in children with CP is not clear and studies related to different IMT techniques are needed. NDT-based balance exercises can improve balance and postural control in children with CP. All childrens' PEF, respiratory muscle strength, functional capacity, balance and postural control values improved, showing that balance training had great impact on these parameters. Further research is needed to investigate the relationship between IMT and the specific components of balance and postural control in children with CP such as posture, spasticity, and peripheral muscle strength.

Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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