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Research Article

Effects of Modified Pilates Training on Hemodynamic Responses in Children with Cerebral Palsy: A Single-Blinded Randomised Controlled Study

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Abstract

Aim: This study aimed to ascertain the impact of Modified Pilates Exercises (MPE) and neurodevelopmental therapy (NDT) on hemodynamic response in children with Cerebral Palsy (CP).

Material and Method: We randomly assigned 18 CP children between expanded and revised gross motor function categorization system (GMFCS-E&R) I–III to study (MPE) and control (NDT) groups. Tests for core stability, the 6-minute walk test (6MWT), and the pressure biofeedback unit test (PBU) were conducted. Prior to and following the 6MWT and physiotherapy sessions, hemodynamic responses, including heart rate (HR), respiration rate (RR), and blood pressure (BP), were assessed before (BPT) and after physiotherapy (APT).

Results: There was a significant difference observed in the MPE group's BP (sistolic) of 6MWT (post) ($p=0.006$), the modified side bridge (MSBT) test ($p<0.05$), the sit-ups test ($p=0.011$), the pressure biofeedback unit test ($p=0.024$), and the abdominal fatigue test (AFT) ($p=0.014$) APT. The Modified Biering Sorensen Trunk Extensor Test (MBSTET) ($p<0.001$), MSBT ($p=0.034$), AFT ($p=0.002$), PBU ($p=0.015$), SUT ($p<0.001$), Modified Push Ups Test (MPUT) ($p=0.018$), BP (sistolic) of 6MWT (post) ($p=0.007$) following the walk, and RR ($p=0.005$) before and after 6MWT ($p=0.006$) in the MPE group were all significantly different APT, according to the initial measurements of the percentage changes.

Conclusion: When compared to NDT, MPEs have a favorable impact on core stability muscles, transversus abdominus (TrAb) activity, and hemodynamic and respiratory responses in children with CP.

Keywords: Cerebral palsy, core, hemodynamics, modified pilates, transversus abdominus

INTRODUCTION

The neurodevelopmental disease known as cerebral palsy (CP) is non-progressive, causes movement and postural abnormalities, and limits an individual's activities (1). Decreased postural and trunk control, muscle weakness, balance issues, stiffness, and other motor and sensory impairments cause children with CP to struggle with transfer, mobility, and social involvement (1).

Trunk control, formed by activating the core muscles, determines automatic postural reactions, postural control, balance, gait, and functional activities (2,3). Pilates exercises that target the Transversus Abdominus (TrAb) muscle can improve trunk muscle stabilization by fostering control as a result of core stabilization training. Additionally, the primary respiratory muscle, the diaphragm, collaborates with the TrAb muscle. Respiratory capacity can be increased by training the TrAb muscle, and thus, hemodynamic responses can be regulated.

Studies examining the effects of Pilates training in healthy adults, the elderly population, multiple sclerosis (MS), stroke, and musculoskeletal problems has shown that pilates increases trunk stabilization (4-6). Therefore, pilates training can be used to improve muscle strength and postural control in selected CP children who can walk and stand on their own but still need to establish a variety of skills for controlled movement (2).

There are deficiencies in their capacity to take part in play and sports activities in which they need to maintain their cardiorespiratory fitness in children with CP (7-9). Studies have reported that these children have

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significant differences in muscle strength, speed, agility, anaerobic endurance, and flexibility measurements in comparison with their peers (9). Children with CP have reduced cardiorespiratory responses, including anaerobic and aerobic exercise responses. However, compared to what motor impairment would have us believe, deficits in aerobic exercise responses and respiratory capacity are not as severe (9). Children with CP are treated using a variety of techniques to improve their cardiorespiratory fitness. To find out which exercise regimens are best for increasing aerobic exercise capacity, more research is necessary (10).

Research has revealed that the hemodynamic responses of children with CP during walking are also crucial in terms of risk factors for chronic diseases at an advanced age (9,11-13). There is a need for applicable and effective interventions to enhance the cardiorespiratory performance of children with CP by increasing their mobility (14). The literature has conflicting data regarding the benefits of exercise for cardiorespiratory and strength training. Therefore, it is thought that most physiotherapy interventions have limited efficacy on cardiorespiratory performance in children with CP (9,10). However, more investigation is required to determine the most effective strategies for improving functional outcomes in children with CP (15). Hence, it is remarkable that the impacts of Modified Pilates Exercises (MPE) training targeting the TrAb muscle, particularly in children with CP, on walking distance and hemodynamic responses have not been researched in the literature. The effects of MPE are not studied enough, and there is a lack of study on the effects of hemodynamic responses and core muscular endurance in children with different clinical forms of CP (16,17). The current research aimed to reveal the impacts of MPE and the traditional Neurodevelopmental Therapy (NDT) approach on hemodynamic responses in children with CP.

MATERIAL AND METHOD

Study Design

This research is randomized controlled (RC) and single-blinded. After being classified based on the Expanded and Revised Gross Motor Functional Classification System (GMFCS-E&R) to identify their degree of functional ability, children with CP (n=18) were randomly assigned using block randomization to either the study (MPE) (n=9) or the control group (NDT) (n=9). An overview of every stage of the research process is provided by the Consolidated Standards of Reporting Trials (CONSORT) flowchart in Figure 1.

The MPE group received care from a blinded physiotherapist who had completed training in MPE, was certified by the Australian Physiotherapy & Pilates Institute (APPI), had 5 years experience with pediatric rehabilitation, and was not involved in the assessments, while the control group received NDT-based physiotherapy for two days a week, one hour per day, for eight weeks. Neither the data collection nor the data analysis were done by the researcher who monitored the randomization procedure. All of the children were evaluated at baseline before physiotherapy (BPT) and eight weeks later after physiotherapy (APT) by a doctor physiotherapist who were experienced in pediatric rehabilitation for 5 years blinded throughout the randomization (Figure 1).

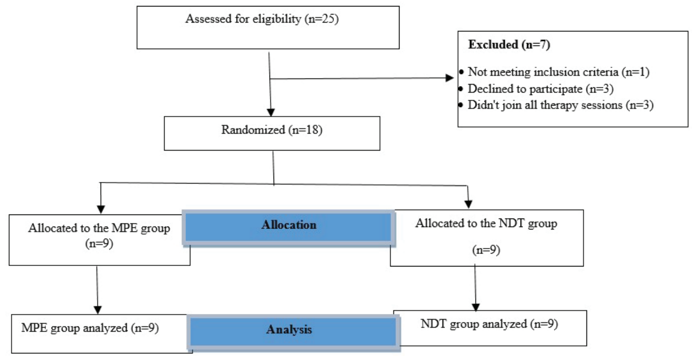

Figure 1. CONSORT flowchart of the study

Participants

Children who applied to the Developmental Physiotherapy and Pediatric Rehabilitation Unit of Gazi University, were diagnosed with CP according to the European CP Surveillance (SCPE) criteria were included. The following criteria had to be met in order to be included: being between the ages of 8 and 18; being able to perform a sit-to-stand activity; and being able to walk with or without the assistance of walking aids (18), having full range of motion with the lower extremity; Modified Ashworth (MAS) score for lower extremity spasticity between 1 and 1+; no recent lower extremities surgery or Botox; able to communicate and follow the verbal instructions. There were 25 children that qualified. Nine patients from each group made up the final total of 18 participants in the trial (10 Diparetic, 4 Hemiparetic, 4 Ataxic). Children with multiple disabilities, congenital or acquired cardiorespiratory diseases, those who had undergone surgery, received special MPE training within the last six months, or received botox injections to the lower extremities were not allowed. Parents gave their written, informed consent. The Ethics Commission at Gazi University gave its approval for this work (2022/09-The research number: 2022-634), and performed acoording to the principles of the Declaration of Helsinki. The clinical trial number is NCT05221307.

Measurements

Functional motor classification was determined by the GMFCS-E&R, lower extremity muscle tone was measured by MAS, TrAb muscle strength was measured by Sharman's core stability test (PBU=Pressure Biofeedback Unit Test), gait endurance and speed was measured by 6 Minutes Walking Test (6MWT). Also the 6MWT walking distance was measured in meters (m) and recorded.

Respiratory rate (RR), blood pressure (BP), and heart rate (HR) were measured and recorded for hemodynamic responses and cardiorespiratory endurance before and after 6MWT. Modified Beiring Sorensen test (MBSTET), prone plank test (PBT), modified side plank test (MSBT), abdominal fatigue test (AFT) was used for core stability performance measurements, and core muscle strength were evaluated by sit ups (SUT) and modified push ups (MPUT) tests.

Modified Ashworth Scale (MAS): Ashworth is a five-point ordinal scale for rating the resistance experienced during against the passive range of motion (19). The hip adductors, flexors, ankle plantar flexors, and knee flexors's tone were measured.

Expanded and Revised Gross Motor Functional Classification System (GMFCS-E&R): Children with CP are categorized using a standart categorization system into levels I through V based on their gross motor skills (18).

6 Minute Walk Test (6MWT): A self-paced, submaximal test called the 6MWT assesses a person's functional ability to walk long distances. A 20 × 45 m calm corridor served as the walking route, and markers were posted to the walls every 30 m. Chronometer started when a participant started to take a step. The finish line for the participant was marked on the wall by the examiner at six minutes. The duration of the completition of 6MWT and the total distance was recorded. The test was conducted without the use of orthotics on a straight line at the subjects' typical gait speed. The test's psychometric properties have been investigated (20).

Core Stability Performance Measurements

Core Muscle Static Endurance Tests

Core stability was evaluated using McGill's core muscular endurance tests (21-23). A stopwatch was used to time each core muscle endurance test, and the results were recorded in seconds (sec). For each test position, subjects were urged to hold their isometric positions for as long as possible. Children's ability to hold the right position for a given amount of time was noted. Every measurement was made twice, and the best measurement was noted as sec. When the position couldn't keep, the tests were stopped and the duration was recorded as sec. These tests:

Modified Biering-Sorensen Trunk Extensor Test (MBSTET): The children stretched their upper bodies over a treatment table while seated with their anterior superior iliac spine aligned with the edge. The treatment table was attached to the participants' knees, hips, and pelvis by the assessor. A chair supported the upper extremities and the body. The chair was then taken away, and the contestants remained on the chessboard with their arms crossed for as long as they could (23). When the position couldn't keep, the test were stopped and the duration was recorded as sec.

Prone Bridge Test (PBT): The children straightened their knees and positioned their elbows and forearms underneath their shoulders. They elevated their hips while keeping their forearms and toes firmly planted on the ground (23). They did this for as long as they could. If necessary, they were supported. When the position couldn't keep, the test were stopped and the duration was recorded as sec.

Modified Side Bridge Test (MSBT): Lying on their left or right sides, the children used their forearms and elbows beneath their shoulders to support themselves as they flexed their legs and raised their hips off the ground (23). They got help if they needed it. When the position couldn't keep, the test were stopped and the duration was recorded as sec.

Abdominal Fatigue Test (AFT): The children were supported at a 60-degree angle from the floor with their trunks in a sit-up position. They crossed their arms over their chest while bending their knees and hips 90 degrees. From having their feet on the ground, they were balanced. Then the trunk support was taken away, and the children stayed in this posture for as long as they could keep this position (23). When the position couldn't keep, the test were stopped and the duration was recorded as sec.

Sharman's Core Stability Test (PBU=Pressure Biofeedback Unit Test): A stopwatch (Heuer Microsplit 1000) and a Chattanooga Stabilizer pressure biofeedback sensor were used to record pressure measurements. Any spesific strategies connected to this were noticed and categorized, such as holding one's breath and raising one's ribcage, using Richardson and Jull classifications. The inflatable device's lower border was positioned in the center of the abdomen, at the level of the anterior superior iliac spines (ASIS). The children were taught how to perform a 10-sec contraction of the abdominal drawing-in maneuver to selectively contract their TrAb. A baseline pressure of 70 mm Hg was used to calculate pressure changes. The calculated mean change in pressure (mmHg) at the end of the three contractions was recorded (24,25).

Core Muscle's Power Tests

Sit-Ups Test (SUT): The children were instructed to flex their trunks while their knees were bent and their feet were supported. The number of sit-ups the children performed from a supine position in 30 secs was counted (26).

Modified Push-Ups Test (MPUT): Children were instructed to elevate their head, shoulders, and trunk off the ground while lying on their backs with their arms, knees, and elbows flexed. They were timed to see how many push-ups they could complete in 30 secs (26). The total number of push-ups was recorded.

Intervention

Modified Pilates Exercises (MPE): The physical therapist presented the fundamentals of Pilates during the first session. All of the sessions began with supine centering and segmental extremity motions as a warm-up. Included were exercises from Matwork levels I–II as per the APPI. Every activity was altered to accommodate the limitations associated with CP as well as the age-specific physical and cognitive needs. For the first five sessions, each exercise was done five times; in subsequent courses, this was increased to ten to fifteen times. The exercises were offered in escalating difficulty order. Also:

1. If any pain strikes, the children stop or take a rest.
2. Without moving their spines or rib cages, the children slowly completed 5 to 10 repetitions of each activity.
3. All of the children underwent multiple training sessions in the five Pilates principles prior to starting the program: breathing, centering (neutral spine posture), positioning the ribs and shoulder blades, and positioning the head and neck. Consequently, the children learned how to regulate their segments, perform the abdominal drawing movement, imprint, contract the TrAb and multifidus muscles, and manage their lumbar region.
4. As a cool-down, posture, breathing, and stretching exercises were performed.

The controlled motions out of neutral position of the lumbar-pelvic region were gradually integrated. Furthermore, the movements were soft and painless. In order to adjust the workout or progression to the children's needs, maintain proper technique, control speed, assist with optimal muscle activation, etc., the physiotherapist provided customized facilitation approaches. Examples of facilitation strategies include the use of verbal or physical cues, mental and visual pictures, and demonstration.

Neurodevelopmental Therapy (NDT-Bobath): Every child received a personalized, traditional exercise program designed in the NDT-Bobath baseline, crafted by a qualified physiotherapist with five years of NDT experience. Therapy included weight-bearing exercises in various positions for equal weight transfer on both upper and lower extremities without interfering with the postural control, enhancing writhing and balance reactions in all positions, and supporting sense-perception-motor development. Proprioceptive and vestibular training, dynamic balance training, functional reaches in many directions, and walking drills in various directions can all be achieved with exercise balls and balancing boards.

Statistical Analysis

For continuous variables that were measured, descriptive statistics provided the mean, standard deviation, median, and minimum and maximum values; for qualitative variables, descriptive statistics provided the frequency and percentage values. Utilizing the Shapiro-Wilk W test, one might assess how well the data fit into the normal distribution. The Mann-Whitney U test was used in group comparisons because the measurement-specified continuous variables did not meet the requirements for parametric tests. When comparing qualitative variables between groups, the chi-square test was used. For normally distributed data, the Wilcoxon paired-sample test was employed in dependent measurement comparisons; for non-normally distributed data, the significance test of the difference between two pairs was utilized. At the $p<0.05$ level, the results were acknowledged to be significant. Based on post hoc power analysis, the sample size was calculated (power=0.80, p=0.05, n=9 for each group; G*power version 3.1.9.2, Axel Buchner, Universität Kiel). Since there isn't a comparable study in the literature to calculate the effect size, the post-hoc power analysis used the 6MWT score of nine participants from each group.

RESULTS

Concerning the mean age of the study groups, it was 9±1.58 (7-11) in the MPE group (n=9) and 10±2.73 in the NDT group (n=9) Table 1 contains the other sociodemographic characteristics of the children.

Table 1. Demographic information of the children in the study

	MPE group (n=9) Median (min-max)	NDT group (n=9) Median (min-max)	Total (n=18) Median (min-max)	p value
Age (years)	9 (7-11)	10 (7-15)	9 (7-15)	0.605
Height (cm)	130 (110-145)	130 (110-155)	130 (110-155)	0.489
Weight (kg)	25 (17-42)	30 (20-50)	28,5 (17-50)	0.136
PT duration (years)	8 (5-10)	7 (5-12)	7,5 (5-12)	1.000
PT frequency (day/week)	2 (1-5)	2 (2-3)	2 (1-5)	0.863
	(n/%)	**(n/%)**	**Total (n/%)**	
Gender				
Male	4/44.4	6/66.7	10/55.6	0.637
Female	5/55.6	3/33.3	8/44.4	
GMFCS (E&R) levels				
I	4/44.1	2/22.2	6/33.3	
II	4/44.1	7/77.8	11/61.1	0.666
III	1/11.1	0/0	1/5.6	
Children's clinical CP types				
Spastic diparetic	5/55.6	5/55.6	10/55.6	
Spastic hemiparetic	2/22.2	2/22.2	4/22.2	1.000
Ataxic	2/22.2	2/22.2	4/22.2	

Mann-Whitney U test, Pearson and Fisher's Chi-Square tests, *p <0.05, GMFCS: Gross Motor Functional Classification System (E&R) levels

A significant difference was found between the two groups in terms of MBSTET, PBT, MSBT (left), SUT, MPUT, 6MWT distance (m), 6MWT Blood Pressure (mmHg) (AW) (diastolic), 6MWT Blood Pressure (mmHg) (BW) (systolic), and 6MWT Blood Pressure (mmHg) (AW) (systolic) after comparing the intra-group results of the children BPT and APT (p<0.05). There was only a significant difference in the MPE group's MSBT right, AFT, 6MWT Respiration Rate (BW), and 6MWT Respiration Rate (AW) when the intra-group findings of the children BPT and APT were compared (p<0.05) (Table 2).

When the core stability performance measurements, 6MWT, and hemodynamic parameters of the children BPT and APT were compared between the groups, a significant decrease was detected in MSBT (right p<0.05, left p<0.05) and AFT (p<0.05) durations, a significant decrease was found in PBU test (p<0.05) measurements, and a significant increase was identified in SUT (p<0.05) in favor of the MPE group (Table 2). Diastolic blood pressure measured before 6MWT was significantly lower in favor of the MPE group (p<0.05) APT. Systolic blood pressure after 6MWT was significantly higher in the MPE group (p<0.05) APT (Table 2).

Table 2. Comparison of children's core stability performance measurements, 6MWT and hemodynamic parameters BPT and APT

		MPE group (n=9) Median (min-max)	NDT group (n=9) Median (min-max)	pa value
MBSTET (sec)	BPT	15.6 (3.93-47.94)	35 (15-66.83)	0.04*
	APT	54.6 (17-126)	36 (18-103.27)	0.796
p^b		0.008*	0.008*	
PBT (sec)	BPT	10.96 (0-32.7)	31.51 (9.24-122.63)	0.024*
	APT	24.6 (8.5-92)	35.61 (9.45-127.89)	0.387
p^b		0.008*	0.038*	
MSBT right (sec)	BPT	24.22 (0-60.5)	13.5 (0-96.7)	0.863
	APT	44.6 (10-130)	14.6 (0-103)	0.04*
p^b		0.008*	0.093	
MSBT left (sec)	BPT	23.88 (0-52.4)	16.6 (4.01-126.27)	0.73
	APT	49 (8-119)	16.95 (4.05-128.2)	0.031*
p^b		0.008*	0.021*	
AFT (sec)	BPT	19.3 (10.96-27.5)	14.96 (7.07-26.88)	0.436
	APT	32 (15-40)	14.5 (7.03-40)	0.014*
p^b		0.008*	0.11	
PBU (mm hg)	BPT	77.20 (72.2-100.7)	91.5 (70-104)	0.258
	APT	71.20 (70-90.3)	87 (70-103)	0.024*
p^b		0.066	0.138	
SUT	BPT	10 (6-14)	10 (0-19)	0.546
	APT	16 (12-23)	11 (1-21)	0.011*
p^b		0.007*	0.034*	
MPUT	BPT	8 (0-17)	9 (0-23)	0.546
	APT	11 (6-20)	10 (1-24)	0.796
p^b		0.011*	0.007*	
6MWT (m)	BPT	120 (0-204)	254 (80-267)	0.113
	APT	156 (18-204)	258 (82-290)	0.387
p^b		0.012*	0.011*	
6MWT pulse (pulse/min) (BW)	BPT	97.33 (60-130)	94 (64-110)	0.478
	APT	97.66 (60-120)	92 (66-110)	0.150
p^b		0.866	0.461	
6MWT pulse (pulse/min) (AW)	BPT	108.44 (90-135)	101 (67-120)	0.438
	APT	106.33 (90-125)	101 (70-125)	0.363
p^b		0.160	1.00	

a Mann-Whitney U test, *p<0.05, **p<0.001, b Wilcoxon signed rank test, BW: before walk, AW: after walk, BPT: before physical therapy, APT: after physical therapy, MBSTET: modified biering sorensen trunk extensor test, PBT: prone bridge test, MSBT: modified side bridge test, AFT: abdominal fatigue test, PBU: pressure biofeedback unit test, SUT: sit ups test, MPUT: modified push ups test, mm hg: millimeter hg, sec: second, 6MWT: 6 minute walk test, m: meter, min: minute

Table 2. Comparison of children's core stability performance measurements, 6MWT and hemodynamic parameters BPT and APT

		MPE group (n=9) Median (min-max)	NDT group (n=9) Median (min-max)	pa value
6MWT respiration rate (rr/min) (BW)	BPT	36 (30-42)	22 (21-28)	p<0.001**
	APT	32 (24-40)	21 (20-24)	p<0.001**
p^b		0.01*	0.655	
6MWT respiration rate (rr/min) (AW)	BPT	40 (32-48)	23 (21-28)	p<0.001**
	APT	35 (32-40)	23 (21-26)	p<0.001**
p^b		0.01*	1.00	
6MWT blood pressure (mmHg) (BW) (diastolic)	BPT	57 (50-60)	65 (50-100)	0.197
	APT	58 (50-70)	70 (50-80)	0.012*
p^b		0.655	0.150	
6MWT blood pressure (mmHg) (AW) (diastolic)	BPT	58 (50-70)	60 (50-80)	0.958
	APT	57 (50-60)	67 (50-80)	0.169
p^b		0.006*	0.005*	
6MWT blood pressure (mmHg) (BW) (sistolic)	BPT	122 (120-130)	121 (120-130)	0.903
	APT	131 (120-140)	128 (120-130)	0.331
p^b		0.011*	0.029*	
6MWT blood pressure (mmHg) (AW) (sistolic)	BPT	124 (120-130)	120 (120-125)	0.081
	APT	131 (130-140)	128 (120-130)	0.006*
p^b		0.007*	0.006*	

a Mann-Whitney U test, *p<0.05, **p<0.001, b Wilcoxon signed rank test, BW: before walk, AW: after walk, BPT: before physical therapy, APT: after physical therapy, MBSTET: modified biering sorensen trunk extensor test, PBT: prone bridge test, MSBT: modified side bridge test, AFT: abdominal fatigue test, PBU: pressure biofeedback unit test, SUT: sit ups test, MPUT: modified push ups test, mm hg: millimeter hg, sec: second, 6MWT: 6 minute walk test, m: meter, min: minute

When the percentage changes in all test parameters were compared BPT and APT, the MPE group showed a substantial significiant increase in MBSTET (p<0.001), MSBT (left) (p<0.05), AFT (p<0.05), SUT (p<0.001), MPUT (p<0.05) durations (Table 3). Also there was significiant decrease in the PBU (p<0.05), 6MWT Respiration Rate (BW) (p<0.05), 6MWT Respiration Rate (AW) (p<0.05), 6MWT Blood Pressure (mmHg) (AW) (systolic) (p<0.05) APT (Table 3).

Table 3. Comparison of the percentage changes in the two groups according to the initial measurements BPT of the tests

	MPE group (n=9) Mean±SD (min-max)	NDT group (n=9) Mean±SD (min-max)	p value
MBSTET (sec)	212.57±118.77 (33-398)	12.65±20.25 (1.22-64.57)	p<0.001**
PBT (sec)	3681.42±2493.78 (1897-9100)	4831,66±4185.98 (845-12686)	0.71
MSBT right (sec)	5666.66±3905.68 (200-12950)	2399.37±3184.80 (545-10203)	0.05
MSBT left (sec)	5831.12±3236.96 (700-11800)	2806±3856.23 (305-12720)	0.034*
AFT (sec)	66.56±71.13 (9.19-222.35)	2.95 ±22.56 (-39.13-50.38)	0.002*
PBU (mm hg)	-8.04±14.95 (-27.11-25.07)	-0.94±1.85 (-4.92-1.13)	0.015*
SUT	79.27±55.85 (27.27-200)	5.37±5.80 (0-12.5)	p<0.001*
MPUT	44.51±35.72 (0-100)	8.51±5.04 (0-14.29)	0.018*
6MWT (m)	21.93±25.17 (0-72)	5.46±7.28 (-0.4-23)	0.132
6MWT pulse (Pulse/min) (BW)	0.33±7.82 (-10-18)	-2±6.06 (-18-2)	0.494
6MWT pulse (Pulse/min) (AW)	-2.11±8.59 (-14-17)	0±3.24 (-7-5)	0.058
6MWT respiration rate (rr/min) (BW)	-4±3.31 (-12-0)	-0.66±2.82 (-8-2)	0.007*
6MWT respiration rate (rr/min) (AW)	-5.11±4.13 (-12-0)	-0.33±1.80 (-5-1)	0.005*
6MWT blood pressure (mmHg) (BW) (diastolic)	1.11±7.81 (-10-10)	4.44±21.27 (-50-20)	0.075
6MWT blood pressure (mmHg) (AW) (diastolic)	8.88±6.0 (0-20)	7.22±6.66 (-10-10)	0.368
6MWT blood pressure (mmHg) (BW) (systolic)	72.22±6.66 (60-80)	68.88±7.81 (30-50)	0.695
6MWT blood pressure (mmHg) (AW) (systolic)	-66,66±7.07 (-80-(-60))	-52.77±7.54 (-70- (-45))	0.003*

Mann-Whitney U test, *p<0.05, **p<0.001, SD: standard deviation, BPT: before physical therapy, MBSTET: Modified biering sorensen trunk extensor test, PBT: prone bridge test, min: minute, MSBT: modified side bridge test, AFT: abdominal fatigue test, PBU: pressure biofeedback unit test, SUT: sit ups test, MPUT: modified push ups test, mm hg: millimeter hg, sec: second, 6MWT: 6 minute walk test, m: meter

DISCUSSION

This is the first study to investigate how children with CP respond hemodynamically to MPE exercises combined with the conventional NDT-Bobath method. The current study demonstrated that MPEs positively affected hemodynamic responses by reducing systolic blood pressure and respiratory frequency and increased the transversus abdominus (TrAb) and core stabilizer muscle strength more compared to NDT.

Children with CP are less physically fit due to their handicap, which is linked to the emergence of secondary illnesses such diabetes, obesity, and cardiovascular disease (9,11,13,24). In the current literature, it is remarkable that aerobic capacity training in children with CP is performed with adaptive cycling, arm ergometer, treadmill, aquatherapy, running, and swimming (10,15). In this study, unlike the literature, the preference for MPE and its positive effects on hemodynamic parameters will contribute to the literature.

Children with CP have inadequate aerobic capacity, one of the elements of physical fitness (26,27). According to studies, children with CP have much poorer cardiorespiratory capacities than their peers (9). Although decreased aerobic exercise responses are reported in such children, it is also indicated that reductions in respiratory capacity and aerobic exercise responses are not as severe as predicted by motor impairment (9).

Although improvements have been observed in maximum heart rate, resting heart rate, oxygen uptake, respiratory frequency, and muscle strength as a result of aerobic training with bicycle in studies, review studies emphasize conflicting results for improved cardiorespiratory fitness (10). In this study, the lower resting diastolic blood pressure in MPE before 6MWT compared to NDT indicates that MPE may positively affect hemodynamic responses in children with CP. It is contradictory that MPE increases systolic blood pressure after 6MWT following physiotherapy. However, upon comparing the percentage changes of the treatment groups, improvements in respiratory frequency with MPE before and after 6MWT following physiotherapy and improvements in systolic blood pressure after treatment were observed more. The above-mentioned development suggested that the TrAb muscle might be strengthened by MPE and positively affect the respiratory frequency and blood pressure in these children. These findings show that MPE training may be an alternative treatment for enhancing cardiorespiratory fitness in children with CP with high mobility levels.

Studies show that children with CP have significantly lower cardiorespiratory capacity than their peers (13,28). Consequently, for at least three days a week, the World Health Organization (WHO) advises engaging in at least 60 minutes of moderate-to-intense physical activity that involves bone- and muscle-strengthening activities (29). Studies have shown that muscle strength training is a safe and beneficial intervention for children with cerebral palsy, although the effectiveness of aerobic exercise is not entirely obvious (13,30). Studies indicating the effectiveness of Pilates exercises on gait, balance, and trunk control by increasing the core muscle strength in this group draw attention (16,31). It is noteworthy, however, that no assessment of cardiorespiratory fitness has been performed. In parallel to the literature, this study showed that MPE exercises increased the TrAb muscle activation by improving core strength and endurance tests. Hence, it is thought that using MPE training in strengthening training, compared to the traditional NDT approaches, may provide enhancements in hemodynamic responses by strengthening the core muscles more.

There is a mechanical and neuromuscular connection between respiration and postural control. Respiratory muscles and spinal stability are involved in both systems. Studies have demonstrated that core muscle training increases respiratory amplitude by causing a considerable alteration in the body position on the sagittal plane. Training of core stabilizer muscles increases trunk stabilization and enhances respiratory control (32). The present study showed that MPE exercises positively impacted hemodynamic responses by activating the TrAb muscle, with a significant reduction in respiratory frequency before and after 6MWT. Postural stability and trunk stabilization are primarily known to be accomplished by the abdominal muscles, which include the rectus abdominis (RA), TrAb, internal and external obliques, and TrAb (33). Accordingly, TrAb provides protection during activities that put the integrity of the lumbar spine in jeopardy. According to certain research, TrAb contributes more significantly than other muscles to the improvement of spinal stability (33,34). Via a variety of functional actions, all oblique muscles, including the TrAb muscle, maintain the stability of the trunk. Studies have indicated that core stabilization training and whole-body vibration therapy increase the TrAb muscle thickness and enhance muscle strength in children with CP (35,36). Although the TrAb muscle has an important duty as a stabilizer, it is also known to form the basis for respiration (37). There is a need for further research to reach a consensus in defining the functions of the respiratory muscles, particularly to understand the duty of the pelvic floor muscles in respiration and phonation (37). It has been shown that respiratory muscle training improves lumbopelvic stability by increasing the local core muscle activity in athletes (38). These results are compatible with the improvement of the respiratory system by training core muscles and the TrAb muscle in our study. The TrAb muscle and internal oblique muscles are much thicker toward the end of expiration than at inspiration, according to other research, and they are also much thicker than at full expiration or near the end of full expiration (39). These findings are consistent with our own, suggesting a cooperative relationship between the respiratory system and core muscle activation.

A decrease in systolic blood pressures measured after 6MWT following treatment in the study group compared to the control group demonstrates that MPE training not only increases core muscle activity but also positively impacts blood pressure by increasing respiratory muscle activity. Hence, it is suggested that MPE can be used as an alternative therapy to enhance hemodynamic responses and increase cardiorespiratory compliance in children with CP.

The study's limitation is the small number of children who can walk at a low mobility level (GMFCS III) and the sample's comprising patients with spastic diparetic, hemiparetic, and ataxic types. In addition, the absence of outcomes from long-term follow-up poses a constraint in terms of the inability to assess treatment efficacy over time. Additional research with long-term follow-ups in various clinical settings and mobility levels is required. It is also advised to do more research comparing or combining MPE training with aerobic training.

CONCLUSION

It is concluded that MPEs were shown to increase the strength of core stability muscles and enhance cardiorespiratory fitness by increasing the TrAb muscle activity compared to NDT in children with CP. It was demonstrated that MPE training would positively impact hemodynamic responses, such as blood pressure and respiratory rate, in such children.

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