JOURNAL OF CLINICAL AND BIOMEDICAL SCIENCES

ORIGINAL ARTICLE

OPEN ACCESS
Received: 21-11-2024
Accepted: 15-04-2025
Published: 25-09-2025

Citation: Mukherjee P, Das PR, Pradhan DK, Sahoo R, Mishra P. Effectiveness of Aerobic Training on Cardiopulmonary Function and Quality of Life in Children with Cerebral Palsy: A Single-Blinded Randomized Trial. J Clin Biomed Sci 2025; 15(3): 163-171. https://doi.org/10.58739/jcbs/v15i3.24.221

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Funding: None

Competing Interests: None

Published By Sri Devaraj Urs Academy of Higher Education, Kolar, Karnataka

ISSN
Print: 2231-4180
Electronic: 2319-2453

Effectiveness of Aerobic Training on Cardiopulmonary Function and Quality of Life in Children with Cerebral Palsy: A Single-Blinded Randomized Trial

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Abstract

Background: Children with cerebral palsy (CP) often experience reduced cardiopulmonary endurance and physical activity levels, which can lead to long-term health complications. This study aimed to evaluate the effects of aerobic exercise combined with conventional physiotherapy on cardiopulmonary endurance in children with CP. **Methods**: A two-group experimental pretest post-test design was utilized, involving 32 children aged 4 to 14 years diagnosed with CP at GMFCS levels I and II. Participants were randomly assigned to an experimental group, which received aerobic exercises in addition to conventional physiotherapy, and a control group that received only conventional physiotherapy. The intervention lasted six weeks, with assessments conducted before and after the treatment period. Key outcome measures included the 6-minute walk test (6MWT), walking speed, heart rate, and energy expenditure index (EEI). **Results**: The experimental group demonstrated significant improvements in the distance covered during the 6MWT, walking speed, and EEI compared to the control group. Statistical analysis revealed that the inclusion of aerobic exercises led to more pronounced enhancements in cardiopulmonary endurance and overall physical capabilities. **Conclusion**: The findings suggest that aerobic exercise, when integrated into rehabilitation programs for children with CP, significantly improves cardiopulmonary endurance and physical fitness. This study supports the incorporation of structured aerobic training as a vital component of therapeutic interventions, promoting better health outcomes and quality of life for children with cerebral palsy.

Keywords: Aerobics; Cerebral palsy; Physical activity; Physical fitness

1 Introduction

Cerebral palsy (CP) is a group of eternal movement disorders caused by non-progressive disturbances in the developing brain. These disorders lead to significant motor impairments and activity limitations. Individuals with CP often experience reduced cardiopulmonary endurance, which is the ability of the cardiovascular and respiratory systems to supply oxygen to the muscles during sustained physical activity. This reduction in endurance can be attributed to several factors, including decreased muscle strength, poor aerobic capacity, and increased energy expenditure during daily activities [1].

Children with cerebral palsy (CP) are often presented with reduced physical fitness and endurance levels and frequently experience limitations in their ability to engage in physical activities, which can further exacerbate their health issues and overall quality of life [2].

Aerobic exercise, defined as any sustained physical activity that elevates heart rate and promotes cardiovascular fitness, enhances cardiopulmonary endurance in various populations, including those with disabilities. For individuals with CP, engaging in regular aerobic exercise can lead to improvements in several key areas: increased oxygen uptake, enhanced muscle efficiency, and improved overall physical fitness. These benefits are crucial, as individuals with CP are at a higher risk for developing secondary health issues, such as obesity, cardiovascular diseases, and decreased quality of life due to sedentary behaviour [3].

Research indicates that structured aerobic training can significantly improve the aerobic capacity of children and adolescents with CP. Studies have demonstrated that such training not only enhances cardiopulmonary endurance but also positively impacts walking speed, functional mobility, and overall physical activity levels. Furthermore, aerobic exercise can help mitigate the effects of Deconditioning that often accompany inactivity, thereby breaking the cycle of disability and promoting a more active lifestyle [4].

Incorporating aerobic exercise into rehabilitation programs for individuals with CP is essential for fostering long-term health benefits. By improving cardiopulmonary endurance, aerobic training can enhance the ability to perform daily activities, increase participation in recreational and social activities, and ultimately contribute to a better quality of life. As such, understanding the role of aerobic exercise in this population is vital for developing effective interventions that support their physical and emotional well-being [5].

Children with CP have a decreased level of daily physical activity in comparison with their healthy peers [6]. They need to train almost 2.5 hours a day to reach the same level of daily physical activity as their healthy peers [7].

Many children, adolescents, and adults with cerebral palsy have reduced cardiopulmonary endurance (the capacity of the body to perform physical activity that depends mainly on the aerobic or oxygen-requiring energy systems), muscle strength, and habitual physical activity participation [8–15]. Reduced cardiopulmonary endurance and muscular weakness both pose significant risks for negative health outcomes and early, cardiovascular- and all-cause mortality [16–19]. People with CP have lower levels of health-related fitness (muscle strength and cardio-respiratory endurance) and reduced levels of physical activity, they are at higher risk for developing metabolic and cardiovascular diseases.

Aerobic fitness may be defined as the ability to deliver oxygen to the muscles to generate energy during exercise [20]. It is any activity that increases the heart rate or proposes to increase heart rate to exact physiological change. The benefits of aerobic exercise for people with disabilities include increased cardiovascular capacity and endurance, weight management and lower blood lipid levels, preservation of bone mass and overall maintenance of function[21].

The study explores the effects of aerobic exercise on improving cardio-respiratory endurance in children with cerebral palsy (CP). This study aims to determine the potential benefits of aerobic training on various parameters, including walking speed, distance covered in a 6-minute walk test, heart rate, and energy expenditure index. The primary objective of this research is to assess the effectiveness of a structured aerobic exercise program when combined with conventional physiotherapy. The authors hypothesized that the combined training group would exhibit better improvements in the outcomes than the conventional training.

The study employed a two-group experimental pre-test post-test design to evaluate the effects of aerobic exercise on cardio-respiratory endurance in children with cerebral palsy (CP). A total of 32 children, aged 4 to 14 years, diagnosed with CP at Gross Motor Function Classification System (GMFCS) levels I and II, were recruited from the private clinics of Bhubaneswar Odisha. Participants were selected based on specific inclusion and exclusion criteria, ensuring they had normal or near-normal cognitive function and the ability to walk continuously for six minutes. Children of both genders aged between 4-14 years were included in the study. Similarly, any form of orthopedic or neurosurgery and botulinum toxin injection in the past six months were excluded from the study. Additionally, any form

of respiratory or cardiac causes that would affect regular physical activity and children with any intellectual problems are also excluded from the participation.

The intervention lasted six weeks, during which both groups received conventional physiotherapy. The experimental group additionally participated in structured aerobic exercises five days a week. Key outcome measures included the 6-minute walk test (6MWT), walking speed, heart rate, and energy expenditure index (EEI), which were assessed before and after the intervention.

1.1 Aim of the study

To know the effect of aerobic exercise in improving cardio-respiratory endurance in children with cerebral palsy.

2 Methodology

- **Study design**

A two-group experimental pre-test & post-test study design was used.

- **Study size & setting**

A total of 32 children were recruited from local clinics from Bhubaneswar according to the inclusion and exclusion criteria.

- **Study duration**

6 weeks.

- **Ethical considerations**

The study was conducted according to the declaration of Helsinki for experiment in human subjects. A written and informed consent was obtained from all the participants prior to the inclusion in the study.

- **Sampling method**

By convenience sampling, the subjects were selected from the CP population according to the inclusion and exclusion criteria and were randomly assigned to 2 different treatment groups after getting the consent from the parents/caregivers.

- **Inclusion criteria**

Children diagnosed with cerebral palsy (Spastic Hemiplegic/Dieplegic/Triplegic/Tetraplegic) with GMFCS level I & II of either sex are aged between 4-14 years with normal or near normal cognitive function with the ability to walk continuously at the best for 6 minutes.

- **Exclusion criteria**

No orthopaedic or neurosurgery should have been done and botulinum toxin injection should not have been administered within last 6 months. Any cardiac or respiratory conditions should be excluded that could negatively affect the proposed training. The subject should be free of intellectual problems that can influence their participation.

- **Outcome measures**

6 minute walk test (6MWT), Walking speed calculated on the basis of 6MWD, heart rate, Energy expenditure index (EEI).

- **Procedure**

After meeting the inclusion and exclusion criteria through an assessment performa, informed consent was taken from the parents/caregivers of the subjects and then were randomly allocated to either of the two groups. 32 children (Spastic Hemiplegic/Dieplegic/Triplegic/Tetraplegic) met the criteria; 16 were allocated to the experimental group (mean age of 9.44 $\pm$ 2. 851; 7 females and 9 males) and 16 were allocated in the conventional group (mean age of 8.56 $\pm$ 3.444; 9 females and 7 males) using the block randomisation method. Two blinded raters performed the randomization and the outcome assessment.

All the participants underwent an initial baseline assessment of heart rate, distance covered in a 6-minute walk test, walking speed calculated based on 6MWD & energy

Table 1. Spastic (Hemiplegic/Dieplegic/Triplegic/Tetraplegic) with GMFCS level I & II of either sex are aged between 4-14 years

Sl. No.	Age	Sex	Type of CP	GMFCS Level	Group
1	7	Male	Right Hemi-legic	I	Experimental
2	9	Male	Diplegic	I	Experimental
3	6	Female	Left Hemiplegic	I	Experimental
4	14	Male	Triplegic	I	Experimental
5	6	Male	Right Hemi-legic	I	Experimental
6	5	Male	Right Hemi-legic	I	Experimental
7	9	Male	Tetraplegic	II	Experimental
8	12	Female	Diplegic	II	Experimental
9	10	Female	Right Hemi-legic	I	Experimental
10	11	Female	Right Hemi-legic	I	Experimental
11	12	Female	Diplegic	I	Experimental
12	14	Male	Tetraplegic	II	Experimental
13	6	Female	Diplegic	II	Experimental
14	10	Male	Right Hemi-legic	I	Experimental
15	9	Female	Right Hemi-legic	I	Experimental
16	11	Male	Right Hemi-legic	I	Experimental
17	12	Female	Diplegic	I	Control
18	12	Male	Diplegic	II	Control
19	11	Female	Diplegic	II	Control
20	5	Male	Right Hemi-legic	I	Control
21	14	Female	Diplegic	I	Control
22	14	Female	Diplegic	I	Control
23	4	Female	Left Hemiplegic	II	Control
24	11	Female	Triplegic	I	Control
25	7	Female	Diplegic	II	Control
26	7	Male	Right Hemi-legic	I	Control
27	4	Female	Left Hemiplegic	I	Control
28	5	Male	Right Hemi-legic	I	Control
29	6	Male	Left Hemiplegic	I	Control
30	10	Male	Triplegic	I	Control
31	7	Female	Left Hemiplegic	I	Control
32	8	Male	Tetraplegic	II	Control

expenditure index. Both the groups received conventional physiotherapy. The experimental group, in addition, received Aerobic exercises. The intervention period was 6 weeks, 5 days/week. After completion of 6 weeks, all participants received a follow up assessment.

- **Intervention (aerobic exercise protocol)**

The children are trained for 21 minutes in the 1st & 2nd week, 30 minutes in the 3rd & 4th week and 45 minutes in the 5th & 6th week (excluding warm-up and cool-down sessions); 5 days a week for 6 weeks, which means the intensity & duration was gradually increased over time. The training consisted of a form of circuit training with three workstations (Figure 1).

Fig 1. Cycling and ball training programs

Warm up period consisted of stretching exercises, AROM exercises of all joints and free walking on a flat surface.

There were three stations-

1. Ramp for walking on an inclined surface
2. Static cycle for cycling
3. Ball & a basket in an open hall for ball game

The cool down period consisted of breathing exercises and stretching exercises.

Table 2. Warmup period

1st & 2nd Week	3rd & 4th Week	5th & 6th Week
Warm up - 5 minutes	Warm up - 5 minutes	Warm up - 5 minutes
Walking - 7 minutes	Walking - 10 minutes	Walking - 15 minutes
Cycling - 7 minutes	Cycling - 10 minutes	Cycling - 15 minutes
Ball game - 7 minutes	Ball game - 10 minutes	Ball game - 15 minutes
Cool down - 5 minutes	Cool down - 5 minutes	Cool down - 5 minutes

There was a period of 2 minutes rest before moving on to the next station. A group consists of a maximum of 4 children. The therapist was always along with the children to instruct, guide & encourage them. During the 6 weeks of the study period, the children continued with their normal therapy program.

- **Data analysis**

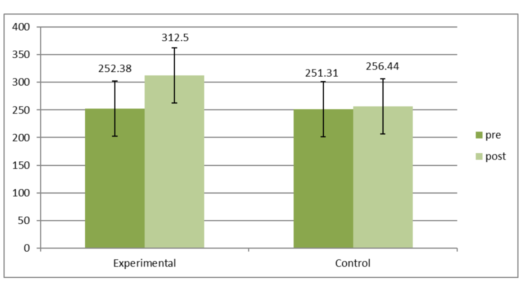
Statistical analysis was performed using SPSS version 23.0. The dependent variables were analyzed using repeated measures ANOVA. There was one between factors (groups) with two levels (groups: aerobic exercises and conventional therapy alone) and one within factors (time) with two levels (pre-test and post-test). All pair wise post-hoc comparisons were analyzed using a 0.05 level of significance.

3 Results

3.1 6 Minute Walk Test

The Graph 1 shows that there is an increase in the distance covered in both groups, with the improvement in the experimental group being more than that of the conventional group when compared.

2 × 2 ANOVA analysis for the 6MWT reveals that there was a main effect for time as F(1,30,0.05) =153.760 and p=(0.000) but no main effect seen in group as F(1,30,0.05)=2.067 and p=(0.161) but it qualified for time × group interaction as F(1,30,0.05)= 109.247 and p=(0.000) (**Tables 3 and 4**).

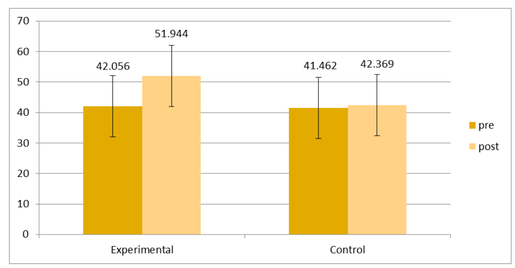


Graph 1:

3.2 Walking Speed

The Graph 2 shows that there is an increase in the walking speed in the experimental group which is more than that of the conventional group.

2 × 2 ANOVA analysis for Walking Speed reveals that there was a main effect for time as F(1,30,0.05) =139.871 and p=(0.000) but no main effect seen in group as F(1,30,0.05)=2.434 and p=(0.129) but it qualified for time × group interaction as F(1,30,0.05)=96.841 and p=(0.000) (Tables 5 and 6).

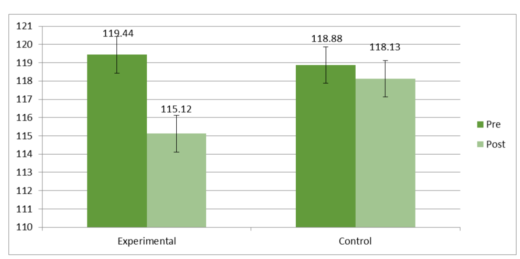


Graph 2:

3.3 Heart Rate

The Graph 3 shows that there is a decrease in the heart rate at the end of the test in the experimental group when compared to that of the conventional group.

2 × 2 ANOVA analysis for the Heart Rate reveals that there was a main effect for time as F(1,30,0.05) =53.749 and p=(0.000) but there was no main effect seen in the group as F(1,30,0.05)=0.482 and p=(0.493) but it qualified for time × group interaction as F(1,30,0.05)=26.617 and p=(0.000) (Tables 7 and 8).



Graph 3:

Table 3. Test between subject and within subject effect

		Sum of Sq	df	Mean Sq	F	Significance
Between subject effect	Group	13053.062	1	13053.062	2.067	.161
	Error	189430.375	30	6314.346		
Within subject effect	Time	17030.250	1	17030.250	153.760	.000
	Time × Group	12100.000	1	12100.000	109.247	.000
	Error	3322.750	30	110.758		

Table 4. Mean and Standard error of mean (SEM in scores)

	Pre	Post
Experimental	252.38 (13.860)	312.50 (17.235)
Control	251.84 (12.523)	256.44 (12.537)
Total	251.84 (9.188)	284.47 (11.629)

Table 5. Test between subject and within subject effect

		Sum of Sq	df	Mean Sq	F	Significance
Between subject effect	Group	413.614	1	413.614	2.434	.129
	Error	5098.177	30	169.939		
Within subject effect	Time	466.020	1	466.020	139.871	.000
	Time × Group	322.651	1	322.651	96.841	.000
	Error	99.953	30	3.332		

Table 6. Mean and Standard error of mean (SEM in scores)

	Pre	Post
Experimental	42.056 (2.3078)	51.944 (2.8908)
Control	41.462 (2.0017)	42.369 (1.9922)
Total	41.759 (1.5036)	47.156 (1.9291)

Table 7. Test between subject and within subject effect

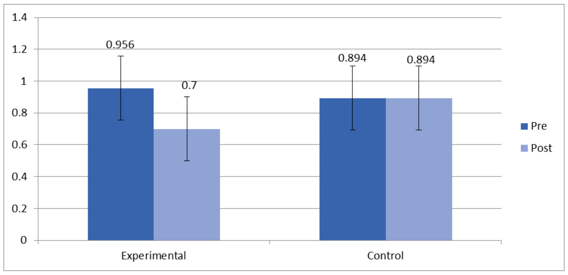
		Sum of Sq	df	Mean Sq	F	Significance
Between subject effect	Group	23.766	1	23.766	.482	.493
	Error	1479.969	30	49.332		
Within subject effect	Time	102.516	1	102.516	53.749	.000
	Time × Group	50.766	1	50.766	26.617	.000
	Error	57.219	30	1.907		

Table 8. Mean and Standard error of mean (SEM in scores)

	Pre	Post
Experimental	119.44 (1.396)	115.12 (1.095)
Control	118.88 (1.307)	118.13 (1.245)
Total	119.16 (0.942)	116.62 (0.859)

3.4 EEI (Energy Expenditure Index)

The Graph 4 shows that there is a decrease in the EEI of the experimental group when compared to that of the conventional group.



Graph 4:

2 × 2 ANOVA analysis for the EEI reveals that there was a main effect for time as F(1,30,0.05) =132.016 and p=(0.000) but there was no main effect seen in the group as F(1,30,0.05)=0.667 and p=(0.420) but it qualified for time × group interaction as F(1,30,0.05)=132.016 and p=(0.000).

4 Discussion

The study findings suggest that after six weeks of intervention, the experimental group (which received aerobic exercises in addition to conventional physiotherapy) showed notable improvements in cardio-respiratory endurance compared to the control group. Specifically, there were significant enhancements in the distance covered during the 6-minute walk test (6MWT), walking speed, and energy expenditure index (EEI).

Both groups demonstrated improvements in their physical capabilities; however, the experimental group exhibited more pronounced changes, suggesting that the inclusion of aerobic exercises is beneficial for enhancing endurance in children with cerebral palsy. The results support the hypothesis that structured aerobic training can effectively improve physical fitness and functional mobility in cerebral palsy children compared to conventional training.

4.1 Minute Walk Test (6MWT & Walking Speed)

Both groups showed improvement in the distance covered in the 6MWT and in the walking speed after the completion of the study, but experimental group showed significant changes than the conventional group.

Strength is an important aspect for maintenance of normal motor control which has been found to be deficient in children with CP.

Damiano et al found that increased lower limb strength has an effect on gait by improving the free walking velocity and speed through increased cadence, but no relation was uncovered between stride length and strength [22].

Gait analysis in a study done by Eek M N et al has shown that increased stride length and plantar flexor generating power at push off after strength training which can be attributed to better stability around both hip and knee which makes it easier for the ankle plantar flexors to push off [23,24].

The experimental group showed significant improvement in walking distance and speed.

In the physically challenged population of CP, neuromuscular impairments secondary to the disease pathophysiology can produce movement patterns that are fatiguing and inefficient when compared with movement in children without disabilities [25]. Increasing strength alone would not seem sufficient to improve energy cost of walking or some measures of function [26]. Children with CP have lower Vo2 peak values, shorter walking distance in set times than normal children. So, fitness training for aerobic fitness is an important intervention for children with CP [27].

Improvement can be explained as the children begin to function at a higher level of activity in their home situations. Those activities become more part of their daily routines, so that the level of daily activities of the children increased [28].

Studies have shown that aerobic training results in reduction in systemic arterial pressure, significant improvement in distance covered due to training induced changes in the cardiopulmonary demands [29,30].

4.2 Heart Rate (HR)

There was improvement in the experimental group which was not a major change still when compared to the conventional group where statistically the means remained unchanged.

Children with CP have been found to have extremely high heart rate and slow walking speeds. The high heart rates are related to the poor fitness levels observed in these children [31] [31]. Bar-Or et al observed that heart rate in children with CP significantly decreased after endurance training [32]. Untrained people have lower aerobic fitness and a higher heart rate in rest or during exercise than normal people. Training programs can decrease the resting and sub maximal heart rate in children with CP [33].

4.3 Energy Expenditure Index (EEI)

There was an improvement (decrease) in the EEI in the experimental group which was significant with time. But, on the other hand, statistically conventional group did not show any improvement in this outcome measure.

Gait abnormalities in children with CP, due to the presence of reduced selective muscle control, abnormal muscle tone, imbalance between muscle agonists and antagonists across joints and deficient equilibrium reactions, have been shown to increase walking energy expenditure compared with healthy children [34,35].

In the conventional group, increased strength in the targeted muscles had led to increased velocity due to the increase in cadence, but energy expenditure remained unchanged. A minor change in the walking speed in this group could not bring any change in this measure[36].

Spastic muscle consumes higher energy and oxygen uptake for exercise than normal muscles and defects or incorrect adaptation in the cardiovascular system decreases the enough transportation of oxygen and nutrition materials to active muscles or other tissues during daily activity or exercise[37,38].

High energy expenditure during walking in combination with a reduced aerobic capacity leads to relatively high levels of physical strain in children with CP. The reasons behind improvement in the experimental group can be attributed to several factors; a combination of lower initial fitness levels, high program adherence, and exercise intensity of more than 20 minutes during a session have influenced improvements in walking efficiency[39,40].

4.4 Clinical implication

Aerobic exercise, along with conventional physiotherapy, can be used in clinical as well as home-based settings to bring about a change in cardiopulmonary endurance, making children more active rather than being sedentary.

4.5 Limitations

small sample size, carryover effect of the study has not been studied; heart rate during the training session was not measured.

5 Conclusion

Children with CP are at risk of a reduced level of physical fitness and physical activity. Since inactive children are more likely to become inactive adults. Adequate physical fitness and an active lifestyle should be stimulated at early age. Aerobic exercise along with conventional physiotherapy brings about more improvement in cardiopulmonary endurance, walking speed, heart rate and energy expenditure than conventional physiotherapy alone.

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