

Effect of Play-Based Exercise Programme on Aerobic Fitness For Children With Neurodevelopmental Disability – A Randomized Controlled Trial

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Abstract

To evaluate the effectiveness of a structured play-based aerobic exercise program in improving aerobic capacity and physical activity enjoyment among children with neurodevelopmental disabilities. Methods: A randomized controlled trial with a single-blind, pretest–posttest parallel design was conducted with 54 children aged 6–12 years diagnosed with various NDDs (including ADHD, Autism Spectrum Disorder, Intellectual Disability, Cerebral Palsy, and Down Syndrome). The intervention group participated in a structured set of ten play-based games, performed three times weekly for one hour over six weeks. Aerobic capacity was assessed using the 10-Meter Shuttle Run Test to estimate VO_2 max, and the Physical Activity Enjoyment Scale (PACES) was used to measure enjoyment. Results: The experimental group demonstrated a significant increase in VO_2 Max, from 18.00 (± 1.00) to 23.10 (± 1.30), whereas the control group showed minimal change, from 17.50 to 18.00. Additionally, PACES scores in the experimental group significantly improved from 58.15 $\pm$ 4.03 to 66.48 $\pm$ 4.00 ($t = 8.448$, $p < .001$). In contrast, the control group exhibited a non-significant change from 57.56 $\pm$ 3.97 to 58.30 $\pm$ 4.06, indicating minimal change with intervention.

Conclusion: Structured play-based aerobic activities offer an effective, enjoyable, and accessible approach to enhance cardiorespiratory fitness and encourage physical activity in children with NDDs. Such programs are particularly useful in environments with limited access to conventional therapy options.

Keywords: Neurodevelopmental disorders, aerobic capacity, play-based interventions, physical activity, children, enjoyment.

Introduction

“Neurodevelopmental disabilities (NDDs)” are a group of long-term conditions that affect function in areas such as mobility, cognition, communication, and daily activities. Conditions like cerebral palsy, autism, ADHD, Down syndrome, and speech or language disorders fall under this category (1). Their prevalence differs across regions, with greater numbers typically seen in children from lower socioeconomic backgrounds. Global studies indicate that the prevalence of neurodevelopmental disabilities varies considerably across different populations, with reported rates ranging from 4.7% to as high as 88.5% (2). In low-resource settings like India, children from socioeconomically weaker backgrounds are disproportionately affected. The burden is greatest in younger age groups, with approximately 11% of children aged 2–6 years and nearly 17% of those aged 6–9 years showing these conditions. (3).

Research indicates that children with neurodevelopmental disabilities tend to have decreased aerobic endurance. This reduced aerobic capacity is largely attributed to issues like diminished muscle mass, which hampers oxygen utilization and results in a lower peak oxygen uptake (VO_2 peak), lead to challenges in daily activities, social interactions, academic performance, and other aspects of overall health status and quality of life, such as impaired motor function, reduced muscle strength, poor balance, and coordination issues. These physical challenges limit participation in physical activities, particularly those requiring gross motor skills like running, climbing, or jumping (4).

This reduced fitness places them at elevated risk for cardio metabolic conditions such as hypertension, obesity, and insulin resistance. Earlier research elucidates that children with NDDs often experience reduced aerobic fitness (9). This is because these children with NDDs persist with complications such as a decrease in muscle mass, which in turn leads to reduced oxygen extraction, and therefore a reduction in maximum oxygen uptake (VO_2 peak) (5,6). This decline may lead to decreased ventilatory and aerobic thresholds (AT) in children with neurodevelopmental disorders (NDD). Regular aerobic activity improves

cardiovascular

fitness, emotional health, and cognitive abilities in children with or without NDDs, largely through mechanisms such as enhanced brain plasticity and better regulation of higher-order functions. Consistent aerobic activity can boost cardiovascular health, emotional balance, and cognitive abilities in all children. It does this by improving the ability of neural networks to modify their function in response to experience to adapt and by fine-tuning the activity in parts of the brain, especially in areas that control movement and coordination. ⁽¹³⁾ Physical activity programs are an effective method for improving the overall functioning and health-related quality of life (QOL) of children with disabilities ^(4,14). Aerobic-based interventions—such as walking on a treadmill, cycling, or swimming—have consistently been shown to enhance cardiovascular health, cognitive control, and psychological well-being, especially when the activities are customized and engaging for the individual ^(5,6).

Therefore, encouraging regular physical activity in children with neurodevelopmental disorders is essential to a critical strategy for mitigating the adverse effects of reduced cardiorespiratory endurance. Regular, targeted physical activity can significantly improve fitness levels, enhance cardiovascular and respiratory health, and reduce the risks associated with sedentary lifestyles. By addressing these needs through structured and engaging interventions, we can help children with NDDs achieve enhanced general health and support improved daily functioning. ⁶ “As stated by the American College of Sports Medicine (ACSM)”, cardiorespiratory training should involve rhythmic, continuous activities engaging large muscle groups ^(4,12). When summarizing the available evidence, it is notable that there are numerous interventions to improve aerobic fitness in individuals with neurodevelopmental disorders. However, due to various factors such as high costs, limited availability of skilled professionals, and numerous social and environmental barriers, many existing aerobic fitness interventions for children with neurodevelopmental disorders (NDDs) are often inaccessible.

Conventional exercise programs for children with NDDs are usually designed for controlled clinical or laboratory settings and depend on costly equipment, for example, treadmills or electronically braked cycles. Beyond these logistical issues, many families encounter obstacles such as insufficient professional guidance, financial constraints, and societal limitations that hinder their child’s involvement in physical activity programs ^(7,8). Furthermore, children with NDDs frequently face additional obstacles, including a shortage of trained staff, negative attitudes from professionals, concerns about liability, and limited funding ^(10, 12).

Therefore, there is a growing demand for low-cost, engaging alternatives to conventional aerobic fitness programs, such as play-based physical activities that can be carried out at home or within community settings. To address this gap, the present randomized controlled trial aimed to evaluate the effect of a play-based aerobic exercise program compared to a conventional physiotherapy program in children with neurodevelopmental disability.

NEED OF THE STUDY

For children with neurodevelopmental disabilities, most interventions are conducted in clinical or community-based settings, often requiring costly equipment and specialized staff. However, play-based approaches that could improve aerobic capacity and increase children’s motivation have not received adequate attention. Play-based aerobic exercise has the potential to enhance physical fitness through enjoyable and adaptable activities that use low-cost materials and are feasible in low-resource environments. Such programs can help overcome barriers such as financial constraints, limited professional availability, and restricted access to specialized facilities. At present, there is limited evidence comparing play-based aerobic training with conventional physiotherapy in this population, highlighting the need for further investigation. Therefore, the purpose of this study is to evaluate the effect of a play-based aerobic exercise program compared to a conventional physiotherapy program in children with neurodevelopmental disabilities. To date, no studies have reported these factors in this population using play-based models in resource-limited contexts.

RESEARCH QUESTION

1. Does a play-based aerobic training program improve aerobic fitness in children with neurodevelopmental disorders?

AIM AND OBJECTIVES AIM:

To evaluate the effect of a play-based aerobic exercise program in children with neurodevelopmental disability.

OBJECTIVES:

To evaluate the effect of a play-based aerobic exercise training program on aerobic fitness in children with neurodevelopmental disabilities

To compare the effect of a play-based aerobic exercise training program versus conventional physiotherapy on aerobic fitness in children with neurodevelopmental disabilities.

HYPOTHESIS:

Alternate hypothesis:

Six weeks of play-based aerobic exercise training will have a significant effect compared to conventional physiotherapy on aerobic fitness in children with NDD.

Null hypothesis:

Six weeks of play-based aerobic exercise training will not have a significant effect compared to conventional physiotherapy on aerobic fitness in children with NDD.

METHODOLOGY

Study design- a randomized controlled trial

Study setting – Special schools and Non-Governmental Organization

Study population – Children with neurodevelopmental disabilities

Study duration – 1 Year

Sampling technique – Probability sampling methods

Method of randomization

Method of generating allocation sequence: computer-generated block randomization Mechanism of implementing allocation: opaque sealed envelopes

Sample size: The study involved 54 participants in total.

Estimation done using G POWER 3.1.9.7

effect size-0.5

α error – 0.5 Power ($1-\beta$ err)-0.9

Blinding: Single-blinded, outcome assessors (physiotherapists) and data analysts were blinded to group allocation.

INCLUSION CRITERIA:

Children aged 6-12 years.

Children with NDD such as cerebral palsy (GMFCS Level I and II)

Children with autism spectrum disorder (level 1 severity as per DSM-5 criteria)

Attention-deficit/hyperactivity disorder

(children with minor impairment in social and school settings according to DSM-5)

Children Diagnosed with Down syndrome

(children with physical and cognitive ability to engage in the activities)

Children who obey verbal commands.

EXCLUSION CRITERIA:

Any other associated neurological/musculoskeletal/cardiovascular disorder, such as unstable seizures, cardiac arrhythmias, or hip dysplasia.

Children having serial casting or fixed lower limb contractures.

Individuals having severe perceptual or visual defects.

MATERIALS REQUIRED:

Balls

Cones

Stick of 8 m length

Baskets

Bench

Powder marker

safety gear - (knee cap, elbow cap, helmet)

PROCEDURE:

Ethical approval was obtained from the Institutional Ethics Committee before the start of the study, following which recruitment of participants was done.

The study was conducted in children with neurodevelopmental disabilities aged between 6 to 12 years.

Children were screened for eligibility from various special schools in the local area.

The baseline assessment of children was done in their residency.

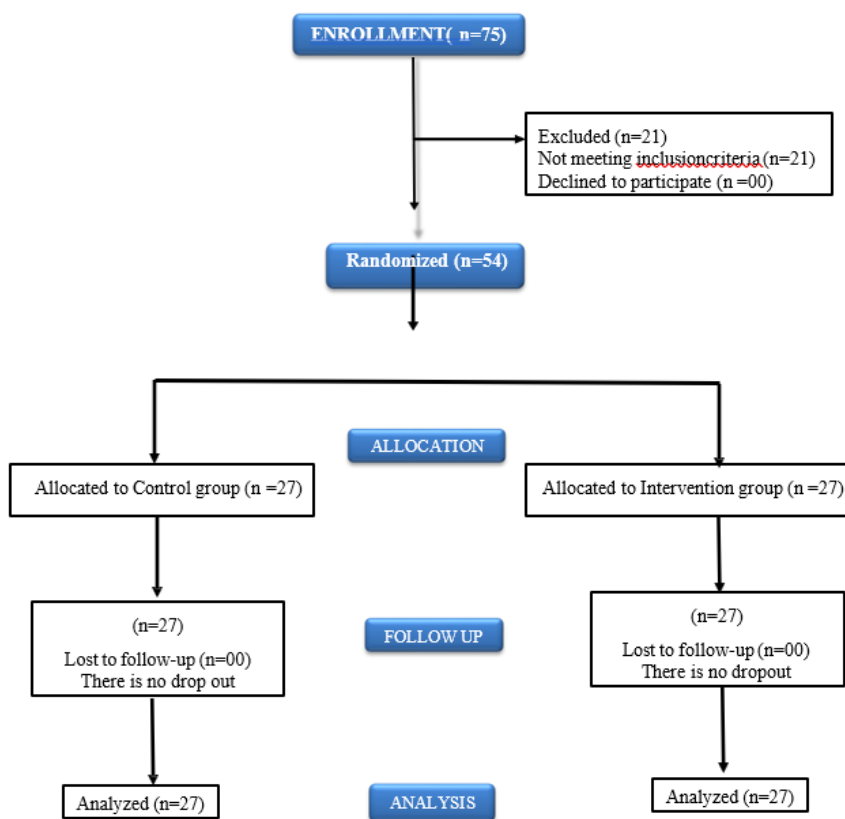
After the initial screening, parents of eligible children were contacted, and informed consent was obtained from them.

A baseline assessment of the participants was performed.

The games that the child was required to play were explained to the parents.

Additionally, video recordings of the games were provided to the parents.

The concept of the logbook was explained to the parents.



Flow Diagram

INTERVENTION

Activity 01: Sideway Running to reach the Target

1. 10 small balls with a diameter of 7 cm. Two baskets with a size of 10 cm high and 25 cm wide,

Materials required

2. 10 meters (length) x 10 meters (width), for sideway running.

Choose a corridor measuring 10 meters (length) x 10 meters (width) for sideways running.

Preparation

Place 1 basket at the starting point and at the end point.

The child begins at the "start point," grasps one ball from the basket, sprints sideways to the end point, places the ball in the

Instructions for child

basket at the end point, then returns to the start point, and repeats this pattern until all of the balls are successfully placed in the basket. The total time duration is 7 minutes, and no of balls placed in the basket/ no of repetitions is noted

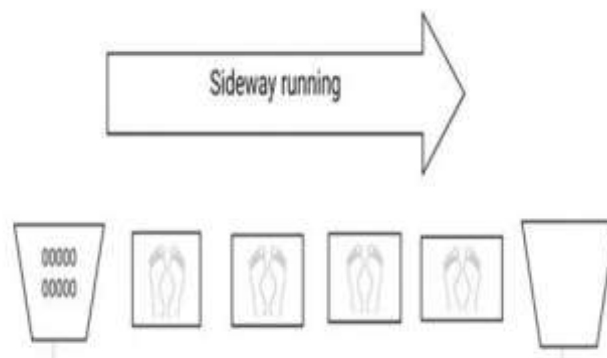


Figure 1: Schematic representation of Sideway Running to reach the Target game



Figure 2 : A child performing the reaching the Sideway Running game

02: Backward Running in a line

Materials required

Powder marker to draw the Line from start point to end point. 2.Ball

preparation

Choose a corridor 10 meters (length)
Draw a Straight line within the room, include space for child to run

Instructions for child

The child begins at "start point," grasps one ball from the basket, sprints backward and put it in basket at end point, The total time duration is 7 minutes and no of balls placed in the basket/ no of repetition is noted

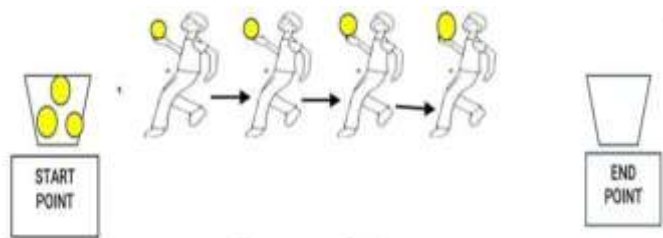


Figure 3: Schematic representation of Backward Running in a line



Figure 4: A child performing the Backward Running in a line

Activity 03: Frog Jump on markers place in a line To Reach the Target Powder marker to draw the Circles from start point to end point.

Materials required

2.cones

preparation

Choose a corridor 10 meters (length) place 6 markers in a straight line

Instructions for child

The child begins at the "start point" and then jumps up to the finish point again returning to the start place. The time required to finish one round is noted. process repeated for 7 minutes

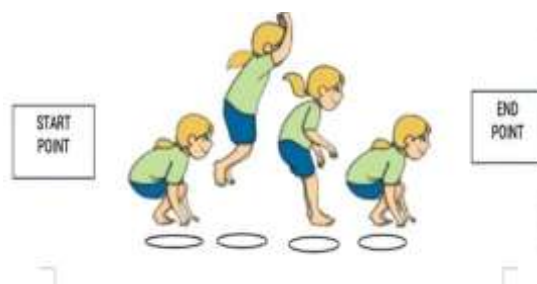


Figure 5: Schematic representation of Frog Jump on markers placed in a line To Reach the Target

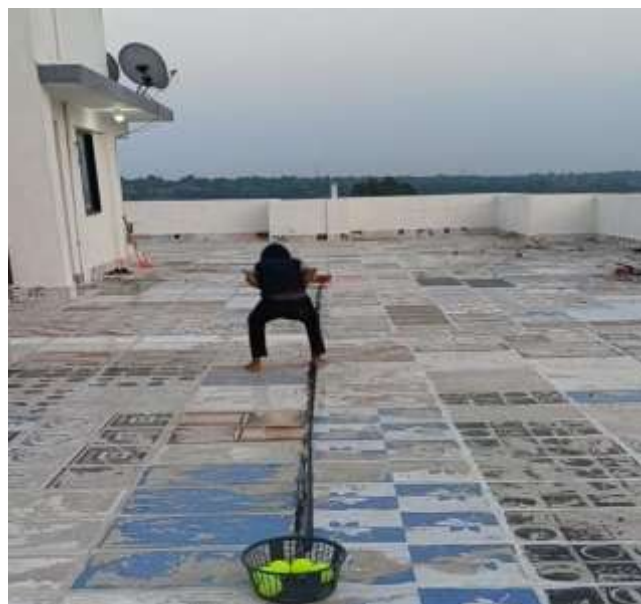


Figure 6 : A child performing the Frog Jum

Activity 04: WALK IN AND OUT

Materials required

10 meters (length) x 10 meters (width) meter corridor
Powder marker

preparation

Choose a corridor 10 meters (length) x 10 meters (width) meter
Use masking tape or chalk to create a straight line on the floor.
Ensure that the line is straight and visible.

Instructions for child

Have the children line up beside the starting point. Instruct them to jump forward Over Point “B”, pause, and then take a jump back over Point “A”. The **number of correct jumps in 6 minutes was noted.**

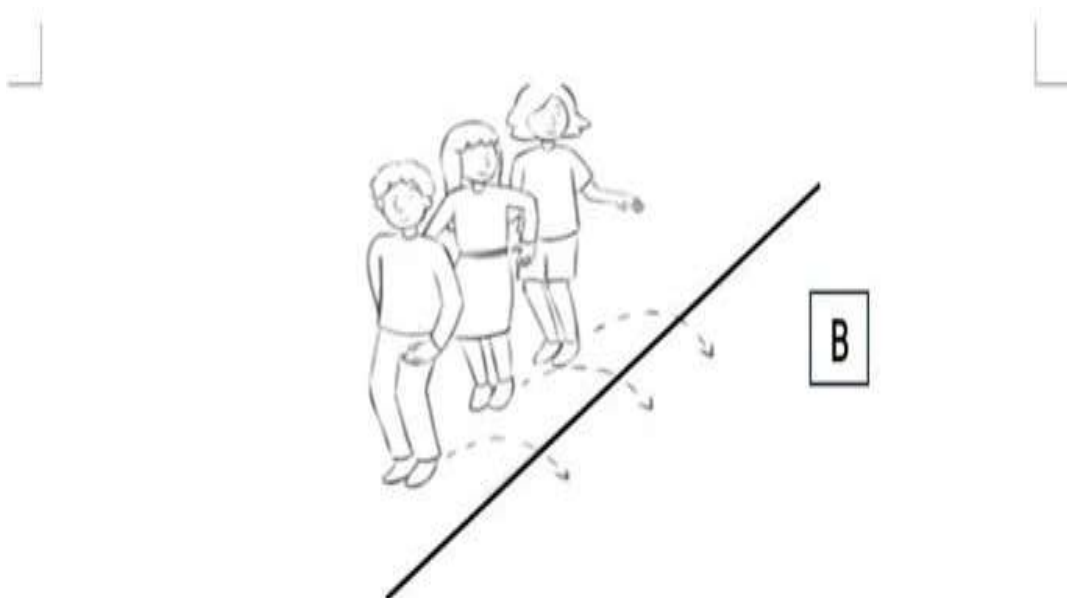


Figure 7: Schematic representation of walking in and out of the game



Figure 8: A child performing the walk-in and out game

Activity 05: Jump zig zag to Reach the Target

Materials required

Powder marker to draw the Circles from start point to end point
2.12meter corridor

preparation

Choose a walk way corridor measuring 12 meter in length and 7 meter in width.
Mark the line at starting point (0 meters) and the end point (12th meter) of length.
Mark 5 circle spaced apart by 2 meters in zig zag manner

Instructions for child

The child jump in a zigzag from the starting point (1st Circle) to the ending point (5th circle),
i.e. jumping on circle mark on the ground, then from the fifth circle to the first circle in the same way.
Time taken to complete one round noted, The process is repeated for five to six minutes.

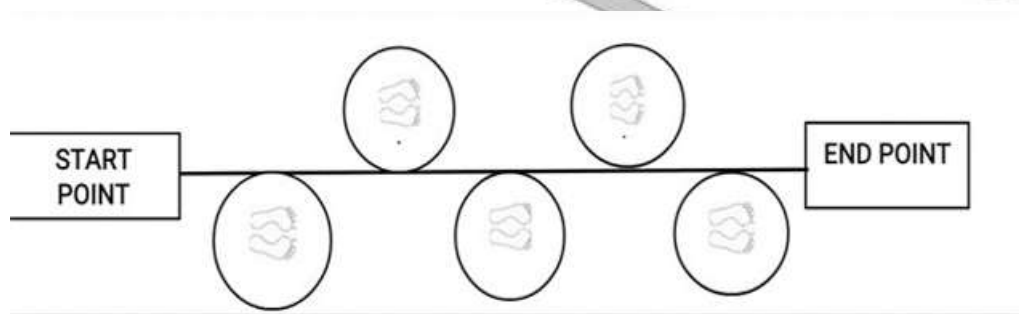


Figure 9: Schematic representation of the Jump zig-zag to reach the Target



Figure 10: The child jumps zig-zag to reach the target

Activity 06: Placement of the ball from end to end across the obstacle

Materials required

5 balls with a diameter 6 to 7 and circumference of 60 to 70 cm.
10 meters (length) x 10 meters (width), bench height 30 cm and 10 m length.

Preparation

1. 10 meters long and 7 meters wide hallway.
Place a bench between the corridors (i.e. at 5 meters) of the corridor.
Place 5 balls at the start and end points with 0.5 meters (50cm) between each ball.

Instructions for child

The child must take a ball from the starting point and quickly walk or run across the step placed between the corridors. The total time duration is 7 minutes and no of balls placed in the basket/ no of repetition is noted.

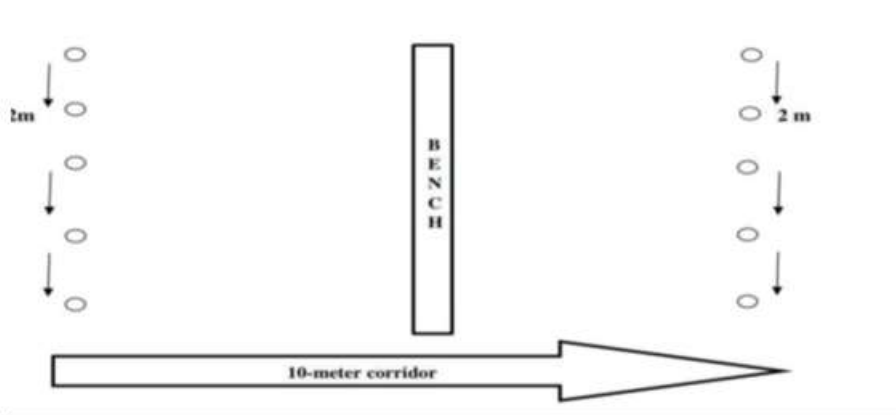


Figure 11: Schematic representation of the Placement of the ball from end to end across the obstacle

Activity 07: Run or walk zigzag to reach the target

Materials required

5 cones
12 meters (length) x 7 meters (width),

Preparation

1. 12 meter in length and 7 meter in width walk way corridor.
2. Mark the line at starting point (0 meters) and the end point (12th meter) of length.
3. Place 5 cones spaced apart by 2 meters

Instructions for child

The child must run or walk in a zigzag from the starting point (first cone) to the ending point (fifth cone), i.e. running between each cone, then from the fifth cone to the first cone in the same way. Time taken to complete one round noted, The process is repeated for five to six minutes.

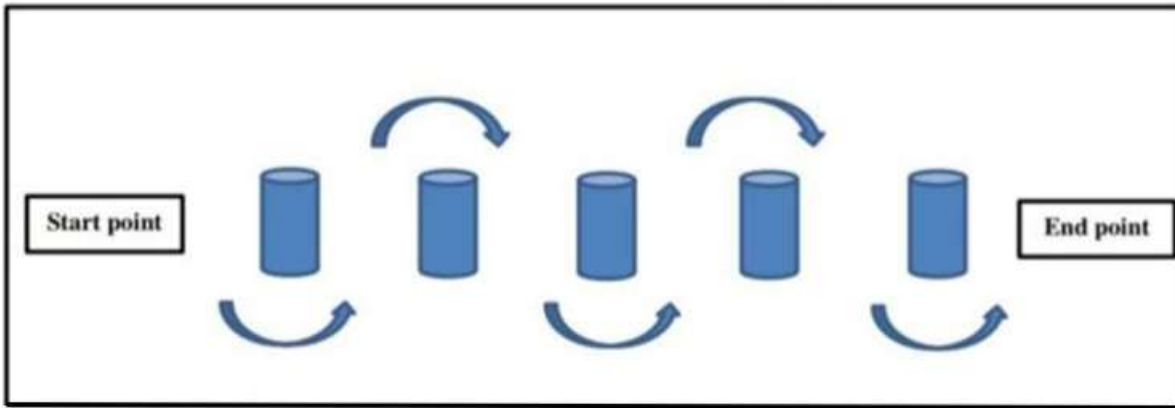


Figure 12 : Schematic representation of the game: Run or walk zigzag to reach the target



Figure 13 : The child performs a game, running or walking zigzag to reach the target

Activity 08: Reach the target

Materials required

1. balls with a diameter 6 to 7 and circumference of 60 to 70 cm.
2. 12 meters (length) x 10 meters (width).

Preparation

12 meters long corridor.

Place 1 basket with 10 small balls at the starting point and an empty basket at the ending point.

Instructions for child

The child has to take a ball one by one from the basket (placed at the starting point) and run 12 meters and drop onto the basket at the other end. The total time duration is 7 minutes and no of balls placed in the basket/ no of repetition is noted.

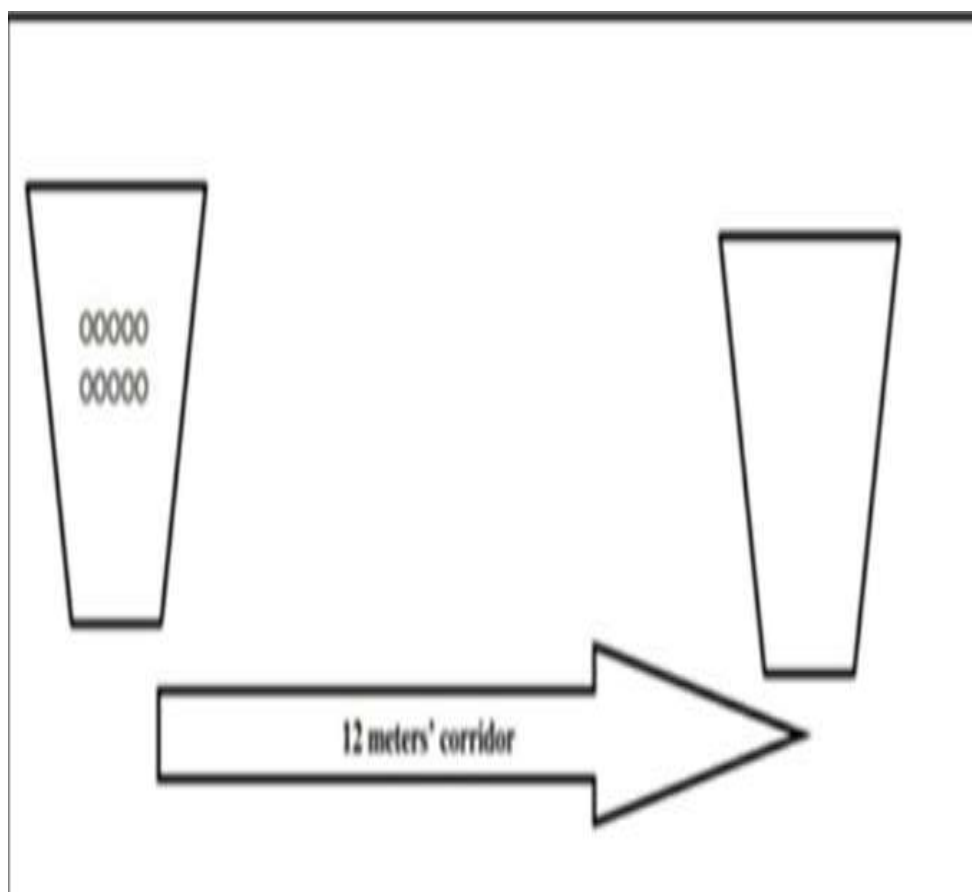


Figure 14: Schematic representation of reaching the target



Figure 15 : The child performing the Reach the target

Activity 09: Run to the four corners

Materials required

- 1.10 balls
- 2.10 meters (length) x 10 meters (width)

Preparation

10 meters long corridor

Place 1 basket at the starting point and three baskets 3 meters from the starting point. Note that the distance between the 1st, 2nd, 3rd and 4th basket is about 3 meters.

Instructions for child

The child from "start point," picks one ball from the basket, runs or walks fast to the first corner, drops the ball in the basket placed, runs or walks fast to the start point, and repeats the process by placing balls in the second basket in the second corner and in the third basket in the third corner. The total time duration is 7 minutes and no of balls placed in the basket/ no of repetition is noted.

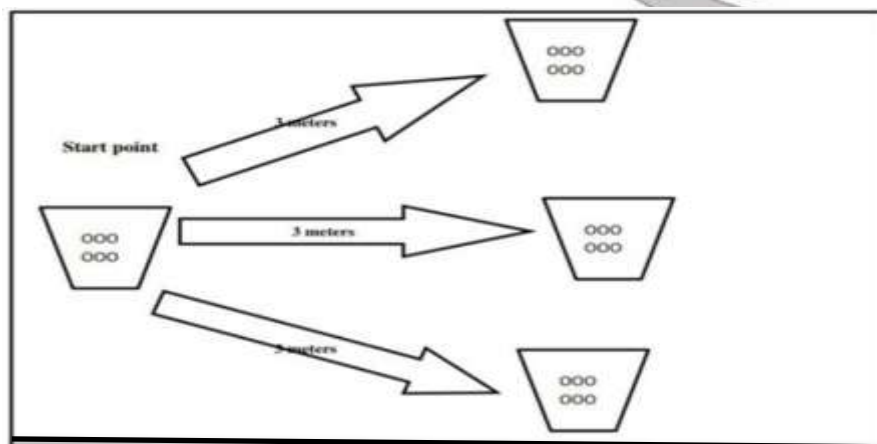


Figure 16 : Schematic representation of Run to the four corners



Figure 17 : The child performing Run to the four corners

The shuttle run test is highly valid for estimating VO₂ max, with correlation coefficients ranging from 0.70 to 0.90 compared to laboratory-measured VO₂ max. Additionally, it demonstrates excellent reliability, with test-retest intraclass correlation coefficients (ICC) between 0.88 and 0.95, indicating stable and consistent performance over repeated assessments.

Enjoyment of exercise: Physical Activity Enjoyment Scale (PACES)

The Physical Activity Enjoyment Scale is a quantitative measure of enjoyment of physical activity. This questionnaire consists of 17 items, consisting of both positive and negative questions. Participants rate their agreement using a 5-point Likert scale, where, 1= Disagree a lot to 5 = Agree a lot. The interpretation of the scores of PACES: < 2.5 = Low enjoyment of Physical Activity, 2.5 – 3.4 = moderate enjoyment of Physical Activity, >3.5 = High enjoyment of Physical Activity. The Physical Activity Enjoyment Scale has been shown to have an alpha coefficient of 0.87.18

STATISTICAL ANALYSIS:

Data were analysed using SPSS version 23.0. Descriptive statistics summarized participant characteristics, with continuous variables such as age and BMI presented as means $\pm$ standard deviations, and categorical variables such as gender and diagnosis reported as frequencies and percentages.

The primary outcome, VO₂ Max measured via the shuttle run test, was evaluated for normality using the Shapiro-Wilk test. Since VO₂ Max data were not normally distributed, non-parametric tests were applied. Within-group comparisons of pre- and post-intervention VO₂ Max were performed using the Wilcoxon Signed-Rank test, while between-group differences were assessed with the Mann-Whitney U test.

To account for potential confounders, ANCOVA was conducted to compare post-intervention VO₂ Max between groups, adjusting for baseline VO₂ Max, age, BMI, and shuttle count

Baseline characteristics of participants in the control and experimental groups.

Variable	Control Group (n = 27)	Experimental Group (n = 27)	TOTAL	p- value¹
Age (years), mean $\pm$ SD	9.33 $\pm$ 1.38	10.37 $\pm$ 1.24	9.85 $\pm$ 1.40	0.354
Gender, n (%)	100	100		0.163
- Male	70.4(19)	51.9(14)	61.1(33)	
- Female	29.6(8)	48.1(13)	38.9(21)	
Diagnosis, n (%)				0.281
- Cerebral palsy	21 (77.8)	22(81.5)	43(79.6)	
- Autism spectrum disorder	2(7.4)	2(7.4)	4(7.4)	
- Intellectual Disability	-	2(7.4)	2(3.5)	
- Down Syndrome	4(14.8)	1(3.7)	5(9.3)	
BMI (kg/m²)	18.14 $\pm$ 1.29	18.87 $\pm$ 1.18	18.51 $\pm$ 1.28	0.798
Baseline Shuttles, mean $\pm$ SD	4.41 $\pm$ 1.01	5.74 $\pm$ 1.43	5.07 $\pm$ 1.39	0.351

Baseline VO2 max (ml/kg/min), [Median (IQR)]	17.50 (1.00)	18.00 (1.00)	18.01± 0.63	0.124
Baseline PACE Questionnaire (Score), mean ± SD	57.56± 3.97	58.15± 4.02	57.85± 3.97	0.589

Table 1 represents the baseline characteristics of the 54 participants divided equally between the control and experimental groups (n = 27 each). The variables include age, gender, diagnosis, BMI, baseline shuttle run performance, VO₂ max, and PACE questionnaire scores. No statistically significant differences were observed between the two groups across any of the baseline measures (p > 0.05).

Table 2: Distribution of patients according to age in years

Age	N	Minimum	Maximum	Mean	Std. Deviation
	54	6	12	9.85	1.406

Graph 1: Distribution of patients according to AGE

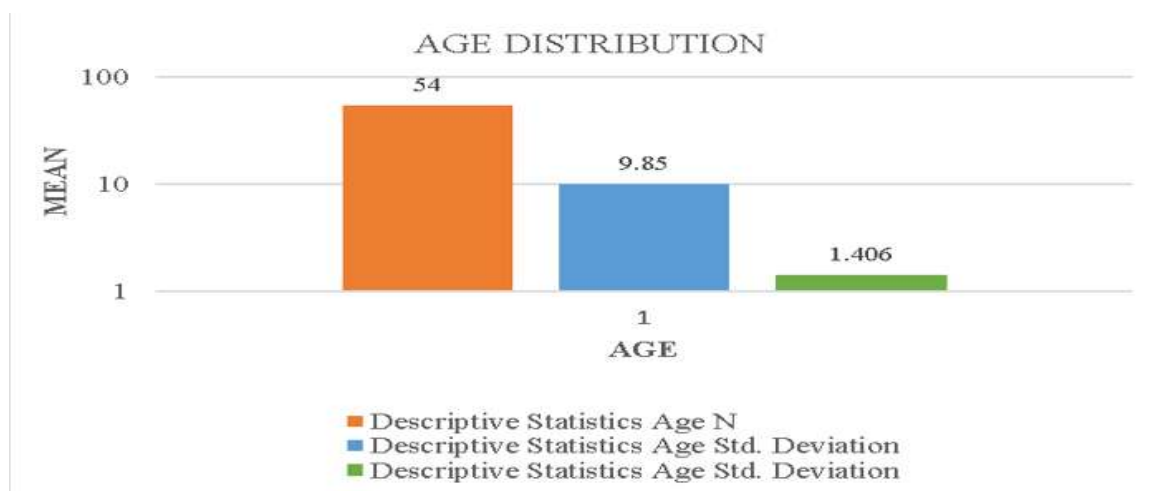


Table 2 represents the distribution of the ages of 54 participants. Ages range from 6 to 18 years, with a mean age of approximately 11.05 years.

Table 3: Distribution of patients according to Gender

Gender	Frequency	Percent	Cumulative Percent
Male	33	61.1	61.1
Female	21	38.9	38.9
Total	54	100.0	

Graph 2: Distribution of patients according to Gender

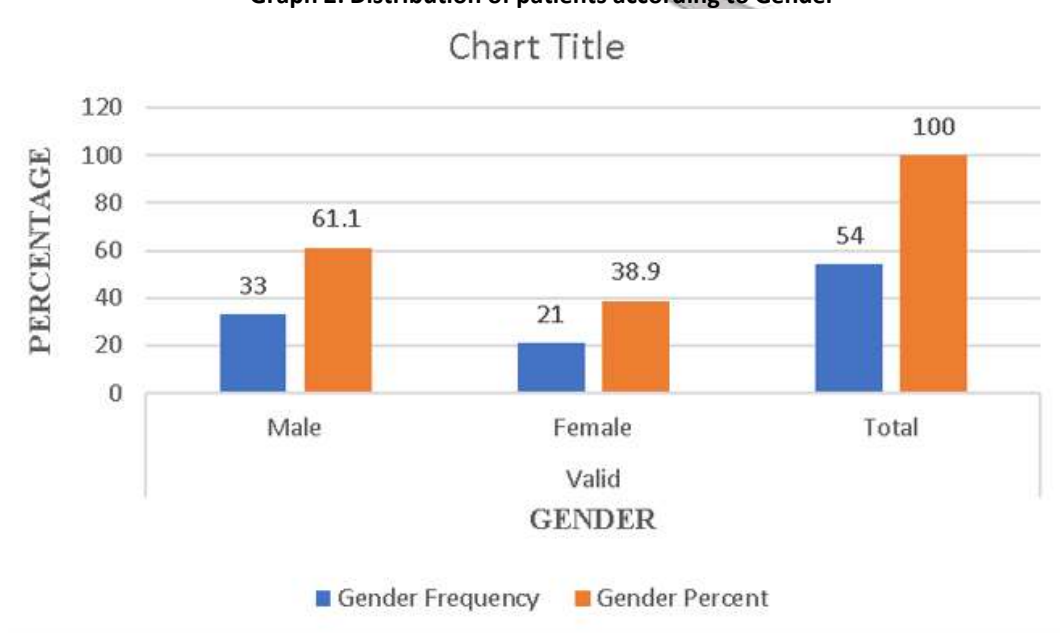


Table 3 and Graph 2 represent the gender distribution of 54 participants. Out of 54 participants, 33 participants were Male (61.1%) and 21 participants were Female (38.9%).

Table 4: Distribution of patients according to Diagnosis

Diagnosis	Frequency	Percent	Cumulative Percent
Cerebral palsy	43	79.6	79.6
Autism spectrum disorder	4	7.4	7.4
Intellectual disability	2	3.7	3.7
Down syndrome	5	9.3	9.3
Total	54	100.0	100.0

Graph 3: Distribution of patients according to Diagnosis

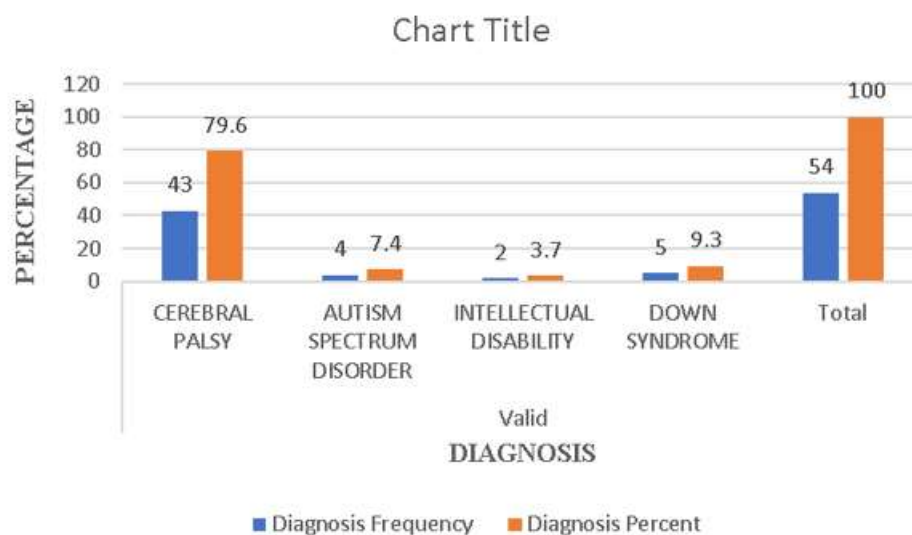
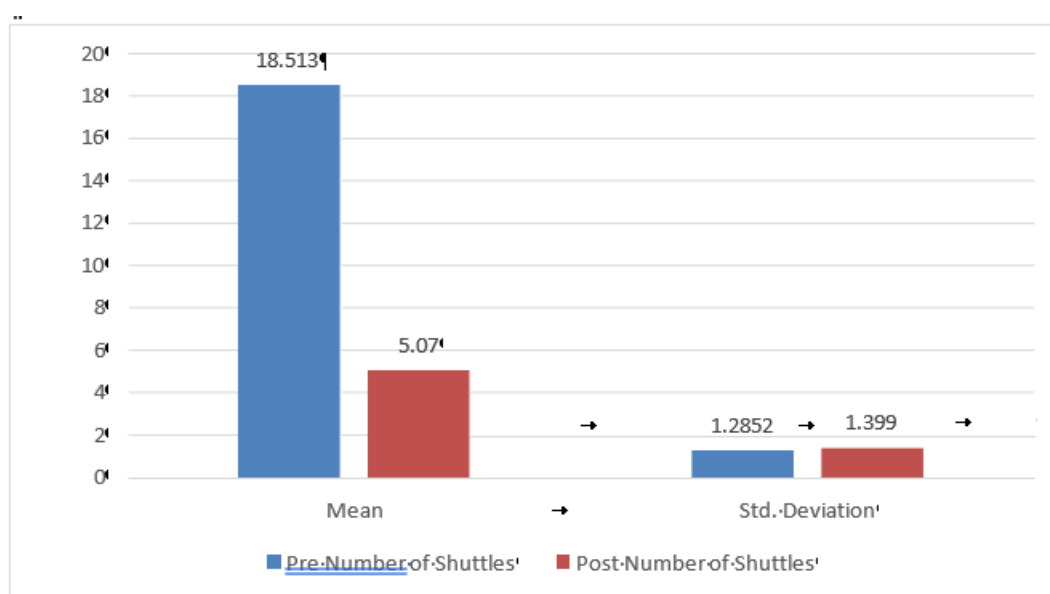


Table 4 & graph 3 represent the distribution of patients according to diagnosis of neurodevelopmental disabilities. The study included: Cerebral Palsy: 43 patients (79.6%), Autism - 4 patients (7.4%), Down's Syndrome - 5 patients (9.3%), Intellectual Disability - 2 patients (3.7%).

Table 5: Distribution of patients according to the Number of Shuttles and BMI

Variables	N	Minimum	Maximum	Mean	Std. Deviation
BMI	54	15.8	20.6	18.513	1.2852
Pre Number of Shuttles	54	3	8	5.07	1.399
Post Number of Shuttles	54	4	13	7.02	2.603



Graph 4: Distribution of patients according to Diagnosis

Table 5 & graph 4 represent the mean BMI of participants was 20.6 with a standard deviation (SD) of 1.29, indicating low variability in body mass. The average number of shuttle runs increased from 5.07 (SD = 1.40) pre-intervention to 7.02 (SD = 2.60) post-intervention, showing improved performance with greater variability after the intervention.

Table 6: Comparison of VO₂ Max between before and after treatment

Measure	Group	Pre [Median (IQR)]	Post [Median (IQR)]	Test Statistic	p-value
VO ₂ Max	Experimental	18.00 (1.00)	23.10 (1.30)	Z = 5.213	< .001
	Control	17.50 (1.00)	18.00 (1.00)	—	—

Graph 5. Graphical representation of the comparison of VO₂ Max before and after treatment

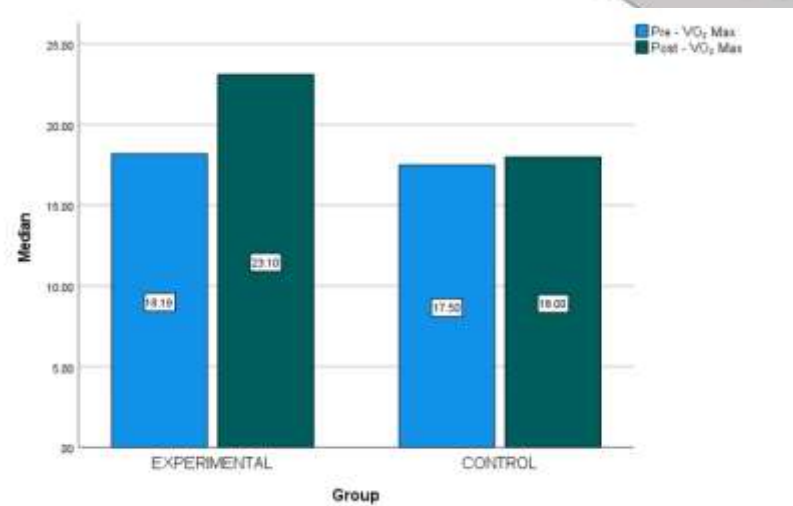


Table 6 and Graph 5: show a significant increase in VO₂ Max in the experimental group from 18.00 (1.00) to 23.10 (1.30). In contrast, the control group showed minimal change in VO₂ Max (17.50 to 18.00).

Table:07: Representation of the comparison between the PACE questionnaire before and after treatment

Measure	Group	Pre [Mean ± SD]	Post [Mean ± SD]	Test Statistic	p-value
PACE Questionnaire	Experimental	58.15 ± 4.03	66.48 ± 4.00	t = 8.448	< .001
	Control	57.56 ± 3.97	58.30 ± 4.06	—	—

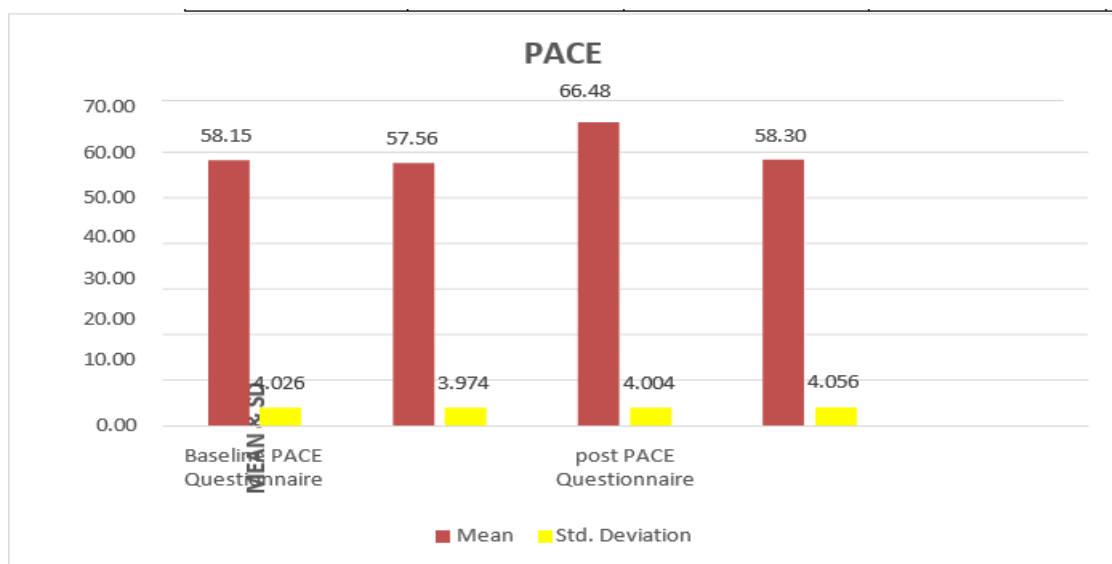


Table 7 and graph 6 show a significant improvement in PACE Questionnaire scores in the experimental group from 58.15 ± 4.03 to 66.48 ± 4.00 ($t = 8.448$, $p < .001$). The control group showed a slight, non-significant increase from 57.56 ± 3.97 to 58.30 ± 4.06 , indicating minimal change without intervention.

DISCUSSION

This randomized controlled trial investigated the effects of a play-based aerobic exercise program compared to conventional physiotherapy on aerobic fitness and enjoyment of physical activity in children with neurodevelopmental disabilities (NDDs). Results indicated that participants in the intervention group showed notable improvements in aerobic capacity and reported higher levels of enjoyment during the exercises. These outcomes highlight that structured, play-oriented aerobic programs can serve as effective and engaging strategies in pediatric neurorehabilitation.

The experimental group exhibited notable gains in aerobic fitness, as assessed by VO_2 Max using the shuttle run test. Children who participated in the play-based program demonstrated a median increase of 4.91 mL/kg/min in post-intervention scores compared to controls, indicating a statistically significant improvement. The finding is clinically significant because maintaining cardiorespiratory fitness helps reduce the risk of heart and metabolic disorders, which is particularly relevant for children with disabilities prone to limited physical activity⁽⁵⁾. Previous studies have similarly reported improved aerobic outcomes following aerobic or task-oriented physical interventions in pediatric neurorehabilitation settings⁽³²⁾. Evidence shows that aerobic fitness improved in 12 out of 14 interventions involving children with disabilities, especially those delivered through school-based or customized programs that incorporated aerobic training and games⁽³²⁾. Similar outcomes were reported in a prior study involving children with cerebral palsy, which reported significant improvements in aerobic capacity (SMD = 0.81; $p < 0.002$), along with notable gains in motor and functional outcomes following aerobic-based interventions.⁽³³⁾

However, many such interventions—such as bodyweight-supported treadmill training or structured sit-to-stand programs—require specialized equipment and controlled environments, limiting accessibility in low-resource settings⁽⁷⁾. A key strength of this study is the contextual

adaptability of the intervention. The play-based program utilized easily available, low-cost materials such as balls, cones, and open spaces, making it highly feasible for school- or home-based implementation. In contrast to more resource-intensive interventions, the program was designed to be functional, engaging, and flexible, allowing for individualization according to a child's motor ability and interest. This is especially important in low-resource settings, where limited clinical infrastructure, staffing shortages, tight budgets, or lack of space can make task-based rehabilitation difficult to carry out. Play-based aerobic training thus presents an inclusive alternative that addresses both physical and psychosocial aspects of therapy.

During the sessions, several practical challenges came up. For example, floor markings had to be redone each day because the surface would change, especially in shared or multi-use areas. The five exercise stations also needed to be adjusted often to match each child's ability, focus, and comfort. Setting up the stations each day took time and careful planning to keep things safe and consistent. These day-to-day issues show the importance of being flexible and prepared when running such programs in real-world, low-resource settings. The level of enjoyment was evaluated through the PACES questionnaire, which also improved significantly in the experimental group. The mean post-intervention PACES score between-group difference of 8.19 points. Notably, 69.5% of children in the experimental group reported moderate enjoyment, and 8.5% reported high enjoyment. Previous research has highlighted enjoyment as an important mediator of adherence and ongoing engagement in physical activity, particularly among children with NDDs who may be susceptible to repetitive or uninteresting tasks⁽³⁴⁾. The current findings extend previous work in the field, emphasized the emotional and motivational benefits of activity-based interventions in children with developmental disabilities. Similarly, one study has shown that interventions incorporating play and physical engagement lead to superior outcomes in motor coordination and aerobic performance compared to conventional physiotherapy approaches⁽³²⁾. However, few studies have directly compared play-based aerobic programs with standard physiotherapy using both physiological and psychosocial outcomes in children with diverse neurodevelopmental diagnoses. This study addressed a critical gap by demonstrating not only statistically significant improvements in VO_2 max but also increased enjoyment of physical activity, an important combined outcome that reinforces the applicability of play-based aerobic interventions in both clinical and community rehabilitation contexts.

Methodologically, the 10-Meter Shuttle Run Test is noteworthy, as it provides a practical method for estimating VO_2 Max, even though lab-based cardiopulmonary testing remains the gold standard. Field-based measures such as the shuttle run test provide a validated, practical, and reliable alternative, particularly suited for paediatric and resource-constrained settings⁽³⁵⁾. This is particularly relevant in school-based or rural rehabilitation contexts, where space and equipment may be limited, and practicality

is essential for routine implementation and progress tracking.

Despite its strengths, the study has limitations. In addition to its strengths, the study has a few limitations. First, because the intervention required active participation and involved specific procedures, due to the nature of the intervention, neither participants nor therapists were blinded when delivering the treatment. This may have influenced how children responded, especially on self-reported measures like enjoyment. Second, while the study included children with different neurodevelopmental conditions, we didn't look at how the intervention worked across specific diagnoses. It's possible that some children benefited more than others, and future research should explore this.

In conclusion, overall, the findings highlight the effectiveness of play-based aerobic as a viable, enjoyable, and effective strategy to enhance aerobic fitness in children with neurodevelopmental disabilities. The program's low-cost, adaptable nature makes it especially suitable for low-resource settings where conventional therapy may be inaccessible. By aligning therapeutic goals with playful engagement, such interventions offer a promising pathway to improve physical functioning and overall wellness in children with.

STRENGTH OF THE STUDY

Including children with a variety of neurodevelopmental disorders increases the generalizability of the findings.

The focus on play-based exercises reflects real-world applicability and allows for the examination of practical, scalable solutions for promoting physical activity among children with neurodevelopmental disabilities.

Play-Based Approach: By integrating play into the exercise regimen, the study capitalized on natural engagement and enjoyment, making physical activity more accessible and appealing to children.

Evaluation of Enjoyment: Incorporating PACES to measure enjoyment adds a valuable dimension to understanding the impact of the intervention beyond just physical fitness.

LIMITATIONS

In addition to its strengths, the study has a few limitations. First, because of the nature of the intervention, Blinding was not possible for participants or assessors because of the intervention's design. This may have influenced how children responded, especially on self-reported measures like enjoyment. Second, while the study included children with different neurodevelopmental conditions, we didn't look at how the intervention worked across specific diagnoses. It's possible that some children benefited more than others, and future research should explore this. Another limitation is that parents and caregivers weren't directly involved in the intervention. Their input could have helped us better understand what makes programs like this work outside of structured settings.

FUTURE SCOPE

Future research should include longer intervention periods and follow-ups to assess the sustainability of improvements in aerobic fitness and enjoyment during the follow-up period.

CONCLUSION

Evidence from this research highlights the effectiveness of play-based aerobic exercise as a viable, enjoyable, and effective strategy to enhance aerobic fitness in children with neurodevelopmental disabilities. The program's low-cost, adaptable nature makes it especially suitable for low-resource settings where conventional therapy may be inaccessible. By aligning therapeutic goals with playful engagement, such interventions offer a promising pathway to improve health status and everyday functioning in children with developmental challenges.

Our findings indicate that such a program can significantly improve aerobic fitness, as evidenced by enhanced performance in the Incremental Shuttle Run Test. Additionally, this suggests that incorporating enjoyable, play-oriented activities into home exercise programs can be an effective strategy for promoting physical health and well-being among children with neurodevelopmental disabilities.

CLINICAL IMPLICATIONS

For children with neurodevelopmental disabilities, implementing an aerobic exercise program through play-based activities may improve aerobic fitness and increase enjoyment of physical activity. Furthermore, the positive association between enjoyment and physical activity suggests that play-based therapy can effectively engage this population and promote their physical activity levels.

SUMMARY

The present study was designed to examine the effects of a structured play-based aerobic exercise program on both aerobic fitness and the enjoyment of physical activity in children with neurodevelopmental disorders (NDDs). A total of 54 children, aged between 6 and 12 years, and diagnosed with Autism Spectrum Disorder, Attention Deficit Hyperactivity Disorder (ADHD), Down Syndrome, Cerebral Palsy, or Intellectual Disability, were selected following a screening process to confirm eligibility. Participants were then randomly assigned to either an intervention group, which received the structured play-based aerobic program, or a control group, within the framework of a single-blind randomized controlled trial.

Children in the intervention group participated in a structured play-based aerobic exercise program that included activities such as running, jumping, and skipping. The program was designed to be developmentally appropriate and engaging, aiming to enhance physical activity levels while ensuring enjoyment. The intervention was conducted over six weeks, with sessions held three times per week, each lasting approximately one hour.

Aerobic fitness was evaluated using the 10-Meter Shuttle Run Test, modified to a 10-meter shuttle run, while enjoyment was assessed through the Physical Activity Enjoyment Scale (PACES). The results showed that children in the intervention group experienced a notable improvement in aerobic capacity, evidenced by a significant increase in VO_2 Max values. Additionally, PACES scores showed that most participants reported moderate levels of enjoyment, suggesting that the activities were engaging, motivating, and well-received by the children.

The findings validate the feasibility, effectiveness, and acceptability of play-based aerobic interventions in children with NDDs. Not only did the program improve aerobic fitness, but it also encouraged participation through enjoyable and accessible activities. These outcomes highlight the potential of play as a therapeutic medium to support physical health and promote positive experiences in physical activity settings.

This study underscores the importance of designing inclusive, low-cost, and adaptable exercise programs that incorporate play-based elements. Such programs are especially valuable in low-resource settings and can serve as effective alternatives or complements to conventional therapeutic approaches. Ultimately, Adding regular physical activity to the everyday routines of children with NDDs can support improved health and quality of life.

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