ORIGINAL RESEARCH

The Effect of a Circuit Training Program on Functional Performance in Children with Spastic Cerebral Palsy – A Quasi-experimental Pilot Study

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Abstract

Background: There is a plethora of literature with some conflicting findings on the effects of implementing strength and/or aerobic (fitness) training to improve motor function of children with spastic cerebral palsy (CP).

Purpose: This aim of the study was to investigate the effects of a circuit training regimen on static and dynamic motor function of children diagnosed to have spastic CP.

Materials and Methods: This is a pilot quasi-experimental study on children with spastic CP (aged 6-11 y; 7 males and 3 females) who underwent a circuit exercise training program (combined endurance and strength training) for 6 weeks. Changes in static (standing) and dynamic (jumping, running, walking) motor function were assessed by dimensions D and E of the Gross Motor Function Measure (GMFM) scale, respectively. In addition, walking capacity was also assessed using the 30 s walk test. The Wilcoxon Signed Rank test was used to compare pre- vs. post-intervention scores.

Results: There was an increase in static and dynamic motor function scores in the GMFM scale of children with spastic CP by 9 % ($p = 0.005$). An increase of 18.5 cm was found in the walking distance following intervention ($p = 0.005$).

Conclusion: Circuit training used in the current study might increase standing as well as jumping, walking, and running abilities of children with spastic CP. However, randomized clinical trials are warranted to confirm these findings.

Keywords: Cerebral Palsy, Gross motor function, Walking ability, Strength training, Endurance training

Introduction

International incidence of cerebral palsy (CP) has been reported to be approximately 2.11 out of 1000 live births[1]. CP is a movement and postural developmental disorder. It is a non-progressive neurological disorder of cerebral origin occurring in developing fetus or infant brain that affects muscle strength and motor control[2]. CP children might present with spastic, dyskinetic/athetotic, ataxic or hypotonic features. Among them, prevalence of spasticity is quite high[2].

Spasticity and weakness might be associated with the same affected muscle(s) in children with spastic CP[3]. Though various therapeutic approaches have been used to treat spasticity and muscle weakness, functional (goal) oriented exercises carried out in a circuit regimen is reported to be a promising intervention to improve muscle strength without aggravating aberrant motor control (spasticity)[4]. Circuit training is an overall physical conditioning method in which a child with cerebral palsy works out through a chain of exercise stations designed to improve muscle strength and endurance, decrease aberrant motor control, and prevent somatic dysfunction associated with lack of mobility[5,6]. On the other hand, context therapy approach emphasizing modification of task and environment without altering the children's abilities has also been reported[7].

There were claims that resisted strength training exercises might aggravate spasticity and lead to aberrant motor control[8]; however, there have been a lot of studies to negate and disprove this argument[5, 6, 9–11, 13, 26]. Previous literature reviews on controlled and non-controlled studies reported that strengthening exercises of limb muscles (isokinetic and/or isotonic) can increase muscle strength without increasing spasticity in children with cerebral palsy[9–11]. In addition to strengthening exercises of the lower limbs, individuals with CP might improve with aerobic workout or mixed exercise regimen (aerobic and strengthening exercises)[12, 26]. At the same time, an improvement in gait and function has been found to improve more with isotonic than isokinetic exercise[13]. However, a subsequent review on randomized controlled trials concluded that strength training is not effective or worthwhile in improving strength, speed of walking and Gross Motor Function Measure (GMFM)[14].

Despite a plethora of literature with some conflicting findings, a majority of reports are in agreement with implementation of strengthening exercises of the lower limbs and/or aerobic fitness to benefit children with CP[5-11, 28-29]. However, there is no clear consensus on improvement in the speed of walking, GMFM score, and quality of life of CP children following these interventions. To be specific, there is a dearth of similar research in children with spastic CP. Therefore, the aim of the study was to assess the effects of circuit training on functional performance in children with spastic CP. This research, being a pilot study, would further inform about feasibility and safety of the proposed circuit training regimen in children with spastic CP.

Materials and Methods

The study protocol was reviewed and approved by the Institutional Human Ethics Committee. Children were recruited through word of mouth, adverts displayed through notice boards, and referral from the departments of Pediatrics and Physical Medicine and Rehabilitation in PSG Hospitals, Tamil Nadu, India.

Participants

Children, aged between 2 and 12 y, diagnosed to have spastic CP (diplegia, hemiplegia or quadriplegia) and undergoing Physical Therapy in the Department of Physical Medicine and Rehabilitation, PSG Hospitals with a motor functional level of I and II based on gross motor functional classification system (GMFCS)[15] and an ability to follow simple verbal commands were included in the study. Children who underwent recent orthopaedic or neurological surgery or on baclofen pump within the preceding 12 months, undergoing botox injections or any recent orthotic intervention/serial casting of the lower limbs within the past 3 months, uncontrolled seizures, cardiac diseases, and severe orthopedic conditions restricting adequate mobility and independence were excluded from the study.

Study design

The study employed a pilot quasi-experimental design. One group of 10 children with spastic cerebral palsy participated in a circuit exercise training program.

Outcome measures

The GMFM scale (dimensions D and E)[6] and 30 s walk test[27] were used to document gross motor function and distance walked, respectively, before and after intervention. Only D (standing) and E (walking, running and jumping) components of the GMFM scale were measured because they are specific to measure outcomes related to the training components in ambulatory children[16].

For the 30 s walk test, CP children were made to walk at their own comfortable speed for 30 s and then total distance walked was measured. If they experienced any breathing difficulty, fear of fall, imbalance, pain and/or leg fatigue then the test was stopped.

Procedure

The parents of CP children were explained about the purpose and need of the study, and a signed informed written consent was obtained. To confirm the eligibility of participants to be included in this study, the initial assessment of CP children was done by a senior Physiotherapist (MR) specialized in Paediatric Physiotherapy with 3 years of clinical experience in treating cerebral palsy children and subsequent assessment was done by the same investigator. On the day of initial assessment, the outcome measures such as GMFM score and distance walked during 30 s were measured. After the initial assessment, circuit exercise training was carried out. Throughout the training phase, if there was any indication to terminate exercise training then exercises were discontinued. Children were allowed to do any sort of physical activity (playing, leisure walking, and running) in addition to circuit training sessions employed at the institution.

Exercise intervention

Participants attended a protocol based on a graded circuit training program at the pediatric neuro-rehabilitation gymnasium of PSG hospitals, India. Circuit training program in the current study included six stations with four aimed at increasing strength of larger muscle groups of both lower limbs and two aimed at increasing cardiopulmonary endurance (Table 1). The exercises were designed to resemble day-to-day activities [5–8, 28-29].

The following equipment were used in the study - a pediatric treadmill (S&T Engineers/Welcare fitness equipment Pvt Ltd, Coimbatore, India), a pediatric recumbent bike (S&T Engineers/Welcare fitness equipment Pvt Ltd, Coimbatore, India), a seated rowing machine (S&T Engineers/Welcare fitness equipment Pvt Ltd, Coimbatore, India), and an armless chair (customized to suit the height of participants) for sit to stand. Strengthening exercises were carefully monitored to avoid elicitation of abnormal synergies and reflexes, as much as possible, during the training.

CP children included in the study attended the program twice a week for six weeks. A senior physiotherapist with clinical experience of more than 5 y in CP rehabilitation supervised the circuit stations for the adaptability of exercises and suitability of motor learning. Children did warming-up and cooling-down prior to and on completion of each session, respectively, for around 10 min, which involved stationary marching, stretching of the thigh and calf muscles of both lower limbs.

The exercise stations were randomly allocated to children. Participants were trained at each station for two to ten min (depending on the task) and transferred to the next station following completion of each exercise in order to reduce neuromuscular detraining effects and boredom of the exercise station[6]. As a safety measure, all the exercise circuit stations were supervised and assisted by the primary investigator (MR).

During the first week of training, participants were familiarized with the equipment and appropriate intensity of exercise was selected. Participants were fitted with polar® heart rate monitors (Polar, S810i, Woodbury NY, USA) during aerobic sessions (treadmill walking and recumbent cycling). Using the Karnoven's formula, the intensity for the aerobic session was set to achieve a heart rate between 65 and 85% of age-predicted heart rate maximum (calculated as 220 minus their age in years). Major stations for circuit training were based on closed kinetic chain exercises (seated rowing, wall push up, side step up, sit to stand). Every two weeks, new intensity for aerobic training was determined on the basis of resting heart rate.

Statistical analysis

Wilcoxon Signed Rank test was used to compare pre- and post-intervention scores. An α level of 0.05 was set as the level of significance and data were analyzed using IBM-SPSS (Version 17, IBM, NY).

Results

Characteristics of the participants

Out of 10 children who volunteered for the study, 3 were females while the rest of them were males. Five participants were using foot drop splints with knee extension straps. Three of the 10 participants were school going children and all of them where physically active. The demographics of the included participants are summarized in Table 2. Eight children completed all the sessions (6 weeks) while one child missed 2 sessions due to seizure episodes and another child could not attend 4 therapeutic sessions due to minor tendon lengthening procedure of tendoachilles.

Changes in gross motor functions

There was a statistically significant change in GMFM dimension D (Standing) score following intervention with a mean difference of 9.8% from the baseline ($p = 0.005$). In addition, the mean difference between the pre- and post-intervention GMFM dimension E (jumping, running, walking) scores was 9.03% ($p = 0.005$). These findings are summarized in Table 3.

Changes in walk capacity (30 s walk test)

There was an increase of 18.2 cm in the walking distance covered in 30 s following six weeks of intervention when compared to the pre-intervention scores ($p = 0.005$). Table 3 summarizes the changes associated with 30 s walk distance before and after circuit training.

Table1. Intervention protocol followed for 6 weeks in the study

Type of exercise	Circuit stations	Frequency per week	Intensity	Duration	Mode/Equipment used	Repetition (except where indicated)
Aerobic training	Warm-up	Twice	Exercise gradually to attain target heart rate	5 min	Stationary march, stretching of the thigh and calf muscles, and calisthenics	-
	Treadmill walking	Twice	65-85% of APMHR	10 min	Treadmill (level walking without inclination)	Walk interspersed with rest periods
	Leg ergometer	Twice	18–24 RPM/4.5–5 km to attain APMHR	5 min	Recumbent bike	Walk interspersed with rest periods
Strength training	Seated rowing	Twice	-	2 min	Rowing machine	10
	Wall push up	Twice	-	2 min	Wall support	10
	Sit to stand	Twice	-	3 min	Armless chair	10
	Side step up	Twice	-	3 min	Stair-step	10
	Cool down	Twice	Exercise to drop to resting level heart rate	5 min	Stationary march, stretching of hamstrings, plantar flexors	-

APMHR, age predicted maximal heart rate; RPM, rotations per minute

Table 2. Characteristic features and study outcome measures of children with spastic cerebral palsy

No.	Participant characteristics			Static GMFM score - standing (%)		Dynamic GMFM score - walking, running, jumping (%)		30 s walk test (cm)	
	Age (y)	Sex	Diagnosis	Pre-Rx	Post-Rx	Pre-Rx	Post-Rx	Pre-Rx	Post-Rx
1	7	Female	Diplegia	56.41	66.66	29.16	37.50	150	161
2	11	Male	Quadriplegia	64.10	74.35	48.61	56.94	156	165
3	8	Male	Diplegia	69.23	76.92	44.44	55.55	153	172
4	10	Female	Diplegia	66.66	84.61	50.00	58.33	164	179
5	7	Female	Quadriplegia	63.51	76.92	61.11	65.27	180	200
6	8	Male	Diplegia	79.48	89.74	63.88	73.61	188	210
7	10	Male	Triplegia	74.35	79.48	51.38	61.11	170	190
8	6	Male	Hemiplegia	82.05	89.74	62.50	75.00	181	205
9	7	Male	Quadriplegia	87.17	92.30	65.27	72.22	190	217
10	8	Male	Diplegia	71.79	82.05	51.38	62.50	176	191

GMFM, Gross Motor Functional Measure; Rx, Intervention.

Table 3: The mean differences between pre- and post-intervention scores and Wilcoxon signed rank values based on within group comparisons for dimensions D and E of the Gross Motor Functional Measure (GMFM) and 30 s walk test

Outcome variables	Pre-Rx	Post- Rx	Mean difference	Standard deviation	P value
GMFM Dimension D (%)	71.47	81.27	9.8	3.86	0.005
GMFM Dimension E (%)	52.77	61.80	9.03	2.38	0.005
30 s walk test (cm)	170.8	189	18.2	5.67	0.005

Rx, Intervention.

Discussion

Our study hypothesized that six weeks of circuit training when appropriately dosed and followed up would improve the motor function of children with spastic CP and our findings support this hypothesis. The major finding of this pilot study is that the exercise program when carried out in a circuit regimen may improve the functional performance of children with spastic CP. These findings are in agreement with previous studies by other researchers[5, 17–19].

Improvements in standing, walking, running and jumping scores following circuit training with tasks such as treadmill walking, (side) step up and sit to stand is clinically and functionally relevant[20]. Hence the principle of specificity in functional training by incorporating functional exercises for CP children with spasticity would increase their functional performance. The exercise regimen employed in the current study might have increased strength and coordination of lower limb muscles and improved trunk balance and strength leading to an improvement in weight-bearing functional tasks. This, in turn, might increase the quality of life in these children which needs further investigation. Our findings agree with the previous literature that functional training programs may improve activities of daily living such as walking, side step ups or transfers (sit to stand) in children with (spastic) CP[2, 5, 17, 20, 22 – 25, 29].

Another finding of this study is that functional walk distance statistically improved after the administration of circuit training. Even so, the magnitude of increase in the walk distance after six weeks of training was about 18 cm, equating to hardly 2 – 3 steps, which is not a clinically significant improvement. Further, Blundell et al. (2003) and Taylor (2009) also claimed no improvement in in cadence, walk distance nor the walk velocity with task oriented functional exercise training program[5, 21]. On the contrary, Pandey and Tyagi (2011)[25] did a controlled trail with a small sample of children with spastic diplegia, aged between 5 and 10 years, and found a significant increase in walking distance during 2 min walk test and walking time during 10 m walk test in the intervention group (n = 9) undergoing functional strength training but not in the control group (n = 9). However, these effects were not maintained in the follow-up session following intervention. As the sample size is low, there is a chance for type II error in their study. Further, this study did not incorporate any aerobic training to their intervention group but the current study included both aerobic and strength training exercises in the circuit training regimen. Though type II (β) error is common with a small sample size, the included participants in the current study may represent a small proportion of population giving a finding with less clinical importance. Therefore, there is a need for high quality randomized clinical trials in future to support or negate the findings of the present study.

Strengths and limitations of the study

All the CP children participated in the study attended most of the sessions and compliance to the functional strengthening exercise was good in the study. Hence, a follow up of 6 weeks for CP children in these types of exercise programs is expected to be good based on the current study. We incorporated treadmill training in the circuit training program for improving functional performance in Indian children with spastic CP while the previous studies on Indian children with CP did not[22-24].

Being a pilot quasi-experimental study on a single group with a small sample, the effects of the circuit training cannot be explicitly recommended for clinical management of children with spastic CP. Hence, robust randomized controlled trials are needed to confirm the true effects of circuit training (endurance and functional strength training) in improving functional performance of CP children. Improvements in muscle strength following the functional training were not measured in the current study but future studies should document strength pre- and post-intervention using isokinetic or hand-held dynamometers. Though isolated strength testing of individual muscles will not reflect dynamic muscle strength required for functional activities, further trials can concentrate on measuring closed chain isokinetic strength testing.

Balance impairments, grade of spasticity, and gait deviations were not measured which is a major limitation of the current study. However, the study population did not report any history of falls or any other adverse effects impeding activities of daily living or requiring any other therapy/medical attention during the intervention period. Future trials should attempt to relate the improvement in functional performance following circuit training with other variables such as gait velocity, grade of spasticity, and balance impairment. Further studies could also implement circuit training regimen with an increase in number of sessions per week and also the total duration of therapy for more than 6 weeks.

Conclusion

The circuit training program employed in the current study improved functional performance by 9% (in GMFM dimensions D and E) in children with spastic CP having mild to moderate impairment. Nevertheless, improvement in walking distance (measured with the 30 s walk test) following the intervention does not appear to be clinically meaningful (18.2 cm) despite being statistically significant. Though definitive conclusions cannot be made from this pilot study, randomized clinical trials are further warranted to confirm the findings of the study in children with spastic CP.

Conflict of Interest

The authors declare that there is no conflict of interest involved with this manuscript.

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