How to Cite:
Fayed, M. A. E. F., Salem, E. E. S., Omar, T. E. S., & Rahman, S. A. A. (2022). Effect of circuit training program on functional performance in children with hemiplegic cerebral palsy. *International Journal of Health Sciences*, *6*(S6), 11069–11079. https://doi.org/10.53730/ijhs.v6nS6.13033

Effect of circuit training program on functional performance in children with hemiplegic cerebral palsy

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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 training or circuit training exercises to improve motor function of children with spastic hemiplegic cerebral palsy (CP). Circuit training is a form of body conditioning that involves endurance training, resistance training, high-intensity aerobics, and exercises performed in a circuit. Purpose: To investigate the effect of circuit training program on gross motor functions and functional capacity in children with hemiplegic CP. Methods: Thirty-two children with hemiplegic CP from both genders (8-12 years) with motor functional level of I and II based on Gross Motor Functional Classification System were assigned into two equal groups (control and study). The control group received a selected conventional physical therapy program for 60 minutes, including 35 minutes directed to lower limb. The study group received circuit training program for 35 minutes. The program for both groups was conducted twice per week for 12 successive weeks. Gross motor functions and functional capacity of both groups were evaluated by the Gross Motor Function Measure (GMFM) version 66 (Domains D and E) and the Six-Minute Walk Test (6MWT) respectively before as well as after the treatment period. Results: Within-group comparison revealed significant improvement in

Manuscript submitted: 9 May 2022, Manuscript revised: 18 July 2022, Accepted for publication: 27 August 2022

gross motor functions and functional capacity. Between-group comparison after intervention revealed significant differences regarding Dimension E of GMFM and functional capacity in favor for the study group. Conclusion: Both circuit training and the selected conventional physical therapy programs are effective in improving functional performance of children with hemiplegic CP. However, the improvement is more statistically significant after the application of the circuit training program.

Keywords---cerebral palsy, circuit training, gross motor functions, functional capacity.

Introduction

Cerebral palsy (CP) describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbance that occurred in the developing fetal or infant brain (Bax et al., 2005). Children with CP often experience neurological symptoms including dystonia, ataxia, athetosis and particularly spasticity (Strøm et al., 2021). It is a non-progressive neurological disorder of cerebral origin occurring in developing fetus or infant brain that affects muscle strength and motor control (Scholtes et al., 2012). Hemiplegic CP children are characterized by muscle weakness on one side of the body, delay in developmental milestones, and mainly upper limb involvement that has a significant impact on global function, fine motor control, personal care (Multani et al., 2019). Spasticity and weakness might be associated with the same affected muscle(s) in children with spastic CP. Though various therapeutic approaches have been used to treat spasticity and muscle weakness, functional (goal) oriented exercises carried out in a circuit regimen are reported to be a promising intervention to improve muscle strength without aggravating aberrant motor control (Kim et al., 2013).

Circuit training is an overall physical conditioning method in which a child with CP 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 (Scholtes et al., 2008). On the other hand, conventional physical therapy method is a group of exercise that not implemented through a chain of stations and depends on neuro -developmental model (Darrah et al., 2011). Circuit training is a generalized conditioning program that increases muscular strength and endurance and improves cardiovascular fitness in the general population. It combines low-resistance, high-repetition exercises aimed at improving muscular endurance with exercises that increase flexibility and cardiovascular fitness. Although circuit training is popular among adolescents and young adults without disabilities, and is offered in many community gymnasiums, its potential benefits for general health and community participation in people with CP have never been assessed (Carr et al., 1988).

There were claims that resisted strength training exercises might aggravate spasticity and lead to aberrant motor control, however, there have been a lot of studies to negate and disprove this argument (Verschuren et al., 2008). 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 CP (Haney, 2009). 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). At the same time, an improvement in gait and function has been found to improve more with isotonic than isokinetic exercise. 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) (Scianni et al., 2009).

Combination of strengthening exercises and/or aerobic fitness as in circuit training exercises in which a child with CP works out through a chain of exercise stations program reported to be a promising intervention and have a lot of benefits for children with spastic hemiplegic CP (Boyd, 2012). There is no clear consensus on improvement in the speed of walking and GMFM score of CP children following these interventions. Therefore, more researches are required to assess the effects of circuit training program on functional performance for children with spastic hemiplegic cerebral palsy. Therefore, the aim of this study was to assess the effects of circuit training on gross motor functions and functional capacity in children with spastic hemiplegic CP. We hypothesized that 12 weeks of circuit training when appropriately dosed and followed up could improve functional performance of children with spastic hemiplegic CP.

Methods

Sample size

The sample size was detected through Steven Sampson equation. Based on the assumption that sample size was calculated on infinite community population (90,000,000) with confidence level equal to 90%, a probability of 50% and the margin of error is 0.05%, a sample size of 32 children will be required and could be increased to 40 children to allow for further 15% drop rate.

Participants

Thirty-two children (21 boys and 11 girls) aged from 8-12 years participated in this study. They were recruited according to the following inclusion criteria: 1) diagnosed as spastic hemiplegic CP, 2) the degree of spasticity was between 1/1+ according to Modified Ashworth Scale1 (MAS) (Bohannon and Smith, 1987), 3) have a motor functional level of I and II based on the Gross Motor Function Classification System (GMFCS) (McCarthy and Drennan, 2009), 4) could understand and follow simple verbal commands. Children were excluded if they: 1) underwent recent orthopedic or neurological surgery, 2) be on baclofen pump within the preceding 12 months, 3) undergoing Botox injections, orthotic intervention/serial casting of the lower limbs within the past 3 months, 4) had uncontrolled seizures, cardiac diseases, and severe orthopedic conditions restricting adequate mobility and independence, and/or 5) serious visual and\or auditory impairment. Eligible Participants were assigned into two equal groups (control and study).

Sample method and venue

Convenient sample was selected from the out-patients clinics of Physical Therapy Department of National Institute of Neuro-Motor System, Giza, Egypt. Assessment and treatment were performed in a private physical therapy center in Cairo.

Materials and Procedures

Study Design

This study is a quasi-experimental pretest-posttest study that was carried out from 1th of January to 30rd of July 2021.

Ethical Considerations

The study was approved by the local ethics committees of Faculty of Physical Therapy, Cairo University, Egypt (P.T.REC/012/002187). A signed written consent form was obtained from children's parents/legal guardian before starting the study.

Subjects' Recruitment

After collecting the consent forms, children were examined by the researcher for the eligibility criteria. Each eligible child (according to the consent form and examination) was participated in the study. Eligible children were divided into two equal groups (control and study groups).

Evaluation

Muscle tone was assessed by the MAS (Bohannon and Smith, 1987) and the level of motor function was assessed by GMFCS (McCarthy and Drennan, 2009). Changes in static (standing) and dynamic (jumping, running, walking) motor functions were assessed by dimensions D and E of the Gross Motor Function Measure (GMFM) scale (Oeffinger et al., 2009). Six–Minute walk test (6MWT) captured submaximal walking endurance over six minutes and it was used to assess functional capacity. It is reliable in children with CP and is clinically used as a "capacity-based" measure of walking activity (Thompson et al., 2008). Assessment of both gross motor functions and functional capacity was performed before as well as after three months of intervention.

Intervention

The required equipment for treatment included up and down stairs, a pediatric treadmill, a pediatric recumbent bike, a seated Orbit rack rowing machine, an armless chair (customized to suit the height of participants) and a polar® heart rate monitors (Polar, S810i, Woodbury NY, USA). The control group received selected conventional physical therapy program for 60 minutes including 35 minutes directed to lower limb training. The program started with warm up stretches for the major muscle groups that included stretching of knee flexors, adductors and hip flexors for 10 minutes. After warming up, children were asked to perform active movements of all the joints of lower extremities, and then children were asked to start weight bearing, strength training, pelvic bridging, kneeling, and half kneeling activities with the use of lower extremity in addition to treadmill training and stationary cycling. The study group received circuit training program for 35 minutes. Circuit training program included six stations with four stations aimed at increasing strength of larger muscle groups of both lower limbs and two stations aimed at increasing cardiopulmonary endurance (Table 1). The exercises were designed to resemble day-to-day activities. Treatment for both groups was applied twice a week for 12 weeks. During the first week of training, participants were familiarized with the equipment and appropriate intensity of exercise was selected. Participants were fitted with the polar® heart rate monitors 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) (Robert and Landwehr, 2002).

Statistical Analysis

Results were expressed as mean ± standard deviation. Comparison between categorical data was performed using Chi square test. Between-groups comparison was performed using unpaired t-test while within-groups comparison was performed using paired t-test. Statistical Package for Social Sciences (SPSS) computer program (version 19 windows) was used for data analysis. P value ≤ 0.05 was considered significant.

Results

The general characteristics of the participants are presented in Table (2) and revealed non-significant differences regarding age, gender as well as side of affection distribution between groups. Regarding the gross motor functions, results revealed statistically significant improvements in the mean values of dimension D (standing) and dimension E (walking, running and jumping) as well as the total score of GMFM when comparing the pre- and post-treatment values in both groups (Table 3). Results also revealed statistically significant differences in the mean values of dimension E and the total score of GMFM between groups post-treatment in favor for the study group (Table 4). Regarding the functional capacity, results revealed statistically significant improvements in the mean values of the 6MWT when comparing the pre- and post-treatment values in the control as well as the study groups with a percentage of improvement of 6.78% and 11.48% receptively. Results revealed statistically significant differences in the mean values of the 6MWT between groups post-treatment in favor for the study group (Table 5).

Table 1
Intervention protocol of the circuit training program

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

APMHR: Age predicted maximal heart rate. RP M: Rotations per minute.

Table 2
General characteristics of participants

Measured Variables		Groups			
		Control	Study		
		Mean±SD		t-value	P-value
Age		9.281±1.622	9.750±1.483	-0.853	0.400
		N(%)		X^2	
Gender	*Boys*	9(56.25)	12(75.00)	1.247	0.264
	Girls	7(43.75)	4(25.00)		
Side of affection	*Right*	12(75.00)	8(50.00)	2.133	0.144
	Left	4(25.00)	8(50.00)		

SD: standard deviation. N: Number. %: Percentage. X^2: Value of chi-square test.

Table 3
Within-group comparison regarding gross motor functions

Groups	Variables	Time of Measure		% of Improvement	t-value
		Pre-measure	Post-measure		
		(Mean±SD)			
Control	Dimension D	85.688±8.972	91.775±5.792	7.71	-6.178*
	Dimension E	83.069±8.448	88.853±6.930	7.26	-13.300*
	Total score	84.028±8.313	89.988±5.943	7.52	-8.960*
Study	Dimension D	87.606±7.025	94.669±3.555	8.49	-6.085*
	Dimension E	87.981±5.450	93.713±4.513	6.62	-13.210*
	Total score	87.778±6.030	94.191±3.927	7.53	-9.052*

SD: Standard deviation. *: Significant as p< 0.001. t-value: Paired t-test.

Table 4
Comparison of gross motor functions between groups

Time of Measure	Variables	Groups (Mean±SD)		t-value	P-value
		Control	Study		
Pre-measure	Dimension D	85.688±8.972	87.606±7.025	-0.674	0.506
	Dimension E	83.069±8.448	87.981±5.450	-1.955	0.060
	Total score	84.028±8.313	87.778±6.030	-1.461	0.155
Post-measure	Dimension D	91.775±5.792	94.669±3.555	-1.703	0.099
	Dimension E	88.853±6.930	93.713±4.513	-2.350	0.026*
	Total score	89.988±5.943	94.191±3.927	-2.360	0.025*

SD: Standard deviation. *: Significant. t-value: Unpaired t-test.

Table 5
Comparison between and within groups regarding functional capacity

	Groups (Mean ± SD)		Paired t-test	
	Control	Study	t-value	P-value
Pre-measure	247.250±37.871	273.438±45.324	-1.774	0.086
Post-measure	264.031±43.449	303.603±58.319	-2.177	0.038*
% of Improvement	6.78	11.48		

Paired Samples Test	t-value	-4.579	-3.297	
	P-value	0.001*	0.005*	

SD: Standard deviation. *: Significant as p< 0.001. t-value: Paired t-test.

Discussion

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 spasticity (Kim, 2013). The results of the current study revealed improvement in gross motor functions and functional capacity in children who received circuit training as well as who received conventional training with a significant improvement for those who received circuit training. Treatment within the traditional approach is based on the developmental model in which therapists attempt to correct specific deficits and remediate underlying processes of movement to promote normalization, while circuit training program provides an interactive way to indulge in exercises stations which designed to maximize the potential of the children with CP, enhance their functional performance, maximize the transfer to normal routine and achieve gains in functional aspect of mobility which ensures the specificity of training principle (Barnes and Whinnery, 2002).

The reason why circuit training in the present study is more effective can be found in the motor behavior and neurophysiology literature. The interventions selected were according to daily activities to maximize the transfer to normal routine as the force and power generated by muscles is directly related to function being trained (Magill and Anderson, 2014). Such exercises have the potential to train aspects of motor performance such as coordination, balance, strength and physical conditioning (Buchner et al., 1996). Further, it has also been stated that once a minimum and task dependent level of strength is attained then factors such as task oriented skill becomes more important for improving functional performance. The exercises used in this study were designed to increase strength to the level required by the task rather than to maximize muscle force production (Schumway and Woolacott, 2000).

Improvement observed in the study group may be attributed to practicing of meaningful daily activities. There is evidence that intervention strategies that provide context relevant, meaningful engagement in activities and promote self-management as in circuit training program are more beneficial for skill acquisition than conventional exercises. In addition, it was demonstrated that increased treatment intensity using repetitive task oriented methods improve motor and functional recovery (Charles and Gorden, 2006). Carr and Shephard (1988) have suggested that training can be organized into a circuit with a series of work stations designed to strengthen the affected muscles can provide opportunity for task practice and provide an interactive way to indulge in exercises. They found that all the subjects in their experimental group demonstrated some improvement and performed their daily activities in a

confident manner which suggests that organization of exercise class into a circuit of workstations is an efficient way to provide training to a group of subjects.
The positive results of this study contribute to the fact that with daily properly tailored intervention, children with CP can be made independent in their everyday activities. Such programs that are designed to maximize the potential of the children with CP and enhance their functional performance may not only improve the quality of life but also reduces the dependency and the need for future institutionalized care. The results of the current study is supported by findings of Krigger, (2006) in a previous one-group pre-test, post-test, follow-up design study which stated that both circuit training and conventional physical therapy are found to be effective in improving functional recovery of extremities due to spastic CP. However, the improvement is more statistically significant in task circuit training group.

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 hence the principle of specificity in functional training by incorporating functional exercises for children spastic CP would increase their functional performance. Another finding of this study is that functional walk distance statistically improved after the administration of circuit training more than selected conventional physical therapy program. The magnitude of increase in the walk distance after 12 weeks of training was about 11.48% in study group which is a clinically significant improvement. However, Blundell et al., (2003) and Taylor (2009) claimed no improvement in cadence, walk distance nor the walk velocity with circuit training program in their study.

On the contrary, Pandey and Tyagi (2011) performed a controlled trail with a small sample of children with spastic CP, aged between 5 and 10 years, and found a significant increase in walking distance during 2-minute walk test and walking time during 10-minute walk test in the intervention group undergoing functional circuit strength training but not in the control group. However, these effects were not maintained in the follow-up session. As the sample size is small, 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.

Conclusion

Circuit training program is effective in improving functional performance of children with hemiplegic CP.

Implication for further studies

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 the total duration of therapy for more than 12 weeks.

Adverse events

There were no adverse events recorded throughout the study.

Declaration of interest

The authors report no declaration of interest.

Funding information

No grant from funding agencies in the public, commercial, or not-for-profit sectors was received in this study.

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