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INFLUENCE OF AEROBIC EXERCISE ON
INHIBITORY CONTROL OF EXECUTIVE
FUNCTION IN SPASTIC HEMIPLEGIC
CEREBRAL PALSY: A Randomized
Controlled Trial

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Abstract

Background: Inhibitory control of executive functions is one of the main specific cognitive impairments that affect children with cerebral palsy, cognitive skills begin to develop in infancy and continue till adolescence it changes across the lifespan of an individual and has great effect on their participation and quality of life. **Aim:** To investigate the influence of aerobic exercise on inhibitory control of executive functions in spastic hemiplegic cerebral palsy. **Methods:** Sixty children with spastic hemiplegic cerebral palsy were enrolled in this study and were assessed for eligibility. Their ages ranged from seven and eleven. Children were assigned randomly into two equal groups. Group (A) received AE in addition to selected physical therapy program and (B) treated with same selected physical therapy program only. The treatment was conducted for one hour, three times / week for three successful months. Eriksen flanker test and Stroop Color-Word test were used to assess inhibitory control of EF pre and post treatment. **Results:** Post treatment there was significant increase in accuracy in Eriksen flanker test and Stroop Color-Word test and decrease in reaction time (congruent and incongruent) only in study group, $P < 0.05$. **Conclusion:** Aerobic Exercises has significant effect on inhibitory control of executive functions in spastic hemiplegic cerebral palsy.

Key words: Hemiplegic cerebral palsy, inhibitory control of executive functions and aerobic exercise.

Implication and contribution: -

This article discuss how aerobic exercise improve inhibitory control of executive function which showed as significant increasing in Flanker/Stroop test accuracy and a significant decreasing in FRTc, FRTic, SRTc and SRTic only in study group this improvement will has great effect on children participation, social interactions and there quality of life.

Introduction:

Cerebral palsy (CP) is permanent disorders of developing movement and posture which led to reduced activity. It is the most common cause of physical disability that refers to non-progressive neurological condition occurs in infant brain [1]. Motor impairment frequently is secondary disturbances as communication, presence of epilepsy [2], and secondary musculoskeletal problems [3].Hemiplegic CP is a subtype in which one side of the body is involved. It affects about 1 in 1,300 live births [4]. It is characterized by a clinical pattern of unilateral motor impairment [5]. Severity motor impairment depends on the site and severity of brain [6].Early injury in brain had concomitantly on motor, function and cognitive [7].Cognitive ability is a mental process of acquiring knowledge and understanding through acquired knowledge and experience [8].

Executive function (EF) is comprise distinct yet highly interrelated components as cognitive flexibility [9].Because EF involved in arrangement of action and behavioral aspect of EF [10], such difficulty initiating new non routine actions, and a lack of impulse control [11].EF received considerable interest and are strong predictors of children's early school success and it includes intentional shifting/flexibility, working memory, and inhibitory control [12].

Inhibitory control is separable cognitive process by comprise construct of executive function and emerge only in middle to late childhood, with improvements ability to execute complex [13].

Aerobic exercise (AE) improves oxygen consumption by the body. Which consider activity uses large muscles. AE interpretation is continuous and rhythmic process led to heart and lungs work better [14].AE create changes and increase in oxygen saturation and cerebral blood flow [15]. AE training increase cerebral perfusion[16],metabolism [17], reduce in A β load [18], up-regulation of neurotrophins [17], and hippocampal neurogenesis [19].Exercises provide rise of serum calcium and might transport to activate rate limiting enzyme for catecholamine synthesis. Nor epinephrine and dopamine are neurotransmitters [20].AE is an efficient strategy to positively influence executive control during [21], and after exercise [22].

Subjects and methods:

A pretest-posttest randomized controlled study conducted in outpatient clinic in Faculty of Physical Therapy, Cairo University. Informed consent was provided for each child from their parents. The procedures followed were in accordance with the Institutional Ethical Committee Clearance of the Faculty of Physical Therapy Cairo University No: P.T. REC/012/002278. The study was registered on Clinicaltrial.gov and registration number was NCT04154566.

Subjects: Sixty children with spastic hemiplegic cerebral palsy were enrolled in this study and were assessed for eligibility. Their aged ranged from seven and eleven years, they were from both sexes, they have left side hemiplegic cerebral palsy and they were able to walk independently. All children were selected with score 28 or more according to pediatric symptom chick list that suggest presence of significance behavior and emotional problems. We excluded children with visual or auditory problems, children with history of drug intake that may affect the cognitive function, medically unstable children especially with cardiovascular disorders and uncooperative children.

Children assigned randomly into 2 equal groups. Group (A) study who received aerobic exercise in addition to selected physical therapy program. Group (B) control who received selected physical therapy program only. The treatment was conducted one hour, three times / weak for three successful months.

Materials for evaluation:

Eriksen Flanker test and Stroop Color-Word test were used to assess inhibitory control of EF pre and after treatment.

- 1) **Eriksen Flanker Test** has been widely examined inhibitory aspect of executive function [23]. The Flanker task consisted of 20 trials consisted of 2 trials with congruent reaction time (FRTc) or incongruent reaction time (FRTic) to certain visual stimuli. Congruent is a horizontally arranged array of arrows presented in the same direction. Incongruent trial have similar array of arrows, but the middle arrow displayed in the opposite direction. Children respond to direction of arrows by press RT or LT finger button quickly and accurately.

2) Stroop Color-Word Test using word color to measure selective attention and cognitive flexibility and most described measured to individual's capability to shift cognitive set [24]; to measure of cognitive inhibition or inhibit an over learned in favor one. Colors names illustrated and printed in conflicting ink and participants asked to respond the name and color of ink more word by pressing corresponding first letter for color if red press(r) button if yellow press (y) button if orange press (o) button if purple press (p) button if green press (g) button if blue press (b) button as quickly and accurately as possible. The Stroop test divided to 20 trials (two trial types) with normal congruent (SRTc) or incongruent reaction (SRTic) to certain visual. Normal trial was when color of the ink is the same color of the word and interfere trial the color of the ink not the same as the color of word.

Flow chart

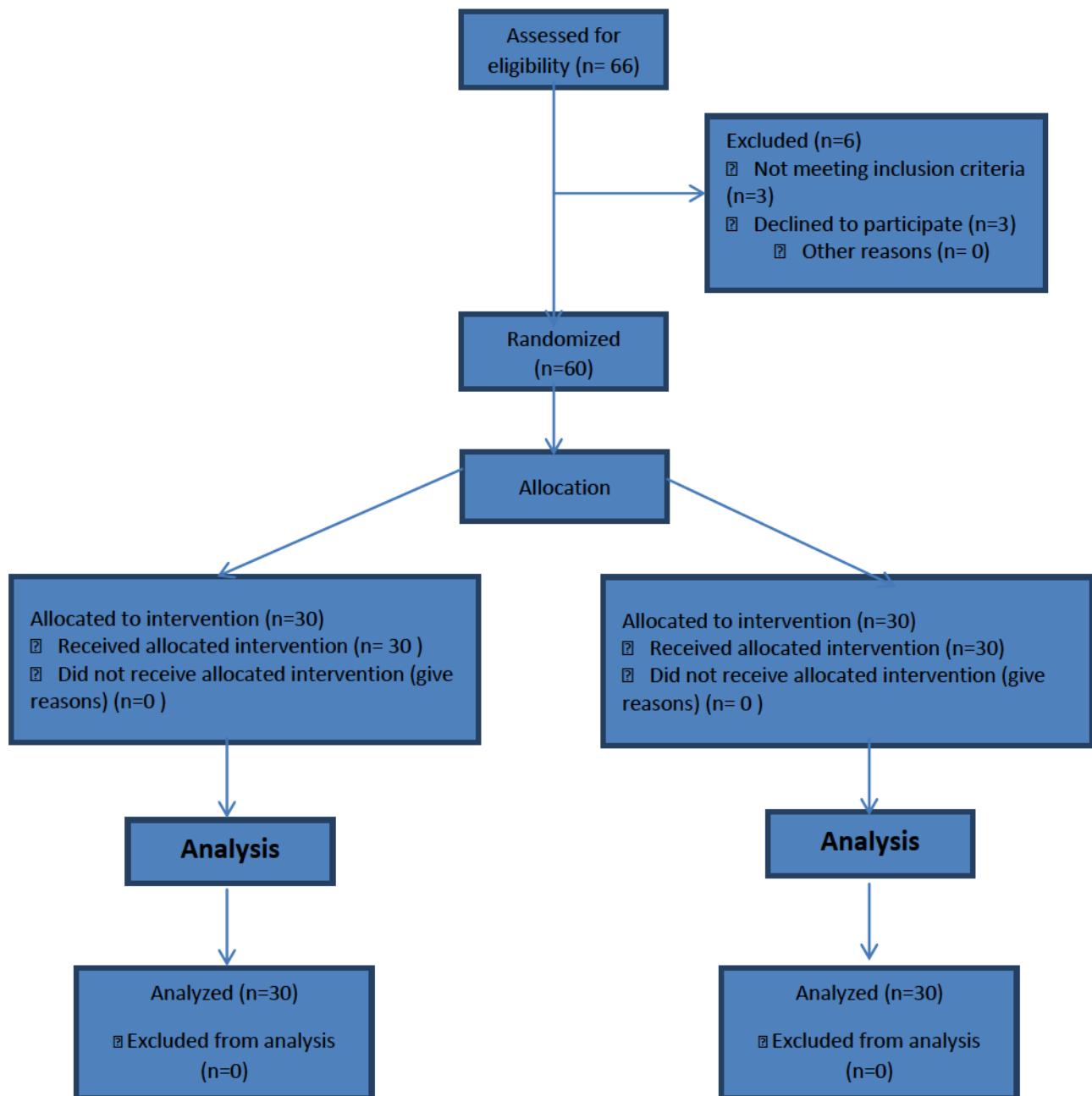


Fig 1, flow chart

Methods of Treatment

Group (A) which is the study group received 20 min. selected physical therapy program which contain strengthening exercises for upper limb and lower limb muscles, stretching exercises for elbow extensors, hand supinator, wrist extensors, knee extensors and ankle dorsiflexors, balancing exercises, coordination exercises and

gait training exercises in open environment. In addition to aerobic exercise on a bicycle ergometer for 40 min. Bicycle ergometer (**Monark Rehab trainer model 88E**) was used to train children in study group. It is a stationary bicycle with an ergometer (electronically braked) to measure the work done by the exerciser. Which equipped with electronic meter illustrated pedal revolutions/min, pedal revolutions and time function. It provides low-gain, safe, and effective cardiovascular exercise. This low-impact movement does not put much stress on joints.

Before starting the training procedure each child was instructed to wear comfortable training suit and shoes and to sit vertically on the bicycle ergometer seat with erect back. Extra strap was placed on child's feet to provide complete fixation on ergometer pedal. The exercise on bicycle was done under supervision of researcher to ensure correct and accurate application.

In the first week, children bicycled to tolerance at 40% to 50% max HR, and to 70% max HR in second week. AE Intensity was systematically increased for child to keep conditioning at 70%.max HR, (max HR =220-age) [25].First five min of each session dedicated to warming up exercise on bicycle in the form of slow increasing followed by active phase of exercise for 30 min., and cooling down for five min. with intensity and speed reduced gradually till resting heart rate [26].

Group (B) which was exposed only to same physical therapy program for one hour. Treatment was conducted one hour, three times / weak for three successful months.

Statistical analysis

For analysis of data in the present study, SPSS software version 21 used for analysis data. Descriptive statistics was used to identify the mean and standard deviation for each variable. Chi-square test was used to compare number and percentage of sex distribution between both groups. Paired t-test was used to compare variables pre and post -treatment within group. Unpaired t-test used determined variables pre and post -treatment between both groups. P- Value ≤ 0.05 was considered significant ($P \leq 0.05$).

Results:

Child's general characteristics:

The characteristic of children represented in (Table 1). There was no significant observation among different groups belong to age, grade and sex distribution.

Table (1): Characteristics of children:

		Study group (GA)	Control group (GB)	P-value
Age (years)		9.77±1.135	9.2±1.243	0.0703
Gender (N. (%))	Male	21 (70%)	17 (56.7%)	0.2839
	Female	9 (30%)	13 (43.3%)	
Grade (years)		4.77±1.135	4.2±1.243	0.0703

Flanker test:

Comparison of the mean values of (Flanker test accuracy, FRTc and FRTic) between both groups pre-treatment revealed no significant difference. Post- treatment; significant increasing was noted in Flanker test accuracy and a significant decreasing in FRTc and FRTic only in study group. The percent of improvement were (21.9%, 25.91% and 22.44%) respectively (**Table 2**).

Table (2): Intra- and inter-group comparison between mean values of Flanker test variables pre and post treatment in both groups:

Flanker test		Pre-treatment (Mean± SD)	Post-treatment (Mean± SD)	P- value
Flanker test accuracy	Study	73.83± 10.4	90± 10.91	0.0001**
	Control	78.5± 11.9	82± 10.88	0.0589
	P	0.1112	0.0061*	
Flanker test congruent reaction time (FRTc)	Study	1567± 369.2	1161± 291.7	0.0001**
	Control	1588± 438.6	1489± 509	0.0923
	P	0.8408	0.0033*	
Flanker test incongruent reaction time (FRTic)	Study	1827± 779.6	1417± 588.1	0.0104*
	Control	1847± 787.6	1792± 755.7	0.6164
	P	0.9213	0.036*	

SD: standard deviation, P-value: probability value, * Significant = P< 0.05.

Stroop test:

Comparison of the mean values of (Stroop test accuracy, SRTc and SRTic) between both groups pre-treatment revealed no significant difference. Post-treatment; there was a significant increase in Stroop test accuracy and a significant decrease in SRTc and SRTic only in study group. The percent of improvement were (18.9%, 24.88% and 11.97%) respectively (**Table3**).

Table (3): Intra- and inter-group comparison by Stroop test variables pre and post treatment in both groups:

Stroop test		Pre-treatment (Mean± SD)	Post-treatment (Mean± SD)	P- value
Stroop test accuracy	Study	70.17± 8.758	83.5± 11.15	0.0001**
	Control	73.17± 9.048	75.67± 12.37	0.1380
	P	0.1971	0.0126*	
Stroop test congruent reaction time (SRTc)	Study	2982± 992	2240± 947.7	0.0001**
	Control	2923± 895.5	2752± 911.1	0.1842
	P	0.8116	0.0373*	
Stroop test incongruent reaction time (SRTic)	Study	3007± 885.1	2647± 729.9	0.0102*
	Control	3118± 746.3	2990± 558.4	0.2187
	P	0.6011	0.0459*	

SD: standard deviation, P-value: probability value, * Significant = P< 0.05.

Discussion:

Children that was selected in this study have left side hemiplegic cerebral palsy that agreed with **Godefroy & Bogousslauky 2007** [27] who concluded that damage in right hemisphere, hemi-spatial neglect is the most frequent deficit where there is impaired or lost ability to react to or to process sensory stimuli in the hemispace opposite to the lesion side. This visuospatial perceptual deficits can affect different cognitive activities which show up as difficulty copying designs, making constructions, discriminating pattern of faces, selecting the correct sleeve and self-monitoring left side or covering the paretic shoulder.

The current study, selection of hemiplegic cerebral palsied children comes in agreement with **Bodimeade et al. [28]** who concluded that EF impairment is a central

feature of CP when compared EF in children with CP (mean age 11 y/o) to typically developing controls.

Using a bicycle ergometer related to safety was our foremost concern for the participants. The bicycles were powered by participants and easy which led to reduce fall risk that considered a prevalent problem.

The present study was revealed significant improvement of all measured variables of inhibitory control of EF after three successful months that agreed with **Renaud et al. 2010**[\[29\]](#) that found 12 weeks supervised exercise is associated with improving the attention.

Results of present study revealed significant improvement of all measured variables in study group (A) as there was significant increase in accuracy and significant decrease reaction time congruent and incongruent that means improvement of inhibitory control of EF this was attributed to AE.

The results of the present study proved that there was no significant improvement in all measured variables of Flanker test accuracy, FRTc and FRTic in the control group (B), while there was significant improvement in all measured variables of Flanker test accuracy, FRTc and FRTic in the study group (A) which might be to physiological effect of AE on brain and increases cerebral tissue oxygenation, blood flow. This result agreed with **Kluding et al., 2011** [\[30\]](#).

The improvement of EF after AEs may be due to activity in cortical areas (right medial frontal gyrus), superior frontal gyrus, and superior parietal lobe. It increases number of interconnections in frontal and parietal gray matter, and increases prefrontal and anterior cingulate plasticity in the aging brain with neurologically intact young adults that agreed with **(Colcombe and Kramer, 2004)**. [\[31\]](#).

The results of this study showed that there was significant changes in all measured variables Stroop test accuracy, SRTc and SRTic when comparing pre and post treatment variables between two groups in favor of the study group (A) this improvement comes in agreement with **Ainslie et al., (2008)** [\[32\]](#) who reported that AE increases oxygen consumption, reduces blood pressure and resting heart rate, also proved to promote angiogenesis and increase in capillary density.

Most studies supported greater improvements of EF after moderate to vigorous AE in typically developing (TD) child (**Verburgh et al., 2014**) [33].

Improvements EF after sustained AEs (over months) is required for cognitive improvement this comes in agreement with **Masley 2009**. [34].

Previous studies have reported improved performance on a variety of cognitive task categories, information processing, memory, and executive function, after a single bout of AE **Hillman et al.,2009**[35].

The significant improvement in post treatment Stroop test accuracy, SRTc and SRTic is supported by **Etnier and Chang 2009**[36] that reported improvement in Stroop Test after acute moderate-intensity strength exercise (10 sets of 10 repetitions for six exercises) session in healthy middle-aged (49 ± 9 years) adults.

Benefits of physical exercise in promoting increased EF and consistent with similar to studies of **Chang et al., 2014**[37] and **Pan et al., 2015** [38].

Our results take the opposite trend of **Ploughman et al., (2008)** [39] that noted the treadmill exercise have not led to improve in cognitive function. Discrepancy between present and **Ploughman et al.** [39] might be due to small size and duration of physical therapy of **Ploughman et al.** [39] study. It was assumed that sustained AE (over months) is required for cognitive improvement (**Masley, 2009**). [37].

Data also contradicted with **Correia et al., (2010)** [40] who found acute strengthening exercises not have significant alterations in levels of brain-derived neurotrophic factor plasma concentrations. The discrepancy of results between two studies may be attributed to the type of exercise program.

Conclusion: AE has significant effect on inhibitory control of executive functions in spastic hemiplegic cerebral palsy children.

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