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The Impact of aerobic exercises on executive function on primary school aged children

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Abstract : The aim of this study was to compare the effect of acute aerobic exercises on selected executive functions. A counter-balanced, crossover, randomized trial was performed. Subjects were thirty two child (18 boys and 14 girls).
6-11 year old with a mean (±SD)= 9.56 ± 1.34 years who were free of any cognitive or learning disabilities . they were randomly submitted to two different conditions: (1) aerobic exercise, the aerobic condition included 15 minutes of jogging on a pediatric trampoline at 60% of target heart rate (2) control condition (resting session). included 15 minutes of seating without any physical or mental activity before and after each condition, executive functions were measured by the Tower of Hanoi . Results: indicated that there was significant improvement in solving time of tower of Hanoi in the exercise group and no significant change in control group(resting session). conclusion; these findings suggest that acute bouts of aerobic exercise on trampoline has positive effect on executive functions(problem solving and planning) on primary school aged children.
Keywords : executive functions, aerobic exercise, primary school aged children.

Introduction

Early development of children has important implications for a number of outcomes throughout life. the transition from early childhood environments to formal schooling, where children's executive functions are needed to be successful in the classroom is an important area ,the ability to sit still in classrooms, pay attention to teachers, problem solve, and be goal directive Are the behavioral aspect of executive function[1].

The executive function hypothesis was proposed based on evidence that aerobic exercise selectively cause increases in prefrontal cortex activity and improves older adults' performance on executive function tasks[2]. The term (executive functions) is a term comprising a wide range of cognitive processes which include resistance to interference, utilization of feedback, multitasking, cognitive flexibility, and the ability to deal with novelty, verbal reasoning, problem-solving, planning, sequencing and the ability to sustain attention[3].

Physical activity has many benefits for children such as reduced risk of disease and improved physical fitness[4], physical activity, and in particular cardiovascular exercise, promotes health and effective functioning and Executive function appears more sensitive than other aspects of cognition to aerobic exercise training [5].

In the several studies using event-related brain potential (ERPs) to examining effect of acute exercise on the P3 have observed increased amplitude that reflect allocation of attention resources[6] and shorter latency of P3 that reflect the person's evaluation speed and classification skill[7]. Following single, acute bouts of moderately-intense exercise the findings suggest an exercise-induced facilitation of attentional resource allocation and stimulus evaluation speed during tasks that requiring the cognitive control of inhibition[7].

Etnier and Chang[8] considered the various definitions of executive function In addition, they identified the most frequently used measures of executive function based on neuropsychological reviews and clinical investigations; the top four were the Wisconsin Card Sorting Test (WCST), the Stroop Test,Verbal Fluency, and the Tower of Hanoi/Tower of London Task (TOL Task).

In this study we will examine the problem solving and planning with Tower of Hanoi .Tower of Hanoi is a task for complex problem-solving that has become a popular measure of the executive function construct, which has been defined as the ability to maintain an appropriate problem solving set for attainment of a future goal [9]**.** This task has demonstrated sensitivity to prefrontal lobe function and dysfunction[10]**.**

Method:

Subjects:

A homogenous sample , of Thirty two healthy primary school children aged 6–11 year (18 boys14 girls, with a mean (±SD)= 9.56 ± 1.34 years) was participated in the study, the following inclusion criteria were required (a) subjects don't take medication (b) subjects are free of cardiovascular-related disease, psychiatric disorders, and neurological abnormalities (c) subjects must be able to perform physical exercises (d) subjects must have normal or corrected-to-normal vision; and don't have any auditory problems(e) subjects were required to display right hand dominance.

Study Design:

This is a counterbalanced crossover trial . the subjects randomly performed two sessions separated by two days each. All sessions were performed between 2 and 6 p.m. The interventions were (1) aerobic exercise session, (2) resting session. Executive functions were measured by the Tower of Hanoi test . in order to compare the effects of exercise versus non exercise on executive function. The subjects were asked to perform sets of Tower of Hanoi before and after exercise session (i.e., 15 minutes of jumping on trampoline) and also asked to perform the same to sets of Tower of Hanoi test before and after nonexercise (i.e., 15 minutes of resting period)on a different day and this would eliminate any practice effects due to extra practices on the Tower of Hanoi

Materials:

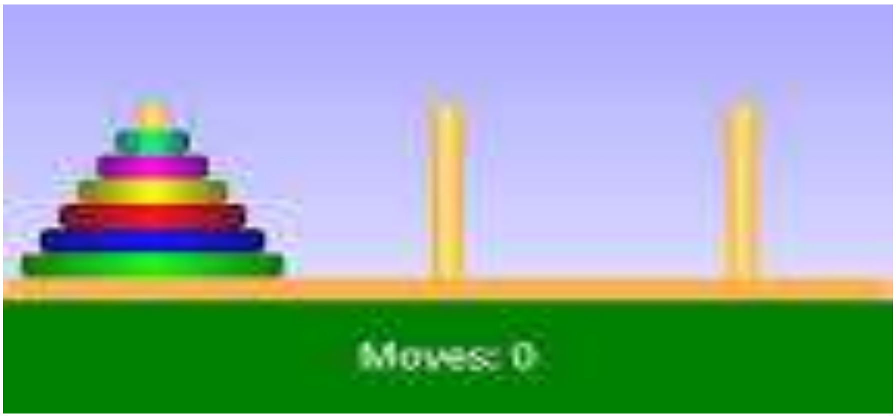
Trampoline:

Trampoline is a device consisting of a piece of tau t, strong fabric stretched over a steel frame using many coiled springs The fabric that users bounce on (commonly known as the "bounce mat" or "trampoline bed") is not elastic itself; the elasticity is provided by the springs that connect it to the frame , it 50 cm apart from ground ,foam covered the frame and edges and columns of the trampoline and with safety nets surrounding columns ,so the risk of falling off the trampoline is reduced.

Tower of Hanoi (TOH):

The TOH task has been termed a disk-transfer task, that is, in a series of different problems, the object is to move the disks from a start state to a goal state in the fewest number of moves as possible while following a specified set of rules the (TOH) A wood apparatus (14.76 cm x 5.5 cm) **Fig(1)** was used consisting of 8 blocks varying in color and size. The stopwatch went off as the first movement started and was stopped when the last block was placed on the tower (s).

There are three rules that dictate moves that can and cannot be made: (1) only one disk may be moved at a time; (2) disks may be moved only to another peg (e.g., they cannot be placed onto the table or held in the hand while another disk is moved); and (3) a disk may never be placed on top of a disk smaller than itself **(Pennington et al, [11])** and we measure time for solving tower of Hanoi in each trial.



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Fig(1): Tower of Hanoi.

Procedure:

At first we should measure target heart rate for each child so the participants were outfitted with a heart rate monitor and their resting heart rate (HR rest) was recorded after 5 minutes of seated rest and then measure maximum heart rate(HRmax) by the equation "208 - (0.7 x age)" this equation was valid for the children, [12] then we measure intensity of exercise with the Karvonen formula to calculate Target Heart Rate (THR) THR = ((HR max − HR rest) × % Intensity) + HR rest [13].

Participants were counter -balanced into two different conditions , such that half of the participants received the resting session the first day and the aerobic exercise session on the second day. The other half received aerobic exercise session on the first day and the resting session on the second day. The resting session consisted of 15 minutes of seated rest, during which time conversation was kept to a minimum. Before and after the seated rest period, participants were administrated of the Tower of Hanoi test.

The aerobic exercise session consisted of 15 minutes of aerobic exercise on a child trampoline jogging at 60% of their estimated maximum heart rate and tests were performed before exercise and following the completion of the acute exercise bout once participant heart rate (HR) returned to within their pre-exercise levels (15 minutes post exercise) tower of Hanoi test was performed.

Statistical Analysis:

Results are expressed as mean ± standard deviation or number (%). Test of normality, Kolmogorov-Smirnov test, was used to measure the distribution of data. Accordingly, comparison between variables in the two groups was performed using Mann Whitney test whenever it was appropriate. Comparison between variables measured before and after session in the same group was performed using Wilcoxon Signed Ranks test. Percent change was calculated from equation:- [(post-pre)/pre] x 100 or vice versa whenever it was appropriate. Statistical Package for Social Sciences (SPSS) computer program (version 19 windows) was used for data analysis. P value ≤ 0.05 was considered significant .

Results:

I- Physical (general) characteristics of the children:

The age of the studied group ranged from 6-11 years with a mean (±SD)= 9.56 ± 1.34 years. As regards, sex distribution, 13 (40.6%) girls and 19 (59.4%) boys were enrolled in this study. Their grade ranged from 1-6 with a mean (SD)= 4.59 ± 1.34 (Table1).

Table1 : General characteristics of the subjects.

Grade	Gender		Age(years)
(Min-max) 1-6	Female	Male	(Min-max) 6-11
(Mean ±SD) 4.59±1.34	13 (40.6%)	19 (59.4%)	(Mean±SD) 9.56±1.34

Data are expressed as mean ± SD or number (%).
NS= p> 0.05= not significant.

Tower of Hanoi :

A- Within group comparison (intra group comparison):

In control (resting session) group, there was no statistical significant difference in the value of the time of Tower of Hanoi measured after session (0.97 ± 0.76) and its corresponding value measured before session (0.98 ± 0.75) with $Z^{\#}$ value = -0.023 and p value= 0.982 (Table 2,Fig 2).

In the exercise session group, there was a statistical significant (decrease) in the value of time of Tower of Hanoi measured after session (0.92 ± 0.75) when compared with its corresponding value measured before session (1.44 ± 1.05) with $Z^{\#}$ value = -3.731 and p value = 0.001 (Table 2 ,Fig 2).

The percent decrease in the mean value of the time of Tower of Hanoi in control (resting session) group was 1.02% while in the exercise session group the percent increase was 36.11% (Table 2 ,Fig 3).

B-Between groups comparison (inter group comparison):

There was a statistical significant decrease in the mean value of difference in time of Tower of Hanoi in exercise session group (0.52 ± 0.76) when compared with their corresponding value in control (resting session) group (0.01 ± 0.51) with $Z^{\#\#}$ value =-3.304 and p value = 0.001 (Table 2).

Table 2: Intra- and inter-group comparison between values of Tower of Hanoi in the two studied groups measured before and after session.

	Before session	**After session**	**Difference**	**% change**	**$Z^{\#}$ value**	**p value**
Control(resting session) gr. (n= 32)	0.98 ± 0.75	0.97± 0.76	0.01 ± 0.51	1.02 ↓↓	-0.023	0.982 (NS)
Exercise session gr. (n= 32)	1.44 ± 1.05	0.92± 0.75	0.52 ± 0.76	36.11 ↓↓	-3.731	0.001 (S)
$Z^{\#\#}$ value	---	---	-3.304			
P value	---	---	0.001 (S)			

Data are expressed as mean ± SD.
NS= p> 0.05= not significant.
S= p< 0.05= significant.
$Z^{\#}$= Willcoxon Signed Rank test.
$Z^{\#\#}$= Mann Whitney test.

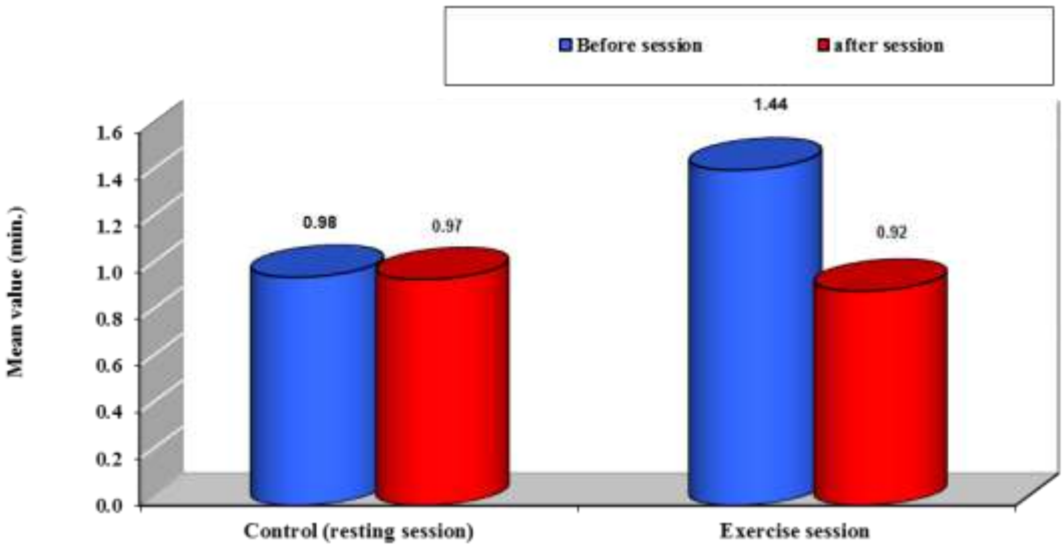

Fig.2 : Mean values of Tower of Hanoi in the two groups.

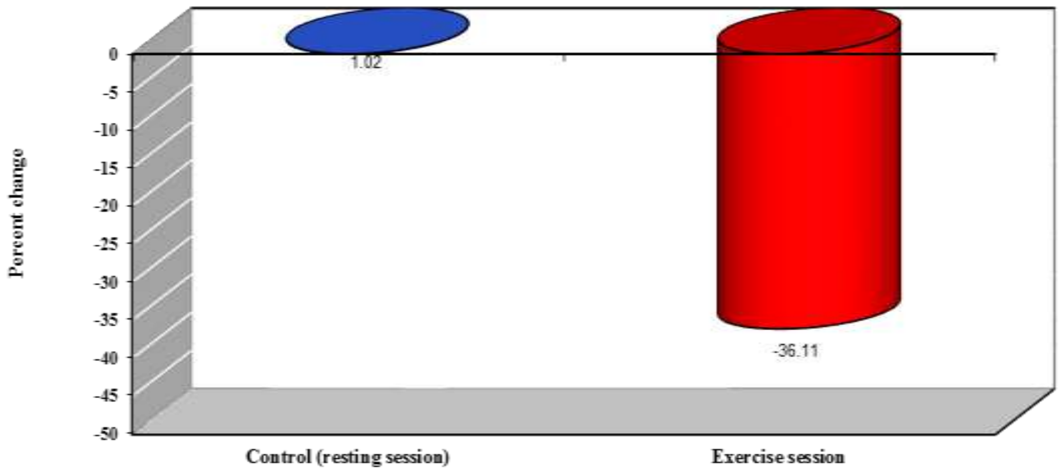

Fig 3. : Percent change in time of Tower of HANOI in the two groups Discussion:

There was a significant decrease in the time for solving Tower of Hanoi in exercise session group and no significant decrease on control (resting session) group , and There was a statistical significant decrease in the mean value of difference in time of Tower of Hanoi in exercise session group when compared with their corresponding value in control (resting session) group, there is a consistent body of literature showing that improving executive function after moderate-intensity exercise in participants from young adults to preadolescents [14,15,16,17,18]**.** The result of the current study is consistent with the study by C. Córdova [19] that compare the effect of acute exercise performed close to anaerobic threshold (AT) at different intensities on the abilities requiring control of executive functions or alertness in physically active subjects. Forty-eight physically active subjects were assigned to one of four groups by drawing lots: control group without exercise or trial groups with exercise performed at 60, 90, or 110% of AT (watts) and submitted to five cognitive tests before and after exercise. Acute exercise executed at 90% of AT resulted in significant ($P < 0.05$, ANOVA) improvement in the performance of executive functions when compared to control in 3 of 5 tests verbal fluency, Tower of Hanoi test, and Trail Making test B [19] **.**

Change et al [20] was examined the effects of an acute bout of moderate to vigorous intensity aerobic exercise on the executive functions of planning and problem solving assessed using a Tower of London Task (TOL Task). Forty-two participants were randomly assigned into either exercise or control group, and performed the TOL Task, before and immediately following exercise or a control treatment. The exercise group performed 30 min of exercise on a stationary cycle at moderate to vigorous intensity while the control group read for the same length of time. Results indicated that the exercise group achieved improvements in TOL Task scores reflecting the quality of planning and problem solving, but not in those reflecting rule adherence and performance speed**.** Other studies have reported that exercise have no significant positive effects on executive function,and some have even found adverse effects [21,22]**.** For example, study by Pontifex and Hillman (2007) in young adults 18-24 years of age showed that moderate exercise (60% HR max) interfered with executive function, resulting in impaired inhibitory control [23]. These findings indicate that an acute bout of aerobic exercise lead to immediate neurochemical changes[24]**.**

There was also up-regulation of growth factors (BDNF)may underlie the priming effects. A study with humans further suggests that exercise has an immediate priming effect [25]**.** Here, learning was superior following a short, intense running effort as compared to a longer, moderately intense run or period of relaxation. This behavioral effect was complemented by increase mono-amines (dopamine, norepinephrine, and epinephrine) and levels of BDNF and that predicted retention of the learned material[26]**.**

Hillman et al. [15] reported that acute treadmill walking results in enhanced P3 amplitude in preadolescent children, that reflecting increased allocation of attention. Hence, exercise not only induces long-lasting morphological changes over time but stimulates immediate chemical changes leading to an increased state of arousal that may enhance cognitive performance**.**

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