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Effect of regular swimming exercise on cognition in normal children

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Abstract
Background: Physical exercise (PE) determines positive biological and psychological effects that affect the brain and the cognitive functioning and promote a condition of wellbeing.
Objectives: Purpose of the study is to determine if swimming aerobic exercise has an effect on cognition (reasoning, memory, attention, perception and coordination) in primary school children.
Subjects: One hundred twenty-eight children from both sexes ranged from seven to ten years were participated in this study.
Methods: Children were divided in two equal groups (sixty-four children in each group). Group (A); They were not involved in any aerobic exercises, Group (B); They were on regular swimming exercises in Wadi Degla Sporting club in El Maadi (60 minutes – 3 times per week for training period of three months). Cognition was evaluated by Cogni Fit brain training program (Initial cognitive assessment); It is a mobile application program that was used to assess cognitive functions.
Results: The obtained results showed statistically significant difference between two groups regarding total score and individual score of each tested cognitive ability except for perception using Cogni Fit.

Keywords: Cognition, aerobic exercise, cognifit

Introduction

Many studies found that physical exercise (PE) has a positive effect on executive control, planning, scheduling, coordination, inhibition and working memory. Studies on behavior and functioning of an aging brain revealed that exercise has a positive effect on performance of tasks regulated by the hippocampus. Especially aerobic or intense fitness accounts for more positive results in cognitive functioning [1]. Swimming is an exercise modality that is highly suitable for health promotion and disease prevention, and is one of the most popular, most practiced and most recommended forms of physical activity. Exercise recommendations involving swimming have been generated primarily from unjustified extrapolation of the data from other modes of exercise (e.g., walking and cycling) [2]. Swimming is an attractive form of exercise, as it is easily accessible, inexpensive and isotonic. Because it does not involve bearing of body weight, due to the buoyancy of water, compressive joint forces are lower and, as a consequence, adverse impact on the musculoskeletal system as well as injuries are rare [3]. In contrast to the public perception that swimming is a 'minor' form of exercise, it is one of the most popular and most practiced forms of physical activity. In the US and most industrialized countries, swimming is the second most popular dynamic exercise modality, second only to walking [4].

Cognitive performance is typically conceptualized in terms of domains of functioning. These domains are hierarchical in nature, with the bottom referring to more basic sensory and perceptual processes and the top referring to elements of executive functioning and cognitive control. Domains are not independent of each other and executive functioning exerts control over the utilization of more basic processes [5]. There are several ways to conceptualize cognitive ability domains. These include classification by the general process involved, such as memory, attention, language, or executive functioning. Other strategies are based on regional brain functions, derived on the basis of lesion studies, which characterize functions as originating from the frontal lobe, temporal lobe, parietal lobe, hippocampus, or other structures [6]. Sensation refers to the ability of a person to detect a stimulus that occurs in one of the five sensory modalities. Thus, tests of intactness of visual, auditory, tactile, gustatory, and olfactory senses fall into this area [7]. Attention and concentration are a multifaceted construct and is generally divided into two global subdomains: selective attention and sustained attention (or vigilance) [8]. Memory functioning is the most complex and multifaceted of cognitive domains. There are multiple subdomains and formal assessments have been developed for most of them including working memory, Procedural memory and Prospective memory [9]. Executive functioning This cognitive domain is also referred to commonly as reasoning and problem solving. The global concept of executive functioning is the set of processes that manifest control over other component cognitive abilities, such that cognitive resources can be effectively utilized to solve problems efficiently and plan for the future [10]. Processing speed refers to cognitive processing assessments that require rapid performance of tasks that range from very simple to complex [11].

The Cogni Fit TM assessment battery is an online cognitive assessment and training tool to measure different cognitive abilities through the use of a computer, tablet or smartphone. The overall evaluation of the Cogni Fit TM assessment battery has been validated against several major neuropsychological tests, including Raven's Progressive Matrices, the Cambridge Neuropsychological Test Automated Battery, and the Wisconsin Card Sorting Test [12]. The reliability and validity of the Cogni Fit TM was also demonstrated in a sample data of 500 participants derived from various studies with an internal consistency of.70 (Cronbach's alpha), and test-retest reliability of.80 correlation coefficient [13]. Gigler *et al* (2013) stated that,

other studies have confidently used the Cogni Fit TM assessment battery to assess levels of cognitive functioning [14].

Subjects, Materials, and Methods

Subjects: One hundred and twenty-eight normal children ranged from seven to ten years voluntary participated in the present study. The participation was voluntary. All participated children were divided using simple random sampling into two equal groups (64 children in each group). Group (A): It included 64 children of both sexes, they were not involved or participated in regular swimming exercises or any other exercises. Group (B): It included 64 children of both sexes and who were involved in regular swimming exercises in Wadi Degla Sporting club in El Maadi (60 minutes – 3 times per week for training period for three months) [15].

Ethical consideration: The current study protocol obtained approval of the Research Ethical Committee at the Faculty of Physical Therapy, Cairo University (No. P.T.REC/012/003442).

Consenting to participation: A detailed explanation of the study significance and procedures was provided to all participants and their /caregivers, and signed consent was obtained from them prior to inclusion.

Evaluation procedures (Cogni Fit brain training program)

It is a mobile application program was used to assess cognitive functions for all children in both groups. It includes several programs. Each program consists of a number of procedures. All the procedures have varying levels of difficulty in the evaluation of multiple cognitive abilities. Cogni Fit consists of multiple assessments programs, some of them measure global cognitive functions and others measure special domain of cognition for each program. The program of the initial cognitive assessment was used in this study. It has seven tasks assessing five cognitive abilities: reasoning, memory, attention, coordination and perception. At the end of the assessment, a report was downloaded for each child that contain scoring of each cognitive ability and global score. [14].

Statistical Analysis

Data was analyzed using IBM© SPSS© Statistics version 23 (IBM© Corp., Armonk, NY, USA), MedCalc© version 15 (MedCalc© Software bvba, Ostend, Belgium).

Normality of numerical data distribution was examined using the D'Agostino-Pearson test. Normally distributed numerical variables were presented as mean ± SD and intergroup differences were compared using the independent samples t test. P-value <0.05 was considered statistically significant.

Results

I) Descriptive Data

Group I (64 children): 28 boys (43.8%) & 36 girls (56.2%) with mean age 8.45+/-1.066.

Group II (64 children): 21 boys (32.8 %) & 43 girls (67.2 %) with mean age 8.42+/-1.126. (Table 1).

Table 1: Gender and mean of age for Boys and Girls of two groups

Groups	Gender			Age (yrs) Mean ± SD	t	P value
		N	Age (yrs) Mean ± SD			
Group I (n 64)	Boys	28	8.39 ± 1.166	8.45 ± 1.126	0.161	0.872 (NS)
	Girls	36	8.50 ± 1.108			
Group II (n 64)	Boys	21	8.67 ± 1.081	8.42 ± 1.066		
	Girls	43	8.30 ± 1.017			

II) Comparison of the results of initial Cogni Fit training program between the 2 groups:

Initial cognition program results were measured automatically by the program. Total score was out of 800. Reasoning, memory, attention, coordination and perception scores was out of 800 for each. Table (2)

1. Over All Score: The mean ±SD of Over All Score in two groups were 400.48±74.23 (group I) and 463.97±69.35 (group II). There was a high statistically significant difference between the two groups (P<0.0001).
2. Reasoning The mean ± SD of reasoning in two groups were 332.22±137.71 (group I) and 434.53±143.99 (group II). There was a high statistically significant difference between the two groups (P<0.0001).
3. Memory: The mean ± SD of memory in two groups were 423.23±156.77 (group I) and 490.98±115.63 (group II). There was a statistically significant difference between the two groups (P<0.05).
4. Attention: The mean ± SD of attention in two groups were 299.98±120.91 (group I) and 402.3±143.84 (group II). There was a high statistically significant difference between the two groups (P<0.0001).
5. Coordination The mean ± SD of coordination in two groups were 512.44±115.76 (group I) and 562.72±102.24 (group II). There was a statistically significant difference between the two groups (P<0.05).
6. Perception The mean ± SD of perception in two groups were 437.95±87.20 (group I) and 452.34±80.69 (group II). There was no statistically significant difference between the two groups (P>0.05).

Table 2: Independent Samples Test of Cogni Fit Profile in Group I and Group II

Groups		Mean ± SD	t	df	Sig. (2tailed)
Over All Score	Group I	400.48±74.23	-5.00	126	0.000**
	Group II	463.97±69.35			
Reasoning	Group I	332.22±137.71	-4.11	126	0.000**
	Group II	434.53±143.99			
Memory	Group I	423.23±156.77	-2.78	126	0.01*
	Group II	490.98±115.63			
Attention	Group I	299.98±120.91	-4.36	126	0.000**
	Group II	402.30±143.84			

Coordination	Group I	412.44±115.76	-2.60	126	0.01*
	Group II	462.72±102.24			
Perception	Group I	437.95±87.20	-0.97	126	0.33
	Group II	452.34±80.69			

Discussion

In the present study participants completed an online game intended to assess the following cognitive areas: reasoning, memory, attention, coordination and perception. Each of these five cognitive areas were comprised of various cognitive functions. These various functions are embedded in the different tasks of the online game.

Mean and individual scores were calculated automatically by the program and results were compared between the 2 groups. The results showed a high statistically significant difference between the two groups ($P<0.0001$) regarding overall score, reasoning and attention. The results showed a statistically significant difference between the two groups ($P<0.05$) regarding memory and coordination. While the results showed no statistically significant difference between the two groups ($P>0.05$) regarding perception.

These finding was supported by Winter *et al* (2007) who found that short bouts of exercise directly improve learning. Although the ages of participants (age 19-22) in Winter *et al*.'s (2007) study differed from the ages of participants in the present study, Winter *et al*.'s (2007) results offered strong evidence for an increase in cognition after exercising. In their study they found that participants who engaged in two short intense three-minute sprints improved their learning with 20% compared to participants in a sedentary or moderate exercise condition [16].

Our results were compatible with a study done by (Stigter A, 2020) that was comparing between 3 groups of the same age group of this study, group I (on moderate exercise), group II (on vigorous exercise) and group III (on no exercise) that stated that [17]: Moderate and vigorous exercise increased cognitive functioning compared to the no exercise condition which did not increase cognitive functioning. A significant main effect of time (pre- and post) on cognitive functioning, was observed accounting for 17.2% of the increase in cognitive functioning. Results showed an increase of memory for moderate and vigorous exercise compared to no increase for the no exercise condition. A non-significant main effect of time (pre- and post) on memory was observed. Results showed an increase of attention for and vigorous exercise compared to a decline for the no exercise condition. A non-significant main effect on attention for both times were observed indicating that only 1% of the increase in memory was explained by time or exercising. Results showed an increase of response time for moderate and vigorous exercise compared to a decline for the no exercise condition. A non-significant main effect of time, $p > .05$ indicating only a very small percentage contributing to increase of response time. Results furthermore revealed that exercising did not have a significant effect on processing speed. In fact, moderate exercise had a negative effect on processing speed compared to a small positive effect of vigorous and no exercise [17].

This study findings were furthermore supported by Hillman *et al* (2009). Their study results indicated that exercise increases cognitive functioning as well as attention. More specifically, Hillman *et al*.'s results found a larger effect (SE = 0.80) on attention following short bouts of exercise which was in line with findings in the current study where a large effect size (SE = 0.61) was observed after vigorous exercising compared to a medium effect size (SE=0.38) after moderate exercising. Hillman *et al*. (2009) further indicated that these effects are especially true for the preadolescent population similar in age to the participants in the present study [18].

A study by Geertsen *et al* (2016) revealed some interesting findings on attention and working memory. Although the researchers were primarily interested in finding associations between motor skills, exercise and cognitive functions and correlations with performance in mathematics and reading, they found a positive association between a leisure form of exercising and increased semantic memory as well as an association between more intense exercise and increased working memory and attention. Moreover, their findings indicated that performance in mathematics (ES = 0.10) and reading comprehension (ES = 0.18) increased significantly for participants in the intense exercise condition as well as for participants in the organized leisure sports (ES = 0.87; ES = 1.59) [19]. These results are supporting the findings in the present study as they can be used to inform parents and educators about the positive effects of exercise on cognitive functioning in school-age children and adolescents.

As the present study predicted, support was found for swimming exercise to have a larger effect on cognitive functions compared to no aerobic exercise form.

Limitations

- The research lasted for a long duration as it was conducted at the time of COVID 19 pandemic hindering the collection of subjects.
- The subjects were collected while they were already in swimming training program, so pre and post comparison could not be done in group II of the study.

Recommendations

- The children should be encouraged to participate in regular swimming exercise to increase their cognitive abilities.
- Using mobile applications to assess cognitive abilities of children as it is an easy and available tool.

Conclusion

From the obtained results of this study, regular swimming exercise has beneficial effect on cognitive abilities (reasoning, memory, attention, perception and coordination) in normal children using Cogni Fit.

Source of Funding

This study had not received any financial support.

Conflict of Interests

The authors declared that there is no conflict of interest.

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