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Relation between Executive Function Domains and Pulmonary Functions in Egyptian School Children

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Abstract:Background: The irreversible alterations in pulmonary functioning have serious implications. The improvement of cognitive and executive processes may be essential therapeutic objectives since they can directly affect children's functioning abilities and quality of life.

Objectives: The purpose of this study was to find out if there is a relation between executive function domains and pulmonary functions in Egyptian school-aged children.

Methods: An observational cross-sectional (correlational) study including 240 school aged children of both sexes, with age ranged from 8-12 years. working memory, inhibitory control, and cognitive flexibility (executive function domains) were evaluated using the Tower of Hanoi, Eriksen flanker test and Trail-making test B respectively. Moreover, pulmonary functions have been investigated through (forced vital capacity (FVC), forced expiratory volume in one second (FEV1), peak expiratory flow rate (PEFR), and FEV1/FVC were measured by the spirometer.

Results: There was a significant correlation between all measurable pulmonary function tests (FVC, FEV1, PEF, and FEV1/FVC) andexecutive function domains (working memory, inhibitory control and cognitive flexibility).

Conclusion: There was a correlation between pulmonary functions and executive functions in Egyptian school children. pulmonary rehabilitation activities can be used by physical therapists to help children with their executive function.

Keywords:*Working memory, Inhibitory control, Cognitive flexibility, Executive functions, Pulmonary functions, School Children.*

Introduction

The ability of the lungs to support breathing is referred to as respiratory function. When breathing, oxygen enters the lungs and flows to the bloodstream, which carries it to the body's tissues. The waste product carbon dioxide is produced by the body's tissues and is exhaled out of the lungs. Pulmonary function tests are a variety of examinations used to assess lung or pulmonary function (PFTs) [1]. A series of tests known as pulmonary function tests are used to evaluate how well the lungs function. This involves breathing capacity and the effectiveness of the lungs' ability to supply oxygen to the body's other organs. [2]. Peak expiratory flow rate (PEFR), forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and the ratio of the two volumes (FEV1/FVC) are among these tests. A spirometer could be used to take these measurements [3]. Measures of lung function such as lung volume, capacity, flow rates, and gas exchange are objectively and quantitatively provided by pulmonary function tests (PFTs). They are used to assess the risks associated with surgery, monitor the effects of pharmacological, occupational, and environmental exposures, evaluate disorders affecting the heart and lungs, and support pre-employment or insurance evaluations [4].Spirometric examination is the most prevalent type of PFTs [5].

The three primary domains of executive function include working memory, inhibitory control, and cognitive flexibility. Neural networks involving the prefrontal cortex are crucial for executive function (EF). Individual variances in EF are becoming more widely acknowledged as a major indicator of long-term consequences related to social and cognitive development [6]. Studies indicate that elements that are both proximal and distal to development—such as sleep, parental care, language, society, financial status, and gene-environment interactions—have an impact on EF [7]. The word "executive function" (EF) refers to a broad category of more complex processes, including working memory, inhibitory control, and cognitive flexibility, that control behavioral goals and adaptability to unfamiliar, complicated, or unclear circumstances [8].

Childhood executive function deficiencies are prevalent at all phases of development in children irrespective of their neurodevelopmental problems, and research has demonstrated that they adversely influence educational, emotional, social and adaptability later in life [9].

Working memory is in charge of actively managing, mentally preserving, and modifying information [10]. Inhibition of prepotent responses, or external and internal interference, and deliberate focus, or the capacity to dismiss unimportant data, are the two mental processes that make up inhibitory control[11]. Cognitive flexibility is the capacity to transition between duties, activities, or conceptual frameworks quickly and effectively [12].

Participants

The cross-sectional (correlational) study's inclusion criteria were met by 240 children. They were selected from governmental schools of Cairo. The participating children's inclusion criteria included selecting an age range between 8 -12 years, and have no learning disabilities or cardiopulmonary diseases. Their intelligence quotient not less than 75% according to the Raven's colored progressive matrices test. According to the exclusion criteria, it included children who had a history of neurological or chronic illnesses, psychological problems, obvious musculoskeletal issues, visual or auditory deficiencies, obvious motor development complications, or who had taken any medications that might have impacted their level of arousal and awareness. All parents of children signed an informed consent form.

Methods

Children were assessed using the following: -

Questionnaire: Including personal information such as the child's name, age, height, weight, gender, address, school grade, parents phone number, the parent's employment status and educational level.

Raven's colored Progressive Matrices test (RCPM):

The RCPM is a “culture-free” and nonverbal test, it is not influenced by cultural factors and can be used in a variety of environments and cultures. It consists of visually presented, geometric-analogy-like problems in which a matrix of geometric figures is presented with one entry missing. It was administered individually, without a time limit, in the book format, according to Raven’s procedure [13].

For evaluation of executive functions:

I-Tower of Hanoi (TOH): It is a valid performance assessment tool for determining executive function. Working memory is one of the complicated EFs that it is used to tested by TOH. Discs are threaded on a peg in descending size from bottom to top in order to play the game. Start with every disk on a single peg. You can move a disk to a different peg one at a time. You cannot fit a larger disk on a smaller disc. Count the number of movements [14].

II-Trail making test part B (TMT B):

It is used to assess cognitive flexibility and set-shifting abilities. A contestant connects 25 dots in a semi-random, predetermined order across the page, switching between rising letters and numbers [15].

III-Eriksen flanker test (EFT):

An Eriksen Flanker task accessible online (online version: cognitivefun.net-task6). It is used to evaluate suppression of selected responses. It is used to assess inhibitory control. Participants must react to the orientation of the center arrow in this task, by pressing the arrow keys corresponding to the target arrow in the center of the computer screen. There were congruent and incongruent trials [16].

For evaluation of pulmonary functions:

I-Spirometer (Contec, China SP10BT)**:** It was used to assess forced vital capacity (FVC), forced expiratory volume in one second (FEV1), peak expiratory flow rate (PEFR), and FEV1/FVC ratio according to the recommendations of the American Thoracic Society standards. The children were given an explanation of the test. The test was conducted after 20 minutes break from any vigorous activity or exercise. The child was seated with the trunk extended by 90 degrees and the neck in neutral alignment. A mouthpiece was placed over the child's mouth after he inhaled as much as he could. He then exhaled as forcefully and quickly as he could, making sure to empty his lungs completely [17,18].

Statistical analysis

Normal data distribution was checked using the Kolmogorov-Smirnov test. To examine the homogeneity. Levene's test for homogeneity of variances was used. For all statistical tests, the level of significance was set at $p < 0.05$. Pearson correlation coefficient was conducted to determine the correlation between pulmonary functions and executive functions. The statistical package for social studies (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA) was used for all statistical analysis.

Results

Subject characteristics:

In this study, school-age Egyptian children's pulmonary functions were correlated with executive function domains (working memory, inhibitory control, and cognitive flexibility). Participants in this study were 240 school-aged children of both sexes, their ages ranged between 8 - 12 years.

The correlation between FVC and executive function domains:

The correlation between FVC and time of Tower of Hanio test was high negative significant correlation ($r = -0.2981$, $p < 0.0001$). (figure 1).

The correlation between FVC and time of trial making test B was high negative significant correlation ($r = -0.3661$, $p < 0.0001$). (figure 1).

The correlation between FVC and Congruent Correct Ratio of EFT was high significant correlation ($r = 0.3233$, $p < 0.0001$). (Table 1).

The correlation between FVC and incongruent correct response ratio of EFT was high significant correlation ($r = 0.3437$, $p < 0.0001$). (Table 1).

The correlation between FVC and congruent correct response time of EFT was high negative significant correlation ($r = -0.2461$, $p = 0.0001$). (Table 1).

The correlation between FVC and incongruent correct response time of EFT was high negative significant correlation (r = - 0.2917, p < 0.0001). (Table 1).

Table (1): Correlation between FVC and executive function tests:

		r value	p value	Sig
FVC	Congruent correct Ratio of EFT	0.3233	< 0.0001	S
	Incongruent correct response ratio of EFT	0.3437	< 0.0001	S
	Congruent correct response time of EFT	-0.2461	= 0.0001	S
	Incongruent correct response time of EFT	-0.2917	< 0.0001	S

r value: Pearson correlation coefficient	**p value: Probability value**	**S: Significant**	**NS: Non significant**

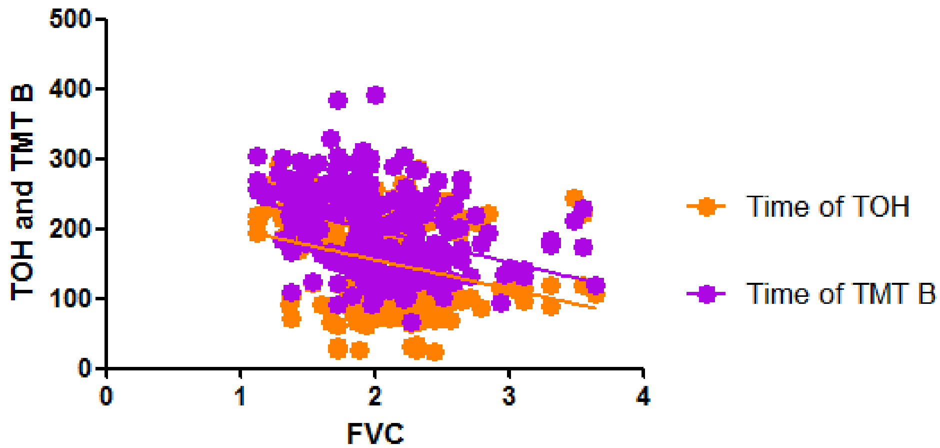

Figure 1: Correlation between FVC and (TOH and TMT B)

The correlation between FEV1 and executive function domains:

The correlation between FEV1 and time of Tower of Hanio test was high negative significant correlation (r = - 0.3709, p < 0.0001). (figure 2).

The correlation between FEV1 and time of trial making test B was high negative significant correlation (r = - 0.4178, p < 0.0001). (figure 2).

The correlation between FEV1 and Congruent correct ratio of EFT was high significant correlation (r = 0.3681, p < 0.0001). (Table 2).

The correlation between FEV1 and Incongruent correct response ratio of EFT was high significant correlation (r = 0.3827, p < 0.0001). (Table 2).

The correlation between FEV1 and Congruent correct response time of EFT was high negative significant correlation (r = -0.3070, p < 0.0001). (Table 2).

The correlation between FEV1 and Incongruent correct response time of EFT was high negative significant correlation (r = -0.3559, p < 0.0001). (Table 2).

Table (2): Correlation between FEV1 and executive function tests:

		r value	p value	Sig
FEV1	Congruent correct Ratio of EFT	0.3681	< 0.0001	S
	Incongruent correct response ratio of EFT	0.3827	< 0.0001	S
	Congruent correct response time of EFT	-0.3070	< 0.0001	S
	Incongruent correct response time of EFT	-0.3559	< 0.0001	S

r value: Pearson correlation coefficient **p value: Probability value** **S: Significant** **NS: Non significant**

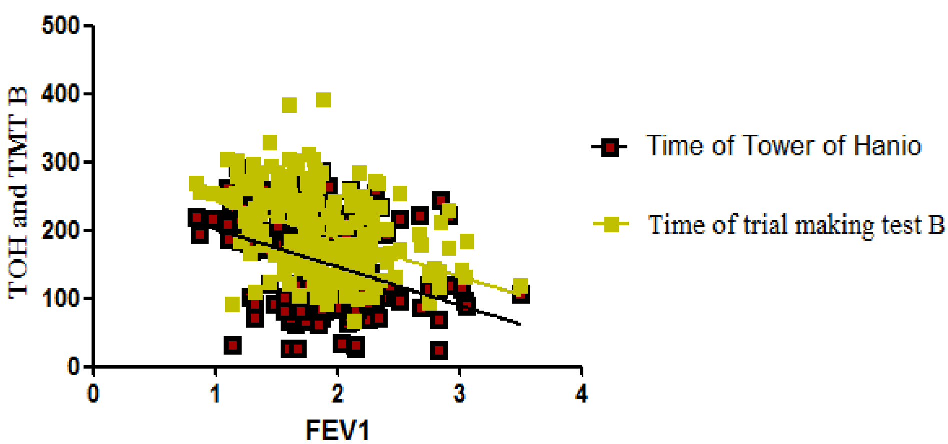

Figure 2: Correlation between FEV1 and (TOH and TMT B)

The correlation between PEFR and executive function domains:

The correlation between PEFR and time of Tower of Hanio test was moderate negative significant correlation (r = -0.2107, p = 0.0010). (figure 3).

The correlation between FEFR and time of trial making test B was moderate negative significant correlation (r = -0.2020, p =0.0017). (figure 3).

The correlation between FEFR and Congruent correct Ratio of EFT was moderate significant correlation (r = 0.1739, p= 0.0069). (Table 3).

The correlation between FEFR and Incongruent correct response ratio of EFT was mild significant correlation (r = 0.1577, p =0.0145). (Table 3).

The correlation between FEFR and Congruent correct response time of EFT was moderate negative significant correlation (r = -0.1907, p =0.0030). (Table 3).

The correlation between FEFR and Incongruent correct response time of EFT was high negative significant correlation (r = -0.2245, p 0.0005). (Table 3).

Table (3): Correlation between PEFR and executive function tests:

		r value	p value	Sig
PEFR	Congruent correct Ratio of EFT	0.1739	= 0.0069	S
	Incongruent correct response ratio of EFT	0.1577	=0.0145	S
	Congruent correct response time of EFT	-0.1907	=0.0030	S
	Incongruent correct response time of EFT	-0.2245	=0.0005	S

r value: Pearson correlation coefficient **p value: Probability value** **S: Significant** **NS: Non significant**

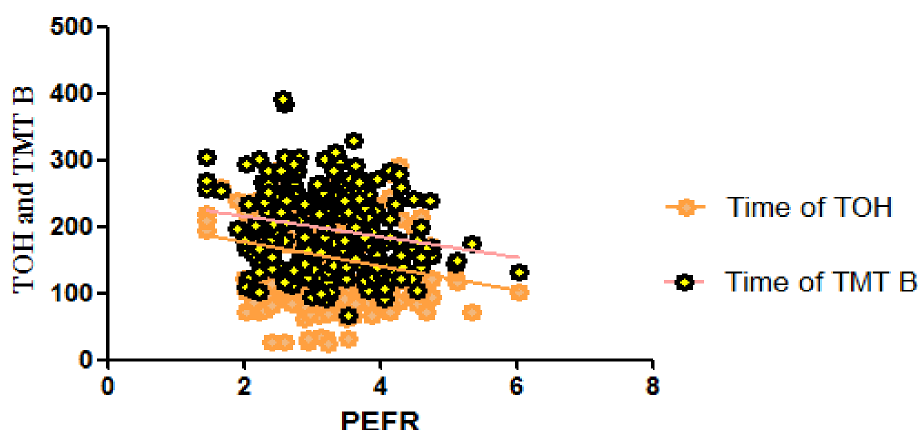

Figure 3: Correlation between PEFR and (TOH and TMTB)

The correlation between FEV1/FVC and executive function domains:

The correlation between FEV1/FVC and time of Tower of Hanio test was high negative significant correlation ($r = -0.3172$, $p < 0.0001$). (figure 4).

The correlation between FEV1/FVC and time of trial making test B was high negative significant correlation ($r = -0.2459$, $p = 0.0001$). (figure 4).

The correlation between FEV1/FVC and Congruent correct Ratio of EFT was high significant correlation ($r = 0.2176$, $p= 0.0007$). (Table 4).

The correlation between FEV1/FVC and Incongruent correct response ratio of EFT was moderate significant correlation ($r = 0.1871$, $p = 0.0036$). (Table 4).

The correlation between FEV1/FVC and Congruent correct response time of EFT was high negative significant correlation ($r = -0.2580$, $p < 0.0001$). (Table 4).

The correlation between FEV1/FVC and Incongruent correct response time of EFT was high negative significant correlation ($r = -0.2869$, $p < 0.0001$). (Table 4).

Table (4): Correlation between FEV1/FVC and executive function tests:

		r value	p value	Sig
FEV1/FVC	Congruent correct Ratio of EFT	0.2176	= 0.0007	S
	Incongruent correct response ratio of EFT	0.1871	= 0.0036	S
	Congruent correct response time of EFT	-0.2580	< 0.0001	S
	Incongruent correct response time of EFT	-0.2869	< 0.0001	S

r value: Pearson correlation coefficient p value: Probability value S: Significant NS: Non significant

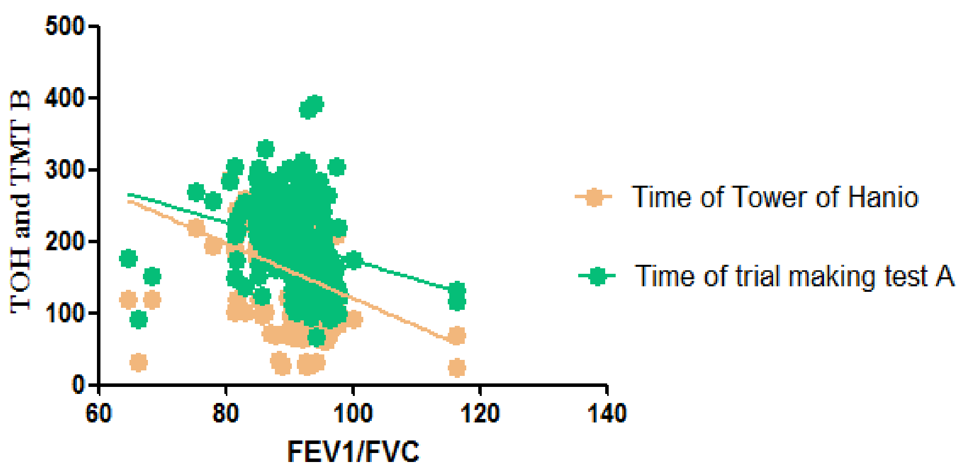

Figure 4: Correlation between FEV1/FVC and (TOH and TMT B)

Discussion

This study conducted to determine whether executive function domains and pulmonary functioning in Egyptian school children were correlated. Furthermore, to the extent of what we know, the present research may be the first to study the relation between pulmonary functions and executive function domains in Egyptian children.

The children in this study ranged in age from 8 to 12 years old, representing the beginning of a child's education journey. Since executive functions are essential for language development, reading and writing, and the interpretation and organizing of novel data, they have a significant value for their performance in school. In another words, they serve as the cornerstone of a child's capacity for learning [(19)].

Because executive functions can differ among demographic variables and socioeconomic categories, our study included children from the same socioeconomic background [(20)].

Furthermore, an increasing amount of research indicates the significance of EF for academic achievement, possibly as a result of their contribution to children's success in organized learning settings. This was in line with earlier studies that showed a variety of abilities, including executive functions, are critical and required for success in school. Children with better EF are able to concentrate, retain knowledge, and process it [(21)].

Our findings indicated a substantial relationship between executive and pulmonary functions. The findings of the Pearson correlation analysis demonstrated a negative correlation between response reaction time and spirometry measures of pulmonary function, such as FVC, FEV1, PEFR, and FEV1/FVC. The outcomes of this research are in line with study of Contreras-Osorio et al. who found that school children who practice sport activities as handball in a sustained manner for 12 weeks demonstrate increase in physical activity, pulmonary functions and improvements in their performance of executive functions in cognitive flexibility, working memory, and inhibitory control [(22)] which in turn improve their academic performance [(23)]. Also, another study conducted on primary school children founded that aerobic exercise which include 15 minutes of jogging on a pediatric trampoline (which improve respiratory fitness and pulmonary functions) has positive effect on executive functions [(24)]. Furthermore, a previous study reported that effect of 16 weeks of different aerobic activity as running, stretching, rope skipping and sport game significantly improve physical fitness parameters (cardiopulmonary fitness), and executive functions parameters (inhibitory control, working memory, reaction time cognitive flexibility) in primary school children [(25)].

Our results can be explained by the finding that as much as the pulmonary functions improve, will lead to good arterial oxygen saturation and good cerebral blood flow which reach to the brain (especially prefrontal cortex) that subsequently lead to improving executive functions. This was consistent with liu et al, (2023) who stated that lung function exercises boost the synthesis of vascular and neurotrophic growth factors, which support new development and plasticity and aid in preserving the structural integrity of the brain and cerebrovascular system which in turn improve executive functions [(26)].

Also, our results were supported by research findings of Laborde et al, (2021) which demonstrated that slow-paced breathing improved executive function tasks, with greater scores for Stroop interference accuracy [(27)]. Another study also discovered that attentive breathing improved error-related alpha reduction and raised alpha power during the performance of executive function tests, suggesting improved error-monitoring and enhancing executive function [(28)].

Prior researches showed that higher levels of physical fitness, particularly cardiovascular fitness is linked to change in the lung volumes, brain structure and function. Also, previous cross-sectional study reported that aerobic fitness is related to executive function domains (inhibition and working memory) in children [(29,30)]. These results were supported by the findings of our study which is important to the physical therapy field to be considered during dealing with children at this age.

Also, based on these results, we can draw the attention of physical therapists who deal with children who suffering from executive function deficits to improve their pulmonary functions which in turn improve their executive functions.

Conclusion

It is noteworthy to add that coordinated neural activity appears to be linked to higher pulmonary function, which in turn lead to improved executive functions. Therefore, pulmonary rehabilitation activities can be used by physical therapists to help children with their executive functioning. Regarding to the results of this current study there was a correlation between working memory, inhibitory control, cognitive flexibility and pulmonary functions in Egyptian school children.

Funding

None.

Conflict of interest

None.

Ethical approval

The current study was approved by the Ethical Committee of the Faculty of Physical Therapy, Cairo University (No: P.T.REC/012/004143) on November 13, 2022.

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