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Effect of Obesity on Cognitive Performance in Egyptian School-Age Children

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ABSTRACT

Childhood obesity is considered to be major concern that puts children at increased risk of poor cognitive functions, physical health and later in life they may develop many chronic diseases. The purpose of the study is to investigate the effect of obesity on children's developmental trajectories of cognitive functions (sustained attention, memory, logical thinking and executive functions) of the obese and normal Egyptian school-age children and to investigate if the BMI can be used as a predictor of cognitive performance in later adolescence and adulthood. This study is a cross-sectional prospective design. A sample of 463 healthy children of both sexes, of age ranged from 6-12 years, from elementary schools in Upper Egypt was recruited. Descriptive statistical analysis revealed that the obese children made more errors than their normal-weight counterparts. Based on study's results, the obese children had lower cognitive performance than their normal-weight counterparts and the BMI can be used as a predictor for the future cognitive functions in executive functions and memory domains but not sustained attention and logical thinking.

Key words: Cognitive abilities, obesity, Rehacom

INTRODUCTION

Cognition is considered the mental action of process of gaining knowledge through thought, experience and the senses, so the word cognition is a cover for all of the mental activities that we engage in; our thoughts and our thinking (Taylor, 2005). Cognition can be divided into different domains of ability, which can be tested separately; the most important of these are attention and concentration, memory and learning, language, visuospatial function and executive functions (Richards *et al*., 2004).

Children's cognitive abilities inversely affected by several factors such as poverty, low parental education, genetics and obesity (Crookston *et al*., 2014). Obesity has become an epidemic in many parts of the world. The World Health Organization has warned of the aggravation of epidemic of obesity that could put the population in many countries at risk of developing non-communicable diseases. In Egypt, the prevalence of overweight and obesity among school age children in 2013 was 17.7 and 13.5%, respectively (Badawi *et al*., 2013). There is a strong relationship between childhood obesity and the cognitive and physical development during childhood which can affect well being and productivity in adult life (Diamond, 2007). The growing body of evidence suggested an association between obesity and altered cognitive functioning in children. Obese children show worse school performance and academic achievement compared to their normal-weight counterparts (Taras and Potts-Datema, 2005; Datar and Sturm, 2006).

Cserjesi *et al*. (2009) found that obesity was associated with poor response inhibition and attentional control. The relationship between obesity and cognition is evident in both children and adolescents with higher Body Mass Indices (BMIs) associated with poor attention and task-switching abilities (Cserjesi *et al*., 2007). Adolescents with excess weight exhibit greater difficulty with response monitoring and switching (Verdejo-Garcia *et al*., 2010). Li *et al*. (2008) found that BMI negatively correlated with cognitive functioning even after controlling for mediating factors such as TV viewing and parental education level. Recent brain imaging work also suggests that cognitive control may be compromised in obesity. Grey matter volume in the orbital frontal cortex, a brain region involved in response inhibition, is reduced in obese individuals (Maayan *et al*., 2011) and higher BMI predicts decreased baseline activation of areas of the prefrontal cortex including the anteriorcingulate cortex ACC (Volkow *et al*., 2008; Willeumier *et al*., 2011).

Despite the growing body of research concerning the association between cognitive functions and obesity, most studies focused only on adolescents or adults and small body of literature focused on the childhood age and in Egypt, it is the first study to investigate the correlation between the development of school-age children's cognitive functions and their BMI.

The purpose of the ongoing study is to investigate the effect of obesity on the developmental trajectory of the cognitive abilities for the Egyptian obese school-age children and their normal weight-counterparts in sustained attention, logical thinking, memory and executive functions domains and if the BMI can be taken as a predictor for predicting the development of the future cognitive abilities during adolescence and adulthood. The assessment conducted by using the Rehacom computerized program which is a method for assessment of cognitive domains. It is computer based software composed of several rehabilitation programs, designed to measure and rehabilitate different cognitive abilities.

MATERIALS AND METHODS

Subjects: The present study was conducted on 463 healthy school-aged children recruited from urban elementary schools. The purpose of the study was to compare the developmental trajectory of the cognitive abilities for the Egyptian obese school-age children and their normal weight-counterparts in sustained attention, logical thinking, memory and executive functions domains. The children were randomly selected by the simple protocol of sealed envelope approach "each child has the same chance of being selected" in order to reduce the probability of imbalance in children selection. Initially, the study included 616 children recruited. One hundred and fifty three children were excluded because their BMI was at or over 85% which classified as overweight according to the CDC chart. The children age ranged from 6-12 years. They were able to follow instructions and understand commands during testing procedures. Children with history of mental, cognitive, neuromuscular disorders, epilepsy, visual, auditory defects or autistic features were excluded.

Testing procedures: Prior to beginning testing, the researches were provided approval from ethical committee Faculty of Physical Therapy, Cairo University, school manager and students' parents consent for agreeing about participating their children in the study and were informed of any limits to confidentiality according to APA (2003).

Anthropometric measurement took place in a separate room. The weight of children was taken using a calibrated electronic scale and the height was taken using a tape measurement without wearing shoes. Children's Body Mass Index (BMI) was calculated as weight divided by height squared (kg m^{-2}) and converted to BMI percentiles using national age and sex-specific reference data (Kromeyer-Hauschild *et al*., 2001).

All tests administered and scored in a manner that is consistent with the test publisher directions as standardized procedures are critical to valid interpretation. The areas of cognitive domains of function assessed were including attention, memory, logical thinking and executive functions. The children were given a brief demonstration of how the Rehacom programs are working in four tested domains, according to the research protocol, before starting the actual testing. Participants were informed that they could quit at any time during the test procedures. All subjects performed a preliminary test to familiarize them with the sit-up and testing procedures. All subjects were started with level 1 on Rehacom. The administration of the tests should be based on the standardized procedures outlined in testing manuals. The testing procedures were conducted in an environment free from any distraction and noise which may affects children's performance.

Testing protocol

For logical reasoning program: The type of test used is 'completion of a series'. By increasing the difficulty of the logic succession and increasing supposition of several logic structures, the child should figure out the concepts underlying each problematic situation and to use these concepts to solve the logic problem. In the testing procedure, a picture series is shown with simple graphic figures. The child must find the relationship between the individual links of the series and through induction derive a rule (figure reasoning) which clarifies what the next link of the series is (Von Cramon and von Cramon, 1993). When the child has established what the rule is-he must then select the relevant picture from a matrix of pictures. The matrix of pictures can be used by the patient to check that he has derived the correct rule.

For vigilance program: In the test, the child works as a high-quality controller at the end of a manufacturing line in a factory (drinks and/or canned food production, furniture industry, electronics manufacturing or production of budget subjects). The task is to identify which objects are not identical to the specimens and remove them from the conveyor at the point indicated. The aim of the program vigilance is to evaluate the child's performance in the area of tonic attention with specific attention focused on maintaining visual vigilance, in difficult observation situations the child's reaction skills are put under pressure in that they are also exposed to irrelevant information.

For topological memory: In this test, a varying number of cards (dependent on the level of difficulty) with concrete pictures or geometric figures are displayed on the screen. The child must memorize the location of the pictures. After a pre-set time-or manually, by pressing the OK button-the pictures in the matrix are hidden (turned face down). The objective of this procedure is to evaluate the memory for visual-spatial information as by a means of ordering the pictures in a topological way, the possibility exists to elaborate and to consolidate, different memory strategies with the child.

For exploration program: The procedure allows assessment for visual exploration. The child is required to slowly search for a series; in locating these precise objects. Varieties of abstract and concrete stimuli are projected on a dark background squares, triangles, circles, asterisks and other see symbols, numbers, letters, objects (flowers, cars etc.). The child has to search the surface for these various stimuli. The stimuli are arranged in lines and columns.

A circular cursor, which is the same size as a matrix unit, moves over the field line by line. In this way the exploration movements of the child can be controlled. Every time a previously defined stimulus is located, the child has to press the OK key on the Rehacom keyboard.

Data analysis: Descriptive statistical analysis was used in the present study to describe the mean number of errors children made across age groups and to compare the performance on for cognitive tasks between the normal and obese children. A linear regression analysis was also used to investigate if we can use BMI as a predictor to suspect the cognitive performance for those children later on.

RESULTS

The present study was conducted on 463 healthy school age children of both sexes (221 females and 242 males) ranging in age from 6 to 12 years. The recruited children were further classified into normal and obese based on their BMI (140 normal females and 81 obese) and (135 normal males and 107 obese) and developmentally into seven age groups (6<7, 7<8, 8<9, 9<10, 10<11, 11<12 and 12 years). Four programs of Rehacom computerized software were selected to represent the four cognitive domains to be assessed (VIGI to represent sustained attention domain, MEMO to represent memory domain, LODE to represent logical thinking domain and finally EXPL to represent executive functions domain).

Mean number of errors of commissions was the key parameter measured to compare the children's performance on the four cognitive tasks. Data were analyzed in SPSS (Statistical Package for Social Sciences®, version 22) along the dimensions of age, BMI and the mean number of errors children made on the four cognitive tasks. Regarding the age there were significant difference between 6 and 12 years in performance on each domain for both normal and obese children indicating developing of such domain of cognitive function. According to the males, the effect of obesity is evident in the four cognitive tasks, the obese males made more errors than their normal-weight counterparts across all age groups on exploration and topological memory tasks with means and SD were 0.069±1.63 for obese boys and 0.37±0.88 for normal on EXPL task and 0.32±0.695 for obese and 0.17±0.415 for normal on memory task, respectively indicating lower performance. On vigilance task, effect of obesity is evident at age 10 and 12 years with means were 0.15 and 0.20 for obese in comparison with their correspondence in normal 0.09 and 0.00, respectively. While on logical reasoning task, the cognitive performance of the obese boys at 6, 7 and 9 years is relatively lower with means 1.93, 1.92 and 1.40, respectively than their normal-weight peers with means 1.42, 1.39 and 1.24, respectively as explained in Fig. 1.

Regarding the females, the effect of obesity on cognition is evident in the four cognitive domains as well. On EXPL and MEMO tasks, the obese females made higher number of errors with mean and SD were 0.83±1.523 than their normal-weight counterparts with mean and SD were 0.44±1.019 indicating lower cognitive performance on executive functions and 0.57±1.072 for obese and 0.29±0.773 for normals on memory domain. Obese females had lower cognitive performance on vigilance task represented in higher number of errors at age 9 and 12 years with means were 0.18 and 0.25, respectively in comparison with their correspondents with means were 0.13 and 0.00, respectively. While on the logical reasoning task the effect of obesity is evident also as males at 6 and 7 years with higher number of errors with means were 1.78 and 1.63, respectively for obese females compared to their normal-weight counterparts with mean were 1.47 and 1.23 as described in Fig. 2.

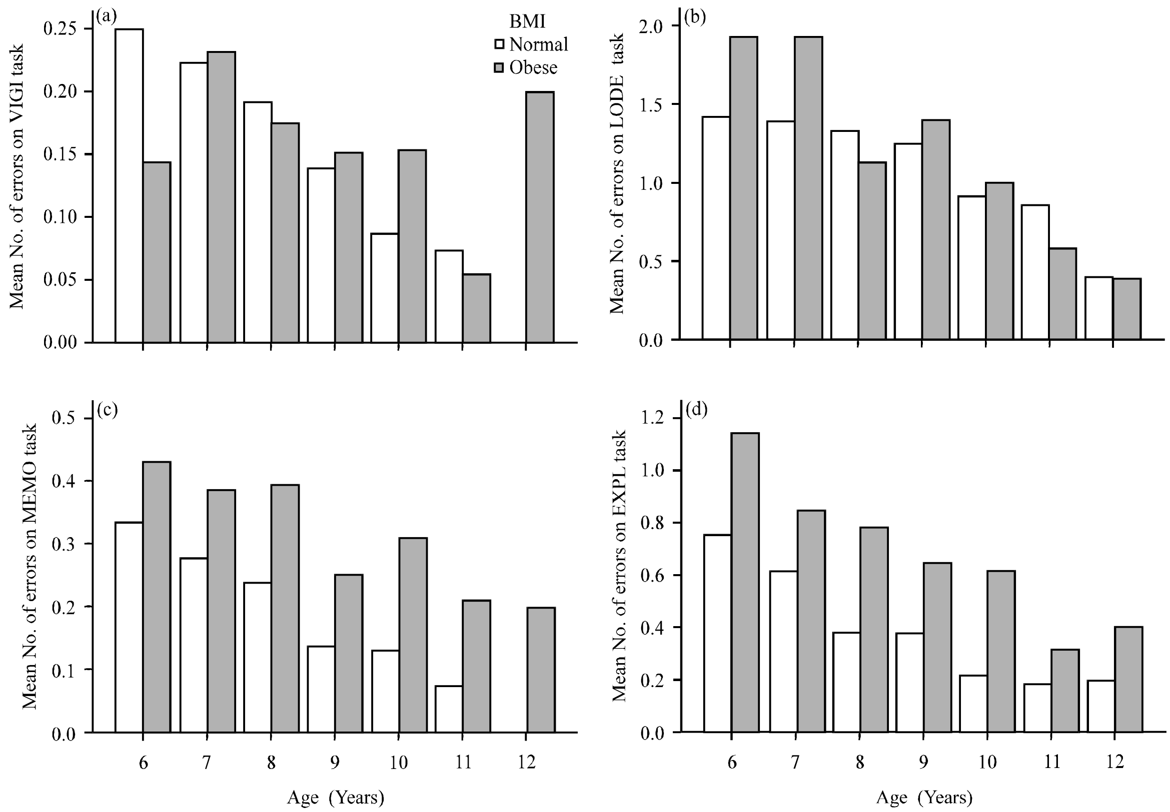

Fig. 1(a-d): Comparison between means of normal and obese males on (a) VIGI, (b) LODE, (c) MEMO and (d) EXPL across age groups

Table 1: Linear regression analysis predicting children's cognitive abilities from their BMI

Cognitive domains and sex	F	Significance
Executive functions		
Male	3.846	0.050
Female	4.754	0.030
Memory		
Male	4.190	0.040
Female	4.821	0.030
Sustained attention		
Male	0.090	0.765
Female	0.091	0.736
Logical thinking		
Male	0.242	0.623
Female	0.076	0.784

N = 463, probability accepted at 0.05

As described in Table 1, the linear regression analysis revealed that the BMI can be used as a predictor suspecting children's cognitive functions in adolescent and adulthood in executive functions and memory domains with significance of (p#0.05 for both males and females) unlike situation regarding sustained attention and logical thinking domains, the significance of the BMI is >0.05.

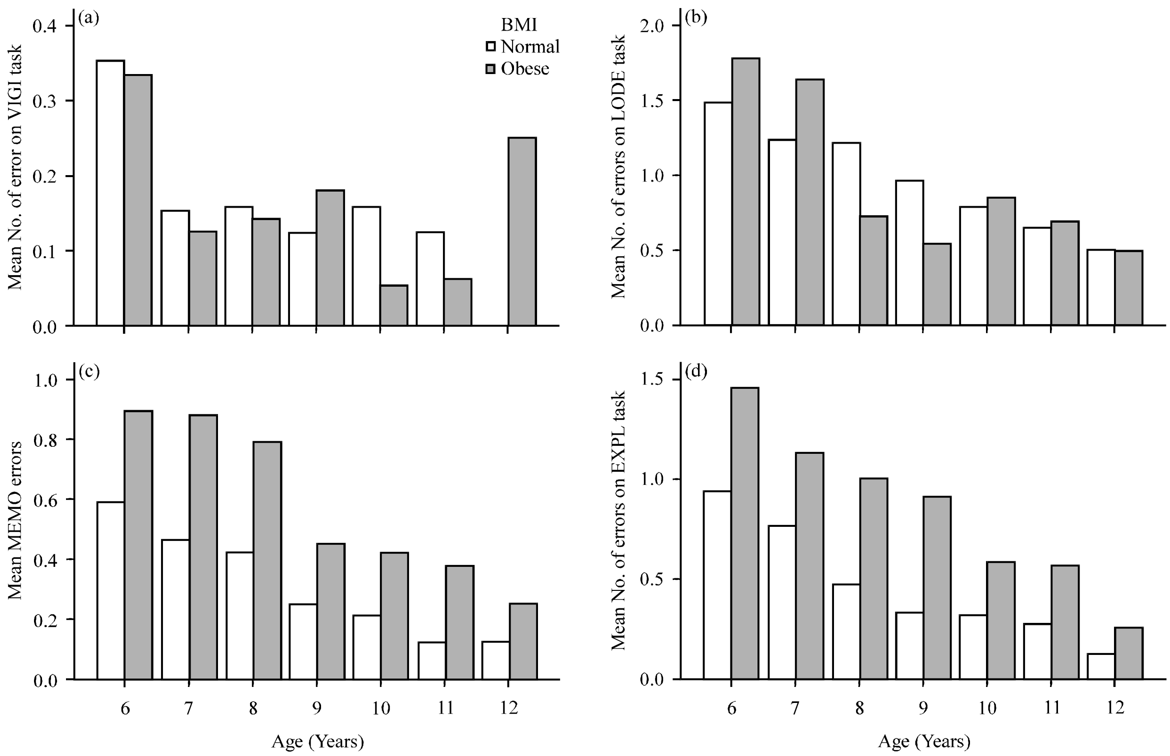

Fig. 2(a-d): Comparison between means of normal and obese females on (a) VIGI, (b) LODE, (c) MEMO and (d) EXPL across age groups

DISCUSSION

The present study was conducted on 463 healthy school-aged children recruited from elementary schools of Upper Egypt for the purpose of investigating the effect of obesity on the developmental trajectory of the cognitive abilities for the Egyptian obese school-age children and their normal weight-counterparts in sustained attention, logical thinking, memory and executive functions domains using Rehacom computerized software because these cognitive processes and their neural substrates provide the foundation for successful learning and scholastic achievement, thereby influencing overall health and well-being throughout life. Another purpose for the ongoing study is to detect if the BMI can be taken as a predictor for predicting the development of the later on cognitive abilities during adolescence and adulthood.

Choosing the study sample to include children aged from 6-12 years supports the finding of Bjorklund (2012) who stated that there is a huge amount of cognitive development that occurs after infancy, after the pre-school years and during the elementary school ages and even into adolescence and also this come in consistent with Coffey *et al*. (2006) who argued that cognitive development is an active and ongoing process that is influenced by both internal and external stimuli from infancy to adolescence. Almost all aspects of cognition show marked development after the pre-school years and during the elementary school ages: Perception and attention, memory, conceptualizing, problem solving and reasoning, symbolic processes. All of these have important implications for education and other practical activities (Pick, 2003).

The present study focused on the cognitive abilities of the Egyptian obese school-age children because despite the growing body of research concerning the association between cognitive functions and obesity, most studies focused only on adolescents or adults and until now no study investigate the association between the childhood obesity and cognitive functions in Egypt. Our results revealed that the number of errors made by the obese children (males and females) is higher than their normal-weight counterparts across all age groups in memory and executive functions domains as described in Fig. 1-2 which might be due to the detrimental effect of the obesity on brain structures and functions especially the prefrontal cortex which is closely associated with executive functions and memory and since it is the last brain region to mature it is vulnerable to a stressor as obesity during childhood. This is supported by Willeumier *et al.* (2011) and Maayan *et al.* (2011) who argued that predisposition to obesity could include a dysregulation of specific limbic neural circuits connected with the prefrontal cortex, given that these limbic circuits and the orbitofrontal cortex are associated with the inhibitory dimension of EF. The orbitofrontal cortex volume is positively associated with performance on measures of executive functions (Cohen *et al*., 2011).

The results of the present study are closely related to the study of Wirt *et al.* (2015) who investigated the role of inhibitory control in regards to body weight in a non-clinical sample of 498 primary school children in Germany. Children performed a Go-Nogo-task to assess inhibitory control. They reported that obese children displayed significantly lower inhibitory control compared to non-overweight and overweight children. The findings suggest that deficits in inhibitory control constitute a risk factor for pediatric obesity.

Regarding logical thinking domain the effect of obesity is variable as it evident at 6 and 7 years old in boys and girls which might be due to the disruption effect the obesity had on the young children task switching ability or mental flexibility which is the ability to shift between mental states, operations or tasks. Few studies can be found examining the association between cognitive flexibility and body weight. Cserjesi *et al.* (2009) found a significant negative correlation in adolescent boys and obese boys significantly performed worse than their healthy-weight counterparts. Verdejo-Garcia *et al.* (2010) used a whole battery of executive functioning tests including response inhibition and flexibility. Similarly, the authors reported significant group differences in the flexibility task and a significant relationship between BMI and flexibility.

In respect to the attention domain, the obese boy sat 10 and 12 years and obese girls at 9 and 12 years tend to made relatively higher number of errors on vigilance task as compared to their normal weight counterparts which might be due to reduced activation of the prefrontal cortex and anterior cingulate cortex sub-serving attention because of obesity as discussed earlier because attention is a subcomponent of executive functions. This is supported by the study of Kamijo *et al.* (2014) who examined the relationship between obesity and cognitive control using neuroelectric and behavioral measures of action monitoring in preadolescent children. Healthy weight and obese children performed compatible and incompatible stimulus-response conditions of a modified flanker task while task performance and the Error-Related Negativity (ERN) were assessed. They found that, the observed lower post-error response accuracy for the incompatible condition appears to be attributed to the larger number of sequential errors of commission. Thus, participants exhibited longer lapses in sustained attention during the incompatible condition, likely due to the increased cognitive control demands in this task condition. Their results suggested that childhood obesity is associated with decreased ability to modulate the cognitive control network involving the prefrontal cortex and anterior cingulate cortex which supports action monitoring.

The higher number of errors on sustained attention task made by 10 to 12 years children may be also due to decreased the level of activity as it was evidenced that higher-fit preadolescent children exhibit greater attention (Hillman *et al*., 2009), faster information processing speed (Hillman *et al*., 2005) and achieve higher scores on standardized achievement tests (Castelli *et al*., 2007; Donnelly *et al*., 2009) relative to their lower-fit counterparts. Wang and van Praag (2012) added that physical activity is a potent stimulator of processes underlying neurogenesis, synaptogenesis, as well as brain vasculature.

CONCLUSION

The present study was conducted in order to investigate the effect of obesity on the cognitive developmental trajectories (attention, memory, logical thinking and executive functions) of the obese Egyptian school-age children and their normal-weight counterparts using four selected Rehacom computerized software programs. Based on the study's results, obese children (males and females) had a lower cognitive performance represented in higher number of errors than their normal-weight counterparts in executive functions and memory domains across all age groups while the obesity had a variable effect on commission errors children's made on logical thinking and attention domains. There was no significant difference in the cognitive abilities between the obese males and females. The study suggested that the BMI can be used as a predictor for the development of executive functions and memory in later adolescent and adulthood unless prevention strategies for childhood obesity had been followed.

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