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Original Article

Short term memory, physical fitness, and serum brain-derived neurotrophic factor in obese adolescents

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Abstract

Background Obesity in adolescents is a major health problem and has been associated with low academic achievement. Brain-derived neurotrophic factor (BDNF), a neurotrophin, plays a role in appetite suppression and memory, and its secretion is enhanced by physical activity. This neurotrophin may be associated with academic achievement in obese.

Objective To compare physical fitness and serum BDNF levels to short term memory levels in obese adolescents aged 10–14 years.

Methods This comparative, cross-sectional, analytic study was carried out on 40 elementary and high school students in Bandung, West Java, who were recruited by stratified random sampling. Short term memory was assessed by a psychologist using the *Wechsler Intelligence Scale for Children-III Digit Span* test (WISC-III Digit Span). Physical fitness was assessed by a clinical exercise physiologist using the *Asian Committee on the Standardization of Physical Fitness Test* (ACSPFT). Serum BDNF levels were measured by ELISA test in a certified laboratory. ANOVA test was used to assess for a correlation between serum BDNF concentration and short term memory, as well as between physical fitness level and short term memory. Pearson's correlation test was used to analyze for a correlation between serum BDNF and physical fitness levels.

Results The majority of subjects were in the physical fitness categories of moderate or poor. Subjects had a mean BDNF level of 44,227.8 (SD 10,359) pg/mL. There was no statistically significant difference in physical fitness with either serum BDNF or with short term memory levels ($P=0.139$ and $P=0.383$, respectively). Also, no correlation was determined between serum BDNF and physical fitness levels ($r=0.222$; $P=0.169$).

Conclusion In obese adolescents, short term memory levels are not significantly different between physical fitness levels nor between serum BDNF levels. **[Paediatr Indones. 2015;55:277-81]**.

Keywords*: brain-derived neurotrophic factor, obese adolescents, physical fitness, short term memory*

Obesity is a complex, multifactorial disease, involving the interplay of genetics, energy balance regulation, and strong environmental influences.[1] In the past 30 years, childhood obesity has more than doubled in children and tripled in adolescents.[2] The percentage of American adolescents aged 12–19 years who were obese increased from 11% in 1988-1994 to 15% in 1999-2000.[3] According to data from the Indonesian Ministry of Health Report [*Riset Kesehatan Dasar/ RISKESDAS 2010*)], the national prevalence of obesity in the population aged 6–12 years were 10.7% in males and 7.7% in females.[4]

Obesity in adolescence has been associated with psychosocial abnormalities, one of which is the decline in academic achievement.[5-9] Research on cognitive function in obesity has focused on BDNF,[10] a neurotrophin involved in appetite suppression and memory.[11,12] Physical fitness is associated with a variety of health benefits in children and is a significant predictor of cognitive function 8–16-year-olds. Exercise triggers the release of BDNF through increased BDNF mRNA expression in the hypothalamus.[13,14]

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Since BDNF mRNA gene expression increases in the hippocampus in response to exercise, the protein has long been considered as a candidate component of the physiological mechanisms underlying the effects of aerobic exercise on the hippocampal memory system.[15] Physical exercise is also known to enhance the mood and cognitive function of active people, although the physiological mechanism of this effect remains unclear. Since a pioneering study showed that physical activity increases BDNF expression in the rat brain, a number of studies were undertaken in order to establish a link between BDNF and post-exercise enhancement of cognitive function in humans.[14,16,17] The aim of this study was to compare physical fitness and serum BDNF levels to cognitive function in the form of short term memory in obese adolescents aged 10–14 years.

Methods

We conducted a cross-sectional, comparative study from February to March 2014 on 40 elementary and junior high school students in Bandung, West Java, who were recruited by stratified random sampling. Healthy obese adolescents aged 10–14 years who met the criteria for obesity according to the 2007 WHO reference were included. Children with fatigue and attention disturbances were excluded. This study was approved by the Ethics Committee of the Padjadjaran University Medical School. The aim, risk, and possible benefits of the study were explained to parents, and informed consents were obtained.

A psychologist used the *Wechsler Intelligence Scale for Children-III Digit Span* test (WISC-III Digit Span) to examine short term memory. A clinical exercise physiologist conducted physical fitness tests using the *Asian Committee on the Standardization of Physical Fitness Test* (ACSPFT). Serum BDNF was measured by ELISA in a certified laboratory. Statistical analyses were performed using *SPSS version 21.0 for Windows*. All data are presented as mean (SD) and median (range). The Saphoro-Wilk test was used to assess normality distribution. ANOVA test was used to compare physical fitness and serum BDNF levels to short term memory and Pearson's correlation test was used to analyze for a possible correlation between serum BDNF and physical fitness levels. A P value of <0.05 was considered to be statistically significant.

Results

Forty healthy obese adolescents from elementary and junior high schools in Bandung were enrolled. None of the subjects were stunted. All data were normally distributed by Saphoro-Wilk test, except for age. The characteristics of subjects are presented in **Table 1**. There were more male subjects than females, and more subjects (11 each) in the 10 year and 13 year age groups than in other age groups. The majority of parents were college graduates with high income.

The majority of subjects had a moderate level of physical fitness, and none had very good physical fitness level. For short term memory levels, 7 out of 40 were considered good, 31 were considered moderate,

Table 1. Subjects' characteristics

Characteristics	N=40
Age, n	
10 years	11
11 years	7
12 years	9
13 years	11
14 years	2
Gender, n	
Male	30
Female	10
Mean age (SD), years	11.6 (1.4)
Median age (range), years	12 (10–14)
Mean body weight (SD), kg	77.4 (15.4)
Mean height (SD), cm	153.8 (10.9)
Mean body mass index (SD), kg/m^2	32.4 (3)

Table 2. Serum BDNF and short term memory levels in obese adolescents aged 10–14 years

	Short term memory levels			P value*
	Good (n=7)	Moderate (n=31)	Poor (n=2)	
Mean serum BDNF (SD), pg/mL	39,314.1 (13,671.3)	45,386.5 (9,366.2)	43,465.5 (14,854.2)	0.383

*ANOVA test

and 2 were considered poor. The mean BDNF level was 44,227 (SD 10,359) pg/mL for all subjects.

Mean serum BDNF in the various short term memory levels are shown in **Table 2.** There were no significant differences in serum BDNF levels among the short term memory levels (P=0,383). Based on the mean values, the highest serum BDNF level was in the moderate short term memory category (45,386.5 pg/mL), and the lowest was in the good category (39,314.1 pg/mL), but this difference was not statistically significant.

Table 3. Physical fitness scores and short term memory levels in obese adolescents aged 10–14 years

	Short term memory levels			P value*
	Good (n=7)	Moderate (n=31)	Poor (n=2)	
Mean physical fitness score (SD)	308.1 (47)	340.3 (36.9)	320 (39.6)	0.139

*ANOVA test

Physical fitness scores and short term memory levels are shown in Table 3. There were no significant differences in mean physical fitness scores among the short term memory levels (P=0.139). Based on the mean values, the highest physical fitness score was achieved by subjects in the moderate short term memory category (340.3), and the lowest was in the good category (308.1), but this difference was not statistically significant.

Pearson's correlation test revealed no significant correlation between serum BDNF levels and physical fitness scores (P=0.169).

Discussion

Few studies have examined how physical activity affects cognitive development. There are likely to be complex associations between physical fitness, motor coordination, cognitive and attentional functions at various developmental ages.[18] This comparative analysis assessed for differences in short term memory in obese adolescents with varying physical fitness and serum BDNF levels. But short term memory levels were not significantly different among physical fitness levels nor were mean serum BDNF levels different among the short term memory categories.

The mean serum BDNF level in all subjects was 44,227 (SD 10,359) pg/mL. Previous studies found that serum BDNF was lower in extremely overweight children and adolescents than those of normal weight.[19,20] Although we did not compare the levels of BDNF in obese adolescents to those with normal nutritional status as a control group, the average levels of BDNF found in this study were lower than the average levels of serum BDNF in children with normal nutritional status in a study by Al-Ayadhi *et al.* [54,000 (SD 5,700) ng / mL].[21]

Gray *et al.* reported the case of an 8-year-old girl with hyperphagia, severe obesity, and general impairment of intelligence quotient, including short term memory (WISC-III Digit Span). She harbored a de novo chromosomal inversion, 46,XX,inv(11)(p13p15.3), a region encompassing the BDNF gene. Serum BDNF protein concentration was reduced compared to age- and BMI-matched subjects.[10] Surprisingly, the lowest serum BDNF level was seen in subjects without impairment of short term memory (good level). This result may be explained by the absence of mutation in the BDNF gene which would alter BDNF function in the memory system. Zegers *et al.*[22] concluded that mutations in the BDNF coding region are uncommon in obese patients and, therefore, are not likely to play an essential role in the pathogenesis of childhood obesity. Since leptin receptor signaling is important for leptin-dependent BDNF up-regulation, the inability of leptin to increase hypothalamic BDNF expression may decrease its serum level. Obesity induces leptin resistance, characterized as a reduced anorectic response to leptin, as well as hyperleptinemia.[23] Additional studies comparing serum BDNF in obese children without neurocognitive difficulties and age- and BMI-matched children who have well-characterized learning problems are required to elucidate the relationship between serum BDNF and cognitive deficiencies in children.

The majority of subjects had a moderate level of physical fitness (47.5%). The mean physical fitness score of all subjects was 333.63 (SD 40), which was lower than the normal score matched for age (359–405).[24] If fitness is considered to be a function of performance in an endurance exercise event, obesity is clearly detrimental.[25] For example, among obese children (mean percentage body fat 49%), a study found a correlation of r=0.82 between BMI and distance on a 12-minute walk/run test.[26] In a general population of 12-year-old boys, Rowland reported that body fat content accounted for 32% of the variance on finishing times in a one-mile run.[27] This negative influence of a state of obesity on field measures of cardiovascular fitness has generally been considered due to the excess "baggage" of adiposity that must be transported.[25] The findings of low levels of physical fitness in this study supports the results of Setiyowati, who found a negative relationship between nutritional status and physical fitness.[28]

In our study, the lowest physical fitness score was achieved by the subjects with good short term memory. As such, the physical fitness score in our study may not have reflected aerobic fitness, which is associated with cognitive function. Whiteman *et al.* found that the interaction between serum BDNF and aerobic fitness, but not fitness alone, could predict recognition memory.[15] Physical fitness was determined by a series of tests that assessed mostly anaerobic capacity, resulting in a lower physical fitness score. Long distance running was the only test to determine aerobic capacity. Therefore, it is necessary to assess aerobic physical fitness by calculating the VO_2 max, the maximal rate of oxygen an individual consumes during exercise measured in mililitres, per minute, per kilogram body-mass.[15] This previous study also found that in subjects with low fitness, increased serum BDNF predicted lower subsequent memory test (SMT) accuracy. As fitness increased, BDNF began to positively predict SMT accuracy, with an estimated inflection point around the 75^{th} aerobic fitness percentile.[15] No correlation was found between serum BDNF and physical fitness level in our study because none of the obese adolescents had a very good level of physical fitness. Only 5 subjects had good physical fitness. These factors may have contributed to the results in this study.

Despite many predictions, few published human studies have tested the hypotheses that relate exercise and fitness to the hippocampus, and none have considered the potential links between BDNF and fitness and other hormonal components. Therefore, further study should be done to evaluate the relationship between these three factors, especially in obese children.

The lack of a cohort group of children with normal nutritional status was a limitation of this study. Also, physical fitness was determined without assessing the type and level of daily physical activity, and the subjects did not come from the same school.

In conclusion, physical fitness scores and serum BDNF levels do not correlate to the different short-term memory levels. It is necessary to advocate the improvement of physical fitness level in obese adolescents.

Conflict of interest

None declared.

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