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Original Article

The Effects of Obesity on Cognitive Functions in Adolescents

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ABSTRACT

Objective: Obesity continues to be an important problem in childhood as well as in adults worldwide. It is known that obesity experienced in childhood has effects on emotional development besides physical effects. In this study, it was aimed to investigate the effects of obesity on cognitive functions in adolescents, which is the most important step of the transition to adulthood.

Methods: Obese and non-obese adolescents with no other known health problems were included in the study. In order to evaluate cognitive functions in obese patients and the control group, tests evaluating auditory and visual memory and attention were applied.

Results: As a result of the assessments made, a statistically significant difference was found in terms of visual memory scores and verbal fluency total and sub-dimension total mean scores. No statistically significant difference in terms of WISC-R verbal, performance, and total score means applied to the participants was found.

Conclusion: In our study, it was observed that obesity may adversely affect cognitive functions in childhood in some areas. It may be necessary to determine the factors that negatively affect cognitive functions in obese children and to take supportive interventions and measures.

INTRODUCTION

Nutrition is among the most vital aspects of lifelong habits that significantly affect the holistic health of a person. Nutrition is an important social phenomenon for emotional satisfaction as well as physical development.[1] However, socio-economic and cultural conditions of the social or familial structure, genetic structure, food production and consumption methods, cognitive and behavioral characteristics play an important role in child nutrition. Nowadays, childhood malnutrition and obesity are among the most common chronic health problems of childhood. In the report published by WHO, in 2016, overweight or obesity impacted nearly 340 million children between the ages of 5 and 19. Less than 1% of children between the ages of 5 and 19 were obese in 1975; by 2016, this number had increased to more than 124 million. Obesity affects all developed and developing countries.[2] It is known that childhood obesity, which is difficult to detect in childhood, is due to genetic and environmental factors. In studies, it was determined that the fat ratio in children was similar to the fat ratio of their families, and the probability of the children of obese people being obese was 2-3 times higher than that of non-obese children. A family's diet, eating habits, socio-economic level, and education level are among the other factors affecting obesity.[1-3]

There are two important reasons for childhood obesity

due to its effects on physical and emotional development. The first reason is that childhood obesity can lead to many metabolic and chronic diseases. Secondly, the psychological problems that have the potential to arise due to social reasons, especially the bullying that these children are exposed to by their peers, cause them to experience problems of lack of self-confidence and adaptation to the environment in the future.[4] There are studies showing that childhood obesity has negative effects on school success.[5] Poor school performance appears to occur, in part, as a result of reduced cognitive abilities. In addition, it is stated that excessive fat deposition accompanies learning and memory problems.[6] In another study on this subject, it was found that overweight/obese male students had lower reading skills and math scores compared to normal-weight students; however, there was no difference in reading skills and math scores of obese female students compared to normal-weight female students.[7]

This study focused on examining the impact of obesity on cognitive functions in adolescents, a critical phase that represents the most significant step towards adulthood.

MATERIALS AND METHODS

The study was conducted as a single-center, prospective study with voluntary participants, whose parents provided written consent. Those with genetic and metabolic diseases, mental retardation and pre-existing cognitive dysfunction, comorbid chronic disease, attention deficit hyperactivity disorder, learning disability, tic disorder, and autism that may affect neuropsychological test performance, diagnosed by a child psychiatrist with a DSM-5-based semi-structured interview, were excluded from the study. The volunteer group included in the study was clas-

Table 1. Comparison of socio-demographic and the characteristics of the time they started reading and writing among voluntary participant groups

	Volunteer Participant Socio-Demographical and the Time to Start Reading-Writing Distribution					
	Study (case) Group (n=35)		Control Group (n=34)			
	Number (n)	Percentage* (%)	Number (n)	Percentage* (%)	X^2	p**
Gender						
Female	16	45.7	14	41.2	0.1	0.7
Male	19	54.3	20	58.8		
Mother's educational status						
Middle school or lower	24	68.6	18	52.9	1.8	0.18
High school and above	11	31.4	16	47.1		
Father's educational status						
Middle school or lower	22	62.9	18	52.9	0.7	0.4
High school and above	13	37.1	16	47.1		
Mother's employment status						
Unemployed	25	71.4	22	64.7	0.4	0.55
Employed	10	28.6	12	35.3		
Income status						
***Hunger level and lower	3	8.6	15	44.1		
***Between hunger and poverty level	23	65.7	15	44.1	11.6	<0.01
***Poverty level and above	9	25.7	4	11.8		
Parent relationship						
Together	35	100	24	70.6	12	<0.01
Separate	-	-	10	29.4		
Kinship status						
None	24	68.6	30	88.2	3.9	0.048
Yes	11	31.4	4	11.8		
Family type						
Nuclear family	5	14.3	34	100	51.6	<0.01
Extended family	30	85.7	-	-		
Literacy						
1st year 1st semester	16	45.7	32	94.1	19.1	<0.01
1st year 2nd semester	19	54.3	2	5.9		

*Column Percentage, **Chi-Square test, ***According to TUIK December 2018 data, Hunger Limit: 1.941 TL, Poverty Limit 6.323 TL.

Table 2. Distribution of physical characteristics of the participants

Distribution of physical characteristics	Case (n=35)	Control (n=34)	t	p*
Height (cm) [min-max]	138-180	139-182	0.8	0.45
(median)	160.4	163.6		
Mean±SD	160.5±10.2	160.2±11.1		
Body Weight (kg) [min-max]	47.2-115.2	34.2-95.5	-6.1	<0.01
(median)	77.7	55.5		
Mean±SD	81.6±18.6	56.3±17.2		
BMI (kg/m^2)[min-max]	23-40.7	13-29.5	-9.3	<0.01
(median)	30.4	21.3		
Mean±SD	31.3 ± 4.8	21.9±3.5		
BMI Z Score(SD)[min-max]	1.62-3.73	0.92-2.63	-6.7	<0.01
(median)	2.53	1.73		
Mean±SD	2.55±0.56	1.67±0.41		
Waist circumference (cm)[min-max]	78-130	41-83	-14.1	<0.01
(median)	101.2	61.3		
Mean±SD	102.4±12.8	65.1±11.2		
Heart Peak Pulse(/minute)[minmax]	68-98	65-86	0.8	0.45
(median)	80	75		
Mean±SD	80±8	160.2±11.1		

*Represents the student's t-test.

sified into two categories: the study and control groups. The study group comprised 35 adolescents, consisting of 16 girls and 19 boys, aged between 10 and 16 years. These individuals were being monitored at the pediatric endocrinology outpatient clinic with a diagnosis of obesity. There were 34 adolescents in the control group, 14 girls and 20 boys, who applied to the general pediatric outpatient clinic between the same dates, in the same age group, and were randomly selected, without any diagnosed disease. National percentile curves were used as BMI percentile curves.[8] Children with a percentile value of >95 were considered obese. Demographic data of all children included in the study and their families, physical examination findings, diet-exercise status, oral glucose tolerance tests (OGTT), fasting blood glucose, insulin, and Homeostatic Model Assessment for Insulin Resistance (HOMA-IR) values were recorded.

The following tests were applied to obese patients and control groups to evaluate cognitive functions:

1. Wechsler Intelligence Scale for Children—Revised (WISC-R); to determine the intelligence levels of children and to evaluate the problems they experience in certain areas,

2. Benton visual memory test; to assess visual memory,

3. Stroop Test; to assess the ability to suppress a habitual behavior pattern and perform an unusual behavior, focused attention, and information processing speed,

4. Trailing; to assess attention speed, motor speed, visual scanning, mental flexibility, endurance, response inhibition, and proneness to interference,

5. Auditory Verbal Learning Test (AVLT); to assess attention, verbal fluency, and verbal learning.

RESULTS

The data gathered in the study were analyzed using the statistical software package SPSS 23 (Statistical Package for the Social Sciences – IBM®). Descriptive statistics were utilized, providing numbers and percentages for categorical variables and mean and standard deviation for numerical variables. For numerical variables, an ANOVA Test was used when the assumption of normal distribution was provided in multiple independent group comparisons, and the Kruskal-Wallis Test was used when the Wilcoxon Test was not suitable. Chi-square test and T-test statistics were used for categorical variables. To establish the statistical significance level, significance was considered at a 95% confidence interval, and $p<0.05$ was considered as indicating significance.

Socio-Demographic and Literacy Time Analysis

Of the obese cases participating in the study, 45.7% were girls, and the mean age was 13.0±1.7 years, while 41.2% of the control group were girls, and the mean age was 12.2±1.7 years (Table 1). When comparing the ages of first walking, pronouncing the first word, producing the first sentence, and receiving toilet training, no statistically significant difference was discovered between the groups in terms of motor mental development ($p>0.05$). Other-

Table 3. Study and control group comparative results of WISC-R, STROOP test, visual memory test, verbal fluency test, trail making test, AVLT test

Assessment tools and subscales		Study (Case) Group (n=35)	Control Group (n=34)	p
WISC-R	WISC-R Verbal [min-max]	69-115	70-127	0.59
	Mean±SD	94±12	96±15	
	WISC-R Performance [min-max]	70-123	86-128	0.06
	Mean±SD	99±14	105±12	
	WISC-R Total [min-max]	73-121	75-128	0.13
	Mean±SD	96±13	100±13	
STROOP TEST	Stroop Total Time [min-max]	72-213	66-180	0.03
	Mean±SD	121 ± 44	102±26	
	Stroop Total Error [min-max]	0-26	0-5	0.68
	Mean±SD	1.8±4.6	2.2±1.6	
VISUAL MEMORY TEST	Visual Memory Test [min-max]	9-15	3-14	<0.01
	Mean±SD	12.7±1.5	7.9±2.9	
VERBAL FLUENCY TEST	Verbal Fluency Total [min-max]	12-60	14-50	0.79
	Mean±SD	28.4±12.7	27.7±9.8	
TRAIL MAKING	Trail A time [min-max]	29-105	16-94	0.79
	Mean±SD	49.5±14.2	48.4±19.9	
	Trail A error [min-max]	0-1	0-1	0.71
	Mean±SD	0.1±0.4	0.2±0.4	
	Trail B time [min-max]	76-288	35-300	0.02
	Mean±SD	153±49	124±56	
	Trail B error [min-max]	0-9	0-5	0.57
	Mean±SD	1.6±2.3	1.4±1.7	
AVLT	AVLT List Total [min-max]	28-67	28-59	0.1
	Mean±SD	43±9	47±9	
	AVLT-LR [min-max]	1-15	5-14	<0.01
	Mean±SD	7.8±3.3	10.2±2.4	
	AVLT Recognition [min-max]	8-28	11-15	<0.01
	Mean±SD	17.9±5.5	14.1±1.4	
	AVLT False Recognition [min-max]	0-2	0-2	0.03
	Mean±SD	0.7±0.6	1.1±0.8	

wise, the living together of the parents, parents being related, and having an extended family type were found to be considerably more than the study group's control group ($p<0.05$).

Analysis of Physical Characteristics

Information on the average body weight, BMI, BMI Z score, waist circumference, and the number of heartbeats of the participants are given in Table 2. Obese adolescents were found to have substantially higher mean body weight, BMI, BMI Z score, waist circumference, and heart rate values than those in the control group ($p<0.01$). However, there was no significant difference in height between the groups ($p>0.05$).

Analysis of Results Obtained from Assessment Tools

The Stroop test is an easy-to-apply assessment tool that is commonly used in the control of frontal functions. Interference sensitivity and inability to suppress inappropriate automatic responses can be evaluated more specifically in this test. The Stroop Test assesses perceptual setup, the ability to change in line with changing demands and under the influence of a disturbance, the ability to suppress a habitual behaviour pattern and perform an unusual behaviour, focused attention, and information processing speed. This test is regarded as the most selective test for inappropriate stimulus inhibition and is sensitive to damage to the left frontal lobe, particularly the orbitofrontal cortex.[9]

Table 3 displays the comparison between groups of the Stroop test administered as part of the study. As a result, obese teenagers had substantially higher Stroop 1-2-3 and Stroop total time means than those in the control group ($p<0.05$). However, there was no appreciable difference in the means of the Stroop total errors across the groups ($p>0.05$).

Trail Making Tests assess the attention speed, motor speed, visual scanning, mental flexibility, persistence, re-

sponse inhibition, and proneness to interference.[10] The analysis revealed a statistically significant difference only in terms of Trail B times in the trailing tests, as shown in Table 3 ($p<0.05$). The average duration of Trail B in the case group was found to be significantly longer than that of the control group.

Auditory Verbal Learning Test (AVLT) is a neuropsychological memory test used to assess verbal memory, verbal learning, backward and forward interference, instant recall, delayed recall, and recognition processes.[11] No statistically significant difference was discovered in terms of the AVLT total, AVLT List 1, AVLT List 5, and AVLT Perseverance scores as a consequence of the test used to compare the two groups within the parameters of the study ($p>0.05$). The study revealed that AVLT long-term delayed recall (AVLT-LR) and false recognition mean scores were significantly higher in the control group, while AVLT recognition mean scores were significantly lower in the case group ($p<0.05$), as presented in Table 3.

Studies show that abstract shapes are encoded in the right prefrontal cortex, and words are encoded in the left prefrontal cortex.[12] The tests employed in this study aimed to assess the verbal and visual memory learning, spontaneous recall, and recognition abilities of the participants. After conducting the assessments (Table 3), regarding scores for visual memory, a statistically significant difference was found ($p<0.01$). In the study group, the mean scores of the visual memory test were significantly higher than those of the control group. Additionally, a statistically significant difference was observed in terms of verbal fluency total and sub-dimension total mean scores ($p<0.05$). The subjects' mean WISC-R verbal, performance, and total score values did not show any statistically significant differences ($p>0.05$).

Analysis of WISC-R Scores by Biochemical and Lifestyle Characteristics

The comparison of WISC-R scores by some biochemical and lifestyle characteristics in the obese adolescent group is given in Table 4. Accordingly, the WISC-R score of those with fasting blood glucose below 100 mg/dl is significantly higher than that of those with 100 mg/dl and above ($p<0.01$). In the study, there were no statistically significant differences observed among obese cases concerning fasting insulin, HOMA-IR levels, exercise and diet status, and WISC-R scores ($p>0.05$).

Analysis of Correlation of WISC-R Scores with Other Test Scores

The correlation of age and WISC-R scores with other test scores in adolescents is given in Table 5. Accordingly, the study did not find any statistically significant correlation between age and WISC-R scores in adolescents ($p>0.05$). However, a statistically significant but weak correlation was found between age and AVLT false recognition (negatively), verbal fluency, and visual memory scores in adolescents ($p<0.05$). In the study, a statistically significant yet weak correlation was observed between WISC-R scores and Stroop total time, AVLT list total, AVLT-LR, Trail A, Trail B, and Verbal Fluency total scores in adolescents ($p<0.05$).

DISCUSSION

In this study, which looked at how obesity affects cognitive abilities in adolescence—the most crucial stage of the transition to adulthood—a significant link between the groups' mean WISC-R verbal, performance, and total scores was found. The WISC-R test is an individually administered intelligence test approved for children aged

Table 4. Comparison of WISC-R scores by some biochemical and lifestyle characteristics in the obese group

Total WISC-R Score	n	Med/DA	Z	p*
Fasting Blood Glucose				
<100 mg/dl	25	103/41	-2.9	<0.01
≥100 mg/dl	10	85/34		
Fasting Insulin Level				
<15 uU/mL	10	96/34	-0.1	0.94
≥15 uU/mL	25	97/48		
HOMA-IR Level				
<3.16	11	93/34	97/48	0.7
≥3.16	24	97/48		
Exercising Status				
None	29	97/48	-0.1	0.95
Yes	6	97/25		
Dieting status				
None	29	97/48	0.7	0.51
Yes	6	92/25		

Table 5. Correlation of age and WISC-R scores with other test scores in adolescents

	Age	WISC-R Total Score	Stroop Total Time	Stroop Total Error	AVLT List Total	AVLT- LR	AVLT Recognition	Trail B time	Verbal Fluency Total	Visual Memory
Age	1	-0.21	0.02	-0.05	0.19	0.06	-0.01	-0.15	0.29*	0.33**
WISC-R	-0.21	1	-.28*	0.04	.33**	0.24*	-0.1	-.35**	.24*	0.01
Stroop total time	0.02	-.28*	1	0.23	-0.23	-0.2	-0.28*	0.14	-0.39**	0.1
Stroop total error	-0.05	0.04	0.23	1	-0.03	0.02	0.06	-0.08	-0.2	-0.17
AVLT list total	0.19	0.33**	-0.23	-0.03	1	0.63**	0.23	-0.19	0.23	-0.1
AVLT-LR	0.06	0.24*	-0.2	0.02	0.63**	1	0.04	-0.21	0.07	-0.22
AVLT recognition	-0.01	-0.01	-0.28*	0.06	0.23	0.04	1	0.25*	-0.13	0.23
Trail B time	-0.15	-0.35**	0.14	-0.08	-0.19	-0.21	0.25*	1	-0.21	-0.1
Verbal fluency total	0.29*	0.24*	-0.39**	-0.2	0.23	0.07	-0.13	-0.21	1	0.26*
Visual memory	0.33**	0.01	0.1	-0.17	-0.09	-0.22	0.23	-0.1	0.26*	1

**p<0.05; ***p<0.01.

6-16. The validity and reliability of the WISC-R have been adapted for children and adolescents in Turkey.[13] When reviewing the literature, it is possible to encounter many studies reporting the relationship between obesity and cognitive functions and different results. It is observed that studies are generally conducted with high school students, university students, and adolescents.[14] However, there are many studies reporting the relationship between high body weight and low intelligence score, and cognitive function.[15,16] Some studies show that obesity can cause a decrease in IQ, while others emphasize that low IQ can cause obesity.[17]

In this study, it was discovered that the mean of Stroop 1-2-3 and Total Time in obese adolescents was significantly higher than those of the control group. The Stroop test, which was used in many studies before, was applied as a mental stressor.[18,19] In a related study by Cohen et al.[20] it was discovered that the obese group's overall Stroop test length was substantially longer than that of the control group. In the same study, attention/concentration assessments, working memory, and psychomotor/processing speed assessments showed significantly better results in the normal-weight group compared to the obese group.[20]

In the study, it was discovered that the case group's mean score on the visual memory test was much greater than that of the control group. In a study by Cohen et al.[20] unlike the findings of the study, visual memory performance has been reported to be higher in non-obese children, both in the forward and backward steps. In the Baltimore Cohort of Aging, obesity indices have been associated with poor performance in various cognitive fields, memory, and verbal fluency functions.[21] However, similar to the study in the Baltimore cohort, obesity was associated with better performance on attention tests and visual-spatial ability.[21] Electrophysiological studies in obese children revealed an association between impaired peripheral nerve conduction and insulin resistance, inspiring other studies showing that the visual and auditory pathways are also affected by hyperinsulinemia.[22] Regarding total verbal fluency and sub-dimension total score means, no statistically significant differences between the groups were found in this investigation. Similarly, in a study by Verdejo-Garcia et al.[23] the performance of overweight children on IQ, working memory, and verbal fluency assessments did not differ from controls, and its relationship with BMI was not reported. In some studies in the literature, it has been reported that poor performance levels in the Trail and Verbal Fluency tests are associated with high leptin levels.

In our study, we found a statistically significant relationship between the groups only concerning Trail B times, one of the trail-making tests. The study group's mean Trail B time was substantially longer than the control group's. The Trail Making Test (Parts A and B) provides information on visual scanning, processing speed, mental flexibility, and executive functions.[10] A shorter time to complete the test indicates better performance. Overweight has lower neuropsychological performance on tests of response inhibition, flexibility, and decision making. In a study, multivariate analyses have shown that BMI has a significant detrimental effect on flexibility performance and cognitive flexibility (as assessed by TMT) may be significantly reduced in overweight adolescents.[24] In the study conducted by Cohen et al.[20] it has been determined that normal-weight participants completed the Trail Making Test B-A in a shorter time than obese participants.

Regarding the study's AVLT total, AVLT List 1, AVLT List 5, and AVLT Perseveration scores, there were no statistically significant differences found between the groups. On the other hand, the study revealed that the mean AVLT-LR and recognition scores were significantly higher in the control group, whereas the mean AVLT false recognition scores were significantly lower in the case group. Similarly, Yesavage et al.[25] have found no significant relationship between AVLT and obesity in their study.

There were no statistically significant differences observed among obese cases concerning fasting insulin, HOMA-

IR levels, exercise and diet status, and WISC-R scores. In studies investigating dieting status, it is commonly reported that obese individuals have a higher propensity for dieting, and there is a statistically significant distinction between the groups.[26] The lack of difference between the groups in the study is believed to be attributable to the fact that obese individuals did not decide to lose weight. Previous studies have shown that diseases associated with insulin resistance, such as metabolic syndrome and type-II diabetes, are also associated with neurocognitive dysfunction, and it has been suggested that the effects of insulin resistance on the neurological system are probably due to abnormalities in insulin-dependent vascular reactivity.[27]

A statistically significant but weak correlation was noted between WISC-R and Stroop total time, AVLT list total, AVLT-LR, Trail A, Trail B, and Verbal Fluency total scores in adolescents in the study. In the literature reporting correlations between age and WISC-R and other assessments. In a study by Belsky et al.[17] it has been reported that age was positively associated with the completion time in TMT-B.

As a result, in this study investigating the effects of obesity on cognitive functions in adolescence, which is the most important step of the transition to adulthood, it was observed that obesity negatively affects cognitive functions in childhood. It is necessary to determine these factors that negatively affect cognitive functions in obese children and to take these factors into consideration in the follow-up of children as they get older, and supportive interventions and measures should be taken.

Ethics Committee Approval

This study approved by the Istanbul University Ethics Committee (Date: 04.10.2018, Decision No: 2018 / 1441).

Informed Consent

Retrospective study.

Peer-review

Externally peer-reviewed.

Authorship Contributions

Concept: M.Ö., A.K.S.; Design: M.Ö., A.K.S.; Supervision: M.Ö., İ.Z.G.; Materials: A.K.S., A.K.; Data: A.K.S., İ.Z.G.; Analysis: M.Ö., A.K.S.; Literature search: M.Ö., A.K.S., A.K.; Writing: M.Ö., İ.Z.G., Y.Ç.; Critical revision: M.Ö., İ.Z.G., Y.Ç.

Conflict of Interest

The authors confirmed that there is no conflict of interest in this study and that no funding is given for this study.

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Ergenlerde Obezitenin Bilişsel İşlevler Üzerine Etkileri

Amaç: Obezite, dünya çapında yetişkinlerde olduğu kadar çocukluk çağında da önemli bir sorun olmaya devam etmektedir. Çocukluk çağında yaşanan obezitenin fiziksel etkilerinin yanı sıra duygusal gelişim üzerinde de etkileri olduğu bilinmektedir. Bu çalışmanın amacı, yetişkinliğe geçişin en önemli basamağı olan adölesanlarda obezitenin bilişsel işlevler üzerindeki etkilerini araştırmaktır.

Gereç ve Yöntem: Çalışmaya herhangi sağlık sorunu olmayan obez ve obez olmayan olarak sınıflandırılan ergenler dahil edildi. Obez ve obez olmayan grupta bilişsel işlevlerin değerlendirilmesi için işitsel ve görsel bellek ve dikkat testleri uygulandı.

Bulgular: Obez ve obez olmayan grup aarsında görsel bellek puanları ile sözel akıcılık toplam ve alt boyut toplam puan ortalamaları arasında istatistiksel olarak anlamlı farklar saptandı. Katılımcılara uygulanan WISC-R sözel, performans ve toplam puan ortalamaları açısından anlamlı bir fark bulunmadı.

Sonuç: Çalışmamdan elde edilen sonuçlar obezitenin bazı alanlarda çocukluk çağında bilişsel işlevleri olumsuz etkileyebileceğini ortaya koymaktadır. Bu nedenle, obez çocuklarda bilişsel işlevleri olumsuz etkileyen faktörleri, önleyici müdahaleleri ve önlemleri belirlemek için tahmin ve önleme temelli sistemlerin kullanılması gerekli olabilir.

Anahtar Sözcükler: Bilişsel fonksiyonlar; ergen; obezite.