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Original article

Is there an association between nutritional status and intellectual capabilities of adolescents?

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Summary. The aim of this study was to investigate the correlations among lifestyles, eating habits, nutritional status and intellectual capabilities of adolescents. A cross-sectional study was carried out using anthropometric measurements and standardized food questionnaire. The sample consisted of 151 adolescents attending a secondary school in central Serbia. Academic achievement was estimated through grade point average (GPA) in the previous academic year. Intellectual capabilities were expressed through intelligence quotient (IQ) determined by Cybernetic battery of intelligence (KOG 3). Totally, 14.5% of students were categorized as overweight or obese. No strong correlation was found between specific dietary habits and nutritional status of adolescents. The percentage of respondents with IQ>110 was higher in the group with increased body mass index (BMI percentile>85) compared to that in the group with normal body weight or underweight (38.5% vs. 15.7%). Besides, 16.7% of students with BMI percentile<85 and only 7.7% of students with BMI percentile>85 had IQ<90. However, Spearman correlation coefficient indicated no strong correlation between IQ test results and students' BMI (ρ=0.144). On the other hand, students with lower academic performance (GPA<3.5) were more prone to certain dietary habits such as frequent consumptions of coffee (p=0.002) and fast food (p=0.044). On the contrary, sedentary lifestyles were rather typical for adolescents with better academic achievements GPA>3.5 (p=0.009). A significant correlation was found between students' IQ and height (Spearman's ρ=0.352). Although there was no strong correlation between intellectual capabilities and nutritional status of adolescents, certain eating habits and lifestyles might be associated with intellectual performance.

Keywords: adolescents; eating habits; nutritional status; intellectual capabilities; academic achievement

Introduction

Adolescence is one of the most critical periods of intensive physiological, cognitive and psychosocial changes, covering the ages of 10 to 19 years (1). Rapid physical growth leads to increased demands for nutrients and micronutrients. Bad nutritional status of adolescents can induce serious health problems and increase the risk for many diseases. Beside the immediate health disorders such as anemia, obesity and dental caries, bad eating practices can also leave some long-term consequences (2, 3). Moreover, eating habits adopted in early life are likely to be maintained in adulthood.

Overweight and obesity have significantly increased during the last century and they have become the most common nutritional disorders among young children and adolescents. According to Force Report from 2005, every fifth European child is overweight or obese (4). The reason for this can be found in bad nutritional habits based on consumption of high-caloric foods with low nutritional value, combined with sedentary lifestyles and lack of physical activities. Obesity has been identified as an important risk factor for development of many serious health conditions such as cardiovascular diseases, diabetes mellitus and some cancers (5-7). In addition, weight disorders can also

induce some mental problems of adolescents, affecting their body image perception and their self-esteem (8).

Some researchers have indicated the association of obesity with poor cognitive function and decreases in brain volume which could possibly reduce intelligence quotients (9,10). Results of certain case–control studies have suggested that childhood IQ is inversely associated with obesity (11-13). Besides, some studies have indicated that better academic achievements are associated with a healthy diet, regular intake of nutritious breakfasts and lower consumption of fast foods (14,15). Although there is a lot of evidence confirming that malnutrition affects different brain functions, it is interesting to notice that a possible correlation between intellectual capabilities and nutritional status might also be interpreted in the opposite way: it can be assumed that people with higher intellectual capabilities are more aware of the harmful effects of unhealthy diet and they are more interested in developing healthy eating habits and lifestyles. Actually, most cross-sectional studies usually conclude that obesity impairs cognitive functions, while most prospective longitudinal studies prefer the opposite causal direction: they suggest that low intelligence leads to obesity (16). Furthermore, there are certain studies that suggest a correlation between IQ-test results and height (17-19). All these assumptions are still under investigation and need further research to be confirmed.

The main aim of this study was to investigate the correlation between nutritional status and intellectual capabilities of adolescents. Dietary habits and lifestyles of adolescents were investigated with regard to their IQ-test scores and academic performances. The correlation between specific eating habits and nutritional status was also analyzed. Besides, the paper reports the results of estimating the prevalence of obesity and associated risk factors among high school adolescents in one of the largest cities in Serbia.

Methods

A cross-sectional descriptive study was carried out during December 2014 in Kragujevac City, in central Serbia. The target subjects were secondary school students, 15-19 years old, selected by stratified random sampling (a simple random sample was selected from each of the four secondary school grades). Totally 151 students were included, 113 males and 38 females. The study was based on anthropometric measurements and standardized 1-month recall food-frequency questionnaire which also included questions regarding students' lifestyles and attitudes. The questionnaire was self-administered and supervised by investigators. It was approved by the school board and the Faculty of Medical Sciences Ethics Committee, University of Kragujevac. All the participants have signed a written informed consent.

Body weight (kg), was estimated using a beam balance OMRON BF511 (Omron Healthcare, Kyoto, Japan) with the accuracy of 1%. The measurements were taken on barefoot participants wearing light clothing. Body fat percentage (BFP) was also measured by the same balance, using the Bioelectrical Impedance (BI) method. The respondents had to stand with their feet slightly apart, holding the grip electrodes with their arms straight out, at the angle of 90 degrees to the body. The results were interpreted using the standards of Gallagher et al. (2000) and McCarthy et al. (2006) (20, 21).

Body Mass Index (BMI) was calculated by dividing body weight (in kg) by the square of height (in m) and the results were converted to BMI centiles (based on the age and gender characteristics). The students were classified into different categories, according to the WHO 2007 distribution standards (22):

– underweight (BMI < 5^{th} centile)
– normal body weight (5^{th} ≤ BMI < 85^{th} centile)
– overweight (85^{th} ≤ BMI < 95^{th} centile)
– obesity (BMI ≥ 95^{th} centile).

Waist circumference (WC) was also used as an indicator of abdominal fat. It was measured as the minimum circumference between the lowest rib and iliac crest.

Eating behaviors and lifestyles of adolescents were assessed using standardized food questionnaire of the World Health Organization. The questions mainly referred to the frequency of consumption of some regular foods like fruits, vegetables, milk and milk products, meat, cereals etc. The consumption of fast foods, soda drinks, energy drinks, coffee and alcohol were also investigated. In addition, questions related to students' physical activities and the average

amount of time spent in front of computer and television screens were included. Students were also asked if they were satisfied with their current eating habits and their physical appearance. The responses were categorised into particular categories (most of them being presented in Table 3 and 4).

Intellectual capabilities were defined through Cybernetic battery of intelligence, KOG 3 (23). This test gives a measure of general intellectual functioning, presented in the form of the Wechsler intelligence quotient, IQ (70-79 borderline, 80-89 low average, 90-109 average, 110-119 high average, 120-129 superior). Academic achievement at the end of the school year was expressed through grade point average (GPA) on a scale of 1 to 5 (where 5 indicated the best performance). These data were obtained from the school records.

The size of the sample was determined using G-power 3.0.10 (with an expected power of 0.95 and significance level α=0.05). Statistical analysis of collected data was carried out using SPSS 20.0 software (Statistical Package for the Social Sciences, Institute Inc., Chic, IL, USA). The following correlations were analyzed:

– eating habits/lifestyles and nutritional status;
– IQ test results/academic achievements and eating habits/lifestyles;
– IQ test results/GPA and BMI percentile;
– IQ test results and GPA.

The dependence of all these variables on gender was also examined. The correlations between categorical data were investigated using chi-square (χ^2) test. Differences were considered statistically significant at $p \leq 0.05$. Bivariate Spearman correlation analysis was applied in order to examine the correlations between continuous variables (IQ test results, GPA and BMI). The distribution of continuous variables was previously tested for normality using the Kolmogorov-Smirnov test.

Results

Sample characteristics

The mean age of adolescents was 16.4 ± 1.1 y (ranged from 15 to 19 y). Table 1 shows the results of anthropometric measurements as well as the indicators of intellectual abilities of the studied population. The mean value of height, weight, waist circumference and circumference of upper arm of boys were significantly higher ($p < 0.001$) than those of girls.

Anthropometric measurements

The results of BMI and BFP measurements are given in Table 2. The most of the students had normal body weight, 4% were underweight, while 14.5% of students were categorized as overweight or obese. High BFP was detected in 6% of the students while very high BFP was measured in 9.9%. Spearman correlation coefficient showed strong positive correlation between BFP and BMI-percentile (ρ=0.557) but there was no statistically significant correlation between BMI-percentile (or BFP) and gender.

Table 1. The results of anthropometric measurements, IQ tests and academic achievements

	Mean ± SD	Mean ± SD for boys	Mean ± SD for girls
Height [cm]	177.3 ± 9.4	181.0 ± 7.1	166.4 ± 6.9
Weight [kg]	68.9 ± 14.0	72.4 ± 13.1	58.4 ± 11.2
Waist circumference [cm]	78.4 ± 9.7	81.3 ± 8.7	69.4 ± 6.3
Circumference of upper arm [cm]	27.1 ± 3.8	28.3 ± 3.2	23.4 ± 2.9
BFP	19.3 ± 8.1	16.8 ± 7.1	26.6 ± 6.5
BMI-percentile	53.4 ± 28.1	54.5 ± 28.0	50.2 ± 28.7
IQ	99.8 ± 9.8	101.9 ± 9.6	93.4 ± 7.6
GPA	3.6 ± 1.1	3.6 ± 1.1	3.7 ± 1.2

Table 2. The results of BMI and BFP measurements

	Total [%]	Boys [%]	Girls [%]
Underweight	4.0	3.5	5.3
Normal	81.5	81.4	81.6
Overweight	7.9	8.0	7.9
Obese	6.6	7.1	5.3
Low BFP	13.9	15.9	7.9
Normal BFP	70.2	68.1	76.3
High BFP	6.0	6.2	5.3
Very high BFP	9.9	9.7	10.5

Eating habits and lifestyles

Table 3 presents eating habits and life styles of the students by gender and BMI classification. Overall 68.2% of the students declared that they never skipped breakfast and 21.2% reported having five or more meals per day. Having three or less meals per day was more common among students with increased body weight.

Almost a third of all students claimed they spent more than three hours a day in front of a computer. This habit was more typical for boys than for girls. On the other hand, totally 86.1% of the respondents self-declared as physically active, either through organized sport trainings or individual exercises. Surprisingly, physical activity was more prevalent among the students with BMI ≥ 85th. More than half of these students admitted they were not satisfied with their physical appearance, but only a fifth of them had ever been on a diet in order to lose weight.

The frequencies of consuming some particular foods and drinks are given in Table 4. A high intake of milk and milk products was reported. More than half of the sample reported everyday consumption of fruit and vegetables. However, fast food appeared to be very popular, especially among boys (82.3%) but only 18% of all students were aware they had bad eating habits. Besides, 4% of the respondents reported everyday consumption of alcoholic and energy drinks, most of them being males. These bad habits were more frequent in overweight and obese students.

According to the students' additional responses, the most common way of preparing food was boiling (used by 47.7% of all students - 65.8% of girls and 41.6% of boys), while frying had a prevalence of 45.7%, (more boys than girls, 51.3% vs 28.9%). There was a statistically significant correlation between gender and food preparation ($p = 0.034$), but there was no correlation between BMI-percentile and the different ways of preparing food.

The questionnaire also included questions related to the most popular types of bread, meat, milk products and fat in the diet. White bread was most frequently consumed while only 2% of students reported regular consumption of whole-wheat bread. The most frequently consumed types of meat were pork (consumed by 66.9% of all students), chicken (41.7%) and beef (19.9%). Frequent consumption of deli meats was also reported by 45.7% of the respondents. The most common type of fat was sunflower oil (used by 88.1% of students), followed by animal fat (43%), olive oil (22.5%) and butter (17.9%). Daily consumption of yogurt was the highest 80.1%, followed by milk 75.5% and cheese 59.3%. Most of the students reported low consumption of whole grain cereals, fish and sea food. However, no significant correlation between all these eating habits and BMI-percentile was found.

IQ test and academic performance

Table 5 presents intelligence quotients and academic achievements of the students. IQ-test results ranged between 73 and 118. Overweight and obese students had slightly higher average IQ (103.5) than those with BMI < 85 percentile (99.3). IQ >110 was measured in 38.5% of overweight and obese students, while only 15.7% of the students with BMI < 85 percentile had high average IQ. Almost a quarter of the boys had IQ >110, while not a single girl had such a high result, possibly due to the small sample size. However, the grade point averages of girls and boys were almost equal. The correlation between IQ and academic achievement was very low (Spearman ρ=0.109).

The correlations between eating habits and the students' intellectual capabilities were investigated.

Table 3. Lifestyles and eating habits of the adolescents by gender and BMI classification

Lifestyles and eating habits	Total [%]	BMI < 85th percentile [%]	BMI ≥ 85th percentile [%]	χ^2 test by BMI percentile: pearson/df/p	Boys [%]	Girls [%]	χ^2 test by gender: pearson/df/p
1. Always having meals at the same time				0.141/1/0.707			0.108/1/0.742
Yes	35.1	34.1	40.9		36.3	31.6	
No	64.9	65.9	59.1		63.7	68.4	
2. Number of meals per day				3.225/2/0.199			2.563/2/0.278
≤3	41.7	38.8	59.1		38.1	52.6	
4	37.1	39.7	27.3		38.9	31.6	
≥5	21.2	22.5	13.6		23.0	15.8	
3. Skipping breakfast				0.063/1/0.802			0.327/1/0.567
Yes	31.8	31.0	36.4		30.1	36.8	
No	68.2	69.0	63.6		69.9	63.2	
4. Eating after 10 pm				5.808/2/0.055			1.497/2/0.473
Every day	28.5	31.8	9.0		31.0	21.1	
Sometimes	42.4	26.3	45.5		41.6	44.7	
Never	29.1	41.9	45.5		27.4	34.2	
5. Varying in weight ≥ 5kg				2.944/1/0.086			0.496/1/ 0.481
Yes	49.0	45.7	68.2		46.9	55.3	
No	51.0	54.3	31.8		53.1	44.7	
6. Ever being on a diet				9.652/1/0.004			3.134/1/0.045
Yes	6.0	3.1	22.7		3.5	13.2	
No	94.0	96.9	77.3		96.5	86.8	
7. Satisfied with the physical appearance				11.607/1/0.010			2.556/1/0.147
Yes	69.5	75.2	36.4		73.5	57.9	
No	30.5	24.8	63.6		26.5	42.1	
8. Physical activity ≥ 2 times a week				1.220/2/0.541			6.638/2/0.210
Sports training	28.5	29.5	22.7		33.6	13.2	
Exercising on their own	57.6	55.8	68.2		54.9	65.8	
No	13.9	14.7	9.1		11.5	21	
9. Time spent in front of computer				0.278/2/0.430			5.764/2/0.056
>3h	27.2	27.1	27.3		30.1	18.4	
1-3 h	49.7	50.4	45.4		51.3	44.7	
<1h	23.1	22.5	27.3		18.6	36.9	

Table 4. The frequencies of consuming some foods and drinks

Consumption of:	Total [%]	BMI < 85th percentile [%]	BMI ≥ 85th percentile [%]	χ^2 test by BMI percentile: pearson/df/p	Boys [%]	Girls [%]	χ^2 test by gender: pearson/df/p
1. Meat				0.765/1/0.332			0.689/1/0.407
Every day	33.1	34.9	22.7		35.4	26.3	
Sometimes	66.9	65.1	77.3		64.6	73.7	
2. Milk and milk products				0.277/1/0.270			0.054/1/0.680
Yes	95.4	96.1	90.9		94.7	97.4	
No	4.6	3.9	9.1		5.3	2.6	
3. Vegetables				0.000/1/1.000			0.639/1/0.543
Every day	55.0	55.0	54.5		53.1	60.5	
Rarely	45.0	45.0	45.5		46.9	39.5	
4. Fruit				0.203/1/0.637			1.425/1/0.233
Every day	61.6	60.5	68.2		58.4	71.1	
Rarely	38.4	39.5	31.8		41.6	28.9	
5. Nuts				1.010/2/0.604			0.747/2/0.688
Yes	39.1	38.8	40.9		38.9	39.4	
No	8.6	7.8	13.6		9.7	5.3	
Sometimes	52.3	53.4	45.5		51.4	55.3	
6. Whole grain cereals				0.000/1/1.000			6.016/1/0.215
Yes	39.7	39.5	40.9		33.6	57.9	
No	60.3	60.5	59.1		66.4	42.1	
7. Added salt				0.544/1/0.334			0.452/1/0.501
Yes	84.8	86.0	73.5		83.2	89.5	
No	15.2	14.0	26.5		16.8	10.5	
8.Fast food				0.000/1/0.778			1.570/1/0.165
Yes	79.5	79.8	77.3		82.3	71.1	
No	20.5	20.2	22.7		17.7	28.9	
9.Fish and seafood				0.007/1/0.817			0.053/1/0.818
Regulary	42.4	41.9	45.5		43.4	39.5	
Rarely or never	57.6	58.1	54.5		56.6	60.5	

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Table 4. The frequencies of consuming some foods and drinks

10. Alcoholic drinks				4.510/2/0.273		0.273/1/0.601
Every day	4.0	3.1	9.1		5.3	0.0
Sometimes	59.6	62.8	40.9		56.6	68.4
Never	36.4	34.1	50		38.1	31.6
11. Energy drinks				2.480/2/0.289		1.863/1/0.172
Every day	4	3.1	9.1		4.4	2.6
Sometimes	49	48.1	54.5		52.2	39.5
Never	47	48.8	36.4		43.4	57.9
12. Coffee				0.191/2/0.909		0.729/2/0.694
Every day	23.8	23.3	27.3		22.1	28.9
Sometimes	22.6	22.4	22.7		23	21.1
Never	53.6	54.3	50		54.9	50
13. Sweetened juices				1.509/2/0.470		0.004/2/0.988
Every day	36.4	35.7	40.9		36.3	36.8
Sometimes	58.3	58.1	59.1		58.4	57.9
Never	5.3	6.2	0.0		5.3	5.3
14. Carbonated drinks				3.119/2/0.210		3.755/2/0.153
Every day	24.5	22.5	36.4		25.7	21.1
Sometimes	62.3	65.1	45.5		58.4	73.7
Never	13.2	12.4	18.1		15.9	5.2

Table 5. IQ and grade point average (GPA) by gender and body mass index (BMI percentile)

	IQ < 90	**90 ≤ IQ ≤ 110**	**IQ >110**	**GPA ≤ 3.5**	**GPA > 3.5**
BMI percentile < 85	16.7%	67.6%	15.7%	23.5%	76.5%
BMI percentile >85	7.7%	53.8%	38.5%	30%	70%
Boys	11.6%	64%	24.4%	25.7%	74.3%
Girls	27.5%	72.4%	0%	21.1%	78.9%
Total	15.6%	66.1%	18.3%	24.5%	75.5%

Students with low academic achievements (GPA<3.5) reported higher frequencies of consuming red meat, deli meats, fast food, coffee, and alcohol. The consumption of carbonated and energy drinks, as well as eating after 10 pm were also more common among the students with low academic achievements. On the other hand, these students (GPA<3.5) were more interested in sport training and they spent less time in front of a computer. The difference in consuming beef (p=0.026), fast food (p=0.044), coffee (p=0.002), and physical activities (p=0.009) were statistically significant.

Besides, a significant correlation was found between students' IQ-test score and height (Spearman's ρ=0.352).

Discussion

The study revealed that 7.9% of the students were overweight. This result is either comparable to or significantly lower than the values reported from other countries (24-26). The prevalence of obese children (6.6%) is quite low in comparison to the data obtained in some developed countries like USA (15%), UK (20%) and France (14%) (26). In contrast to some other studies (24, 28, 29), no significant difference was observed in the prevalence of overweight and obesity among males and females. Females increase their body fat mass during puberty while boys, in contrast, stabilise their fat mass and enlarge their fat-free mass (30). However, female adolescents are generally more concerned about their weight status and they are more inclined to dieting. They are also more interested in developing healthy eating habits. Accordingly, the study confirmed that boys had higher prevalence of consuming fast foods, red meat, alcohol and energy drinks.

On the other hand, skipping breakfast is more common among girls than boys. Although this difference was not found to be statistically significant, it confirmed the results of some previous studies (31, 32). Regular breakfast consumption was reported by 68.2% of all students, with higher prevalence among the students with normal weight. It has already been suggested that skipping breakfast is associated with increased risk of cardiovascular diseases and obesity (33, 34). Breakfast intake may also have positive effects on students' cognitive functions related to memory, test grades, and school achievements (35). However, this study found no significant correlation between breakfast pattern and GPA (or IQ test results).

Furthermore, 41.7% of the students reported having only three or less meals per day. This percent is lower than those obtained for the majority of European students (36,37). New recommendations for adequate and balanced nutrition propose having five meals (three main meals and two snacks) per day.

More than half of the students reported everyday consumption of fruit and vegetables, which is more in comparison to other countries (38). This can be considered as a very good habit since the regular intake of fruit and vegetables can improve protection against obesity, cardiovascular diseases, and even some types of cancer (39, 40). A higher percentage of girls than boys reported frequent consumption of fruits and vegetables.

Many studies have supported positive effects of physical activity on the body weight status of youth and adults (41-44). The present study found a high percentage of students who declared themselves as very active. Boys were more physically active than girls, confirming the results of some previous studies (45,46). However, no significant correlation was found between physical activity and students' BMI. Overweight and obese students appeared to be even more active than those with normal body weight. This could be explained by the fact that students with high BMI were rather concerned about their health and physical appearance and many of them reported doing exercises in order to lose weight.

Almost one third of the respondents reported spending more than three hours a day in front of a computer screen. More boys than girls seemed to be addicted to computers and Internet. Sedentary lifestyles increase the risk of obesity, cardiovascular diseases, diabetes, and colon cancer (47, 48).

Although there is a number of studies indicating an inverse association between intellectual capabilities and obesity (11-13,49,50), the results of our investigation could not confirm this association. However, similar results have been reported by some other authors too (51-53). Our study has even found a bit higher average intelligence quotient in overweight and obese students, but the correlation between IQ score

and BMI-percentile was not statistically significant (ρ=0.144). However, these students (BMI percentile>85) had lower academic achievements and slightly lower GPA. One possible reason for this may be the fact that obesity can cause some mental problems such as low self-esteem, anxiety disorders or depression that can reduce students' academic performances (54,55). On the other hand, students with higher intellectual capabilities seem to have healthier eating habits but less physical activities. Although the association between intellectual capabilities and nutritional status was not confirmed, a significant correlation was found between students' IQ-score and height. This result is in agreement with some previous studies (17-19) and can be explained by both, genetic and environmental factors (56,57).

Conclusions

The prevalence of obesity is relatively low in comparison to developed countries. No statistically significant correlation was found between eating habits and students' body mass index. It suggests that weight status of adolescents is also influenced by many other factors such as genetics, hormonal status, socioeconomic status etc. Students' dietary habits were not associated with their intellectual capabilities. Students with lower academic achievements were more prone to some bad eating habits, but they also reported to be more physically active than those with better school outcomes.

Competing interests: No conflicts of interests.

Ethical approval: The study was approved by the school board and the Faculty of Medical Sciences Ethics Committee, University of Kragujevac.

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