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Original Article

Relationships between Dietary *Inflammatory* Index and Intelligence Quotient in Female Students Aged 15–18 Years in Districts 1 and 19 of Tehran, 2020

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ABSTRACT

Background and Objectives: Increased dietary inflammatory index can be one of the factors affecting brain function and occurrence of academic failure in adolescents. There are evidence that diet modification in adolescents and anti-inflammatory diets play important roles in improving intelligence quotient and further academic achievements in adolescents. The aim of this study was to investigate relationships between dietary inflammatory index and intelligence quotient in adolescent girls.

Materials and Methods: In this cross-sectional study, 162 female students were selected using cluster sampling. Raven intelligence quotient test was used to measure student intelligence quotient. Dietary inflammatory index score was calculated through food data collected using 3-day food recalls.

Results: The mean age of the 162 students was 16.3 y ±1.06 and the mean value of using intelligence was 103± 9.8. Nearly 74% of the students had moderate intelligence and 17% were smart.The mean dietary inflammatory index score in these individuals was -0.08 ±1.54. No significant relationships were seen between dietary inflammatory index and intelligence quotient in the crude model and after adjusting for confounding variables.

Conclusions: No significant relationships were reported between diet inflammatory index score and intelligence quotient in adolescents. Extensive and prospective studies on genetic and environmental factors affecting intelligence quotient are recommended.

Keywords: Dietary inflammatory index, Intelligence quotient, Adolescent

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Introduction

Intelligence quotient (IQ) is the score of a test that compares cognitive skills (attention, memory, judgment, assessment, comprehension, language skills, reasoning, inference and abstract thinking) of the subject to the general population. The IQ is achieved by dividing the mental age by the chronological age of the individual. Techniquelly, IQ is not similar in all people and individual differences such as physiological factors, heredity, learning, family status, socio-environmental conditions and individual factors play roles in the level of IQ (1). Distribution of IQ in a society and in people of the world follows a normal curve. The IQ is averaged 100 and the standard deviation is 15. In classification and division of intelligence, nearly 70% of the world people have moderate, 12% have above-average and 12% have below-average intelligence. Moreover, 2% are very intelligent and 2% are very low intelligent. Nearly 1% of people are highly intelligent and 1% are mentally retarded (2). Inflammation is a defensive reaction against harmful stimuli that can trigger defensive responses in the body. Studies have shown that systemic inflammation can stimulate the immune system to cause inflammation in brain and over-increase the neurotoxic metabolites of the quinornine pathway, which are responsible for regulating inflammatory pathways in central and peripheral nervous systems (3). This abnormal increase with the increase of pro-inflammatory cytokines in brain leads to increased oxidative stress and decreased total antioxidant capacity and thus oxidative damages, which can cause destruction of neurons in brain and neurotoxic effects. In fact, one of the factors that affect IQ is frontal lobe shape and size (4,5). Several factors lead to chronic inflammation in children and adolescents. One of the most important factors is unhealthy diet. Adolescents consume low-value foods for various reasons such as inappropriate eating habits in the family, lack of nutritional awareness, low parental

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supervision, high influence from peers and lack of healthy foods in school cafeterias. Consumption of these low-value foods such as fast foods, fried foods, red meats, refined grains, sweets and snacks can lead to increased inflammation in the body (6). Several studies verified relationships between the serum markers of inflammation such as IL-6, CRP, IL-10 and TNF-α and IQ in children, adults and eldery people (7–11). Studies on relationships between systemic inflammation and nutritional factors have shown that dietary inflammatory index (DII) reflects inflammatory potential of the diet. Studies have shown that use of anti-inflammatory diets such as fruits, vegetables, fish, omega-3 and fibers can decrease systemic inflammation by modulating preinflammatory cytokines (12,13). In two studies, significant relationships between increased DII and decreased cognitive function in adults were shown (14,15). Use of inflammatory diets can include devastating effects on individual cognitive functions. Evidence suggest that diet modification in adolescents play important roles in improving brain functions, increasing IQ and ultimately increasing their learning and academic achievement, as well as decreasing occurrence of age-linked cognitive disorders such as Alzheimer's disease in middle age (16,17). Since no studies have been carried out on relationships between DII and IQ in adolescents, the aim of the present study was to investigatethese relationships in female adolescent students.

Materials and Methods

The present study was a cross-sectional descriptive-analytical study carried out on 162 female students (81 students from District 1 and 81 students from District 19), Tehran, Iran, using random cluster sampling. Since socioeconomic differences could be considered as a background variable in this study, District 1 as a northern rich area and District 19 as a poor southern area were studied. Due to the limitations of the present study, availability of non-governmental schools in District 1 and availability of only public secondary schools in District 19, two private high schools and one state secondary school from District 1 and two governmental high school and one secondary school from District 19 were selected and a total of six schools entered the study after receiving necessary permissions and approvals from the Ministry oF Education, Iran. Due to the known number of the study population, Cochran-Morgan formula was used for sampling with 90% quantile calculation and a total of 162 students were randomly selected from Grade 9 of the high school and Grades 10, 11 and 12 of secondary school. Due to the prevalence of Covid-19 and school closures, the study was described for the students online and informed consent forms were sent to the students, which must be completed by the parents and the students. Then, students who completed their forms and needed criteria were included in the study and asked for their socioeconomic status, physical activity, weight, height and food intake. Inclusion criteria were an age range of 15–18 years, willingness to participate in the study, no acute or chronic diseases such as diabetes and liver or kidney diseases or problems that could occured during pregnancy/infancy affecting student IQ such as maternal smoking, thyroid dysfunction in mothers and students, no special diets for any reasons (e.g. weight loss and vegetarian diets) and no prescribed medicines and supplements. The study was approved by the Research Ethics Committee of the Faculty of Medical Sciences, Science and Research Branch (ethical codeIR.IAU.SRB.REC.1399.007).

Anthropometric measurements

Due to the limitations caused by Covid-19 and school closures, it was not possible to measure height and weight of the students in person. Therefore, student weight and height were asked online. Body mass index (BMI) wascalculated by dividing weight in kilogram by height in square meter. Students with BMI for age of the World Health Organization (WHO) were classified into very thin (Z-score <-3), lean (Z-score <-2), normal weight (-2 < Z-score < 1), weight gain (1 < Z-score < 2) and obese (2 > Z-score) groups. Based on the height chart for age of WHO, students were divided into groups of severe short stature (Z-score < -3), short stature (-3 < Z-score < -2), normal height (-2 < Z-score < 3) and tall height (Z-score > 2) (18).

Assessment of dietary intake

The 24-h food recall questionnaires were validated by the Nutrition Methodology Working Group (19). Data of student food intakes were collected online using 24-h food recall questionnaires within three consecuent days (two week days and one weekend). Students were recommended to ask their mothers about the components and quantities of foods they ate. Quantities of foods were converted to grams using home scale guide. Foods were coded according to the instructions of Nutritionist-IV Program. Codes were entered N4 Software and analyzed. Thus, values of energy intake, nutrients and share of carbohydrates, protein and fats in the energy supply were calculated.

Calculation of dietary inflammatory index

The DII was actually a scoring algorithm based on an extensive review of the literature (1950–2010) that links 1943 articles to food parameters, including various macronutrients and micronutrients. Each food parameter was scored according to whether it increased (+1), decreased (-1) or included no effects (0) on the six inflammatory indices of IL-1β, IL-4, IL-10, IL-6, C-reactive protein (CRP) and tumor necrosis factor-alpha

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(TNF-α). The DII was calculated based on the intake of 45 nutritional parameters, which inflammatory score, mean and SD of the global intake were calculated. In DII score calculation process, intakes of each of 45 food parameters were first achieved from the 24-h food reminders. Then, values of each variable were subtracted from the corresponding mean global intakes and divided by the global SD to achieve Z-scores. To minimize effects of right skewness, Z-scores were converted to a portion (value 0 to 1) and centered by multiplying by 2 and subtracting 1. Then, numbers for each food parameter were multiplied by the corresponding inflammatory scores and inflammation scores of all food parameters were summed to achieve the total inflammatory scores for each person. Higher (more positive) DII scores indicated more pro-inflammatory diet and lower scores represented anti-inflammatory diets. The theoretical minimum of the DII score was -8.87, while the maximum score was +7.98 (20). In the present study, 35 dietary parameters [energy intake, protein, total fat, fiber, saturated fatty acid (SFA), mono-unsaturated fatty acid (MUFA), poly-unsaturated fatty acid (PUFA), trans fatty acids, Omega 3, omega 6, cholesterol, carbohydrates, caffeine, vitamin A, beta-carotene, thiamine, riboflavin, niacin, vitamin B6, folate, vitamin B12, vitamin C, vitamin D, iron, zinc, vitamin E, magnesium, selenium, green, black tea , garlic, onion, pepper, turmeric, ginger and saffron] were used to calculate DII.

Assessment of intelligence quotient

Raven progressive matrix test is a non-verbal intelligence test developed by Raven in the UK to measure Spearman's general factor (g) and is used to measure the intelligence of individuals with moderate and above-average mental abilities (11 years to adulthood) (21). Cronbach's alpha coefficient of this questionnaire was 0.82, which revealed appropriate validity of this questionnaire (22). Based on this test, scores between 90 and 110 were reported as average, 110 to 120 as smart, 120 to 127 as very smart and those above 127 as excellent intelligence (21).

Assessment of other variables

General information questionnaires were used to assess students' age, level of education and occupation as well as their parents' economic status. Data of the students' physical activity were collected using international physical activity questionnaire (IPAQ) (23). Economic statuses were assessed using number of items they possessed (personal homes, personal cars, washing machines, large color flat-screen TVs, dishwashers, freezers or twin freezers, hand-woven carpets, computers and microwaves). Possessing ≤ 3 of these items was reported as poor economic status, having 4 to 6 items was reported as moderate economic status and having 7 to 9 was recorded as good economic status.

Statistical Assessment

SPSS Software v.24 (IBM Corporation, Armonk, NY, USA) was used for data analysis and p-value < 0.05 was considered statistically significant. Kolmogorov-Smirnov test was used to assess normality of the distribution of variables. The mean standard deviation was used to describe quantitative variables, and the frequency report was used to describe qualitative variables. To compare quantitative variables between the two groups of students in Districts 1 and 19, independent t-test was used. To compare qualitative variables in the two districts, Chi-square test was used. To investigate relationships between IQ and DII, linear regression was used in crude form and after adjustment for confounding variables.

Results

In this study, the mean value of IQ was 103 ±9.8. A total of 74% of the students had moderate intelligence and 17% were smart. The mean DII score in these individuals was -0.08 ±1.54. Table 1 shows IQ scorse, demographic characteristics and economic statuses of the students in Districts 1 and 19 within inflammatory index tertiles. No significant relationships were seen between the highlighted variables and DII ($p < 0.05$).In Table 2, components of DII are presented based on DII tertiles in Districts 1 and 19. With increasing DII score, consumption of SFA and total fat significantly increased ($p < 0.01$) and consumption of energy, carbohydrates, protein, vitamin B6, thiamine, riboflavin, folic acid, magnesium, zinc, selenium, fibrin, green/black tea, caffeine, beta-carotene, iron, omega-3 and omega-6 fatty acids, vitamins A, C and E, PUFA and MUFA decreased ($p < 0.05$). Relationships between IQ scores and DII tertiles in Districts 1 and 19 are shown in Table 3. The first tertile was used as reference. In crude model, no significant relationships were seen between IQ and DII. After adjusting for age, education level, parents' job and economic status in Model 1 and further adjustment for BMI for age and physical activity in Model 2, no associations were detected (data are not shown in the table).

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Table1. Intelligence quotient scores, demographic characteristics and economic statuses of the students in Districts 1 and 19based on the tertiles of dietary inflammatory index

		The whole population				
		Tertile1	Tetile2	Tertile3	Total	p *
		(3.68-(-0.81))	(-0.82-0.65)	(0.66–3.61)	n=162	
		n=54	n=54	n=54		
IQ		103.54±8.8	102.44±10.6	103.04 ±10.1	103.67±9.8	0.39
age		16.4± 1.02	16.1± 1.08	16.4±1.09	16.3±1.06	0.42
weight		62.7± 11.2	63±10.5	60.9±12.8	62.2±11	0.06
height		1.63±0.05	1.62±0.05	1.62±0.05	1.62±0.05	0.74
BMI		23.4± 3.6	22.8± 4.04	23.8±3.7	23.3±3.8	0.41
BMI status for age						
	thin	5(3.9)	2(3.7)	4(4.7)	11(6.8)	
	normal	33(1.61)	31(57.4)	37(68.4)	101(62)	0.62
	obese	1 (1.9)	5(3.9)	5(3.9)	11(6.8)	
height staus for age						
	short	1 (1.9)	2(3.7)	0(0)	3(1.9)	
	normal	53(98.1)	52(96.3)	54(100)	159(98.1)	0.36
physical activity						
	intense	4(7.4)	2(3.7)	0(0)	6(3.7)	
	moderate	8(14.8)	9(16.7)	12(22.2)	29(17.9)	0.44
	low	42(77.8)	43(79.6)	42(77.8)	127(78)	
mother's education						
	highschool	8(14.8)	13(24.1)	12(22.2)	33 (20.4)	
	Diploma	12(22.2)	19(35.2)	16(29.6)	47(29)	
	Bachelor	24(44.4)	17(31.5)	17(31.5)	58(35.8)	0.56
	Master	7(13)	3(5.6)	7(13)	17(10.5)	
	PhD	3(5.6)	2(3.7)	2(3.7)	7(4.3)	
father's education						
	highschool	10(18.5)	16(29.6)	7(13)	33(20.4)	
	Diploma	6(11.1)	10(18.5)	10(18.5)	26(16)	
	Bachelor	27(50)	20(37)	26(48.1)	73(45.1)	0.47
	Master	7(13)	6(11.1)	6(11.1)	19(11.7)	
	PhD	4(7.4)	2(3.7)	5(9.3)	11(6.8)	
mother's job						
	Doctor	3(5.6)	2(3.7)	1(1.9)	6(3.7)	
	employee	11(2)	10(18.5)	11(20.4)	32(19.8)	
	military	0(0)	0(0)	1(19)	1(6)	0.85
	teacher	5(9.3)	5(9.3)	9(16.7)	19(11.7)	
	self-employment	4(7.4)	3(5.6)	4(7.4)	11(6.8)	
	housekeeper	31(57.4)	34(63)	28(58.9)	93(57.4)	
father's job						
	Doctor	4(7.4)	2(3.7)	5(9.3)	11(6.8)	
	employee	15(27.8)	15(27.8)	15(27.8)	45(27.8)	0.68
	military	5(9.3)	6(11.1)	5(9.3)	16(9.9)	
	manual worker	4(7.4)	10(18.5)	6(11.1)	20(12.3)	
	teacher	6(11.1)	2(3.7)	7(13)	15(9.3)	
	self-employment	37(20)	19(35.2)	16(29.6)	55(34)	
economic status						
	good	29(53.7)	17(31.5)	19(35.2)	65(40.1)	
	moderate	17(31.5)	25(46.3)	22(40.7)	64(39.5)	0.15
	poor	8(4.8)	12(22.2)	13(24.1)	33(20.4)	

* ANOVA test or Chi-square test.

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Table 2. Dietary inflammatory index components based on the tertiles of dietary inflammatory index scores in students of Districts 1 and 19

	The whole population				
	Tertile 1 (-3.68- (-0.81)) n=54	Tertile 2 (-0.82-0.65) n=54	Tertile 3 (0.66 – 3.61) n=54	total n=162	$p*$
Energy (Kcal)	632±2510	510 ± 2109	494 ±1678.6	641 ±2102	0.0001
Protein (g)	60±100.09	34.2 ± 83.02	27.7± 57.06	46.4± 80.06	0.0001
Carbohydrate (g)	114 ± 400	85.5±331.5	76.5 ± 258.3	109± 330.2	0.0001
Total fat (g)	23.7 ± 47.9	22.2±53.05	20.04 ± 68.1	23.5± 56.4	0.0001
Cholesterol (mg)	181 ± 197	119.4 ± 155.7	127.3 ±161	145.7 ±171	0.28
Saturated fatty acid (g)	7.3 ±15.09	10.7 ±16.4	7.6 ± 20.1	8.9 ±17.2	0.008
MUFA (g)	7.4 ± 23.06	8.2 ± 18.1	8.5 ±16.06	8.5±19.07	0.0001
PUFA (g)	6.95 ± 16.7	5.8±13.6	5.04 ± 10.5	6.4±13.6	0.0001
Omega 6 (g)	6.54± 15.4	5.3 ±11.6	4.7± 9.03	6.1±12.02	0.0001
Omega 3 (g)	0.58±0.66	0.54 ±0.62	0.34± 0.41	0.5 ±0.56	0.01
Trans fat (g)	0.2 ± 0.004	0.01 ± 0.0003	0.02 ±0.0002	0.1±0.001	0.15
Vitamin C (mg)	77.2± 102	40.6 ± 48.8	46.6±39.9	63.2±63.8	0.0001
Vitamin A(µg)	1136 ±796	536.6±346	167.6±204.3	770.4±449	0.0001
Vitamin D(µg)	1.5 ± 1.19	1.08±1.22	0.95 ± 1.16	1.07±1.32	0.64
Vitamin E (mg)	4.7± 14.8	4.6 ±11.4	4.1± 9.5	4.9±11.9	0.0001
Thiamin (mg)	1.07 ± 2.9	0.78 ± 2.5	0.67 ±1.81	0.96± 2.41	0.0001
Riboflavin (mg)	0.9±2.3	0.65± 1.7	0.6 ±1.23	0.8± 1.77	0.0001
Iron(mg)	8 ± 24.6	5.8± 19.48	4.5 ± 13.6	7.8±19.1	0.0001
Niacin(mg)	10±31.1	9.9 ±28.1	9.5 ±20.5	11 ± 26.6	0.13
Vitamin B12(µg)	10 ±4.11	4.72 ±2.6	1.3 ±1.76	6.6 ± 2.85	0.15
Vitamin B6 (mg)	0.5 ± 2.08	0. 5 ±1.6	0.5± 1.1	0.6 ±1.6	0.0001
Folic acid(µg)	257 ± 697	188± 628	157± 466	255 ±597	0.0001
Magnesium (mg)	204±511	139.8 ±326	70.1± 205.6	194.4 ±347	0.0001
Zinc(mg)	5.12 ±13.8	3.45 ±10.38	2.69 ± 7.14	4.75±10.4	0.0001
Selenium (µg)	98 ±183.7	60.9± 126.9	37.2±82.48	81.3±131	0.0001
Beta-carotene(µg)	5400±4727	1759±2165	1317.7±730.5	3675±2630	0.0001
Total Fiber (g)	30.6 ±64.8	34.1±57.1	31.9±39.5	33.7± 53.8	0.0001
Caffeine (g)	0.03 ±0.01	0.03 ± 0.02	0.03±0.01	0.03±0.02	0.02
Black/green tea (g)	0.24 ±0.22	0.26 ±0.13	0.16±0.14	0.19±0.18	0.01
Pepper(g)	34 ± 20.9	25± 14.6	39.7±22.5	33.6±19.3	0.44
Turmeric (mg)	2.6 ± 4.01	2.8 ±3.87	2.4±3.13	2.6±3.6	0.19
Garlic (g)	0.3 ±0.17	0.6 ±0.27	0.3±0.22	0.4±0.22	0.51
Onion (g)	58 ± 121	49± 109.7	56.6±128	55± 119.6	0.23
Ginger(g)	0.0003± 0.0001	0.00005±0.00002	0.00006±0.00002	0.007±0.0003	0.06
Saffron(g)	0.001±0.0001	0.0002±0.0001	0.0006±0.0003	0.006±0.0001	0.52

*ANOVA test, Data are expressed as mean ± SD

Table 3. Standardized regression coefficients (B), confidence intervals (95% Cl) and P-trend of the associations between dietary inflammatory index scores and intelligence quotient scores of students from Districts 1 and 19

	Tertile1 (-3.68- (-0.81))	Tertile2 (-0.82-0.65)	Tertile3 (0.66 – 3.61)	$p - trend*$
Total population	1.00	-1 (-4.8-2.6)	1.5 (-2.2-5.2)	0.39
District 1	1.00	-2.9 (-8.7-2.8)	1.2 (-4.4-6.8)	0.38
District 19	1.00	0.64 (-4.4-5.7)	2.04 (-3.1-7.2)	0.71

*linear regression
Only unadjusted models are given

Discussion

This study investigated relationships between DII and IQ in 162 female students aged 15–18 years in Districts 1 and 19 of Tehran, Iran. Based on the results, no significant associations were reported between IQ and DII in students of these two districts. As far as the authors know, no similar studies are available in this field. However, several studies have assessed relationships between dietary patterns and IQ or cognitive ability of individuals. Results of these studies showed no significant relationships between IQ and following dietary approaches to stop hypertension (DASH) diet or the Mediterranean diet as anti-inflammatory diets (24–27).In studies that assessed dietary pattern in the middle-aged individuals, risks of cognitive impairment in groups, who followed western and unhealthy diets (e.g. meats, refined grains, fried foods and processed foods) were not different from the groups, who followed healthy diets (e.g. further fruits and vegetables) (28,29). These results were similar to those from the present study. In contrast with these results, a number of studies reported significant inverse relationships between DII and memory or cognitive functions; hence, cognitive and memory functions decreased by increasing DII, and earlier onset of cognitive disorders such as Alzheimer's disease were detected (15,30,31). These different results might be due to differences in participants' age and race as well as number of dietary parameters used to calculate DII, various methods of collecting food intake data and effects of confounding variables. In addition to genetic factors, intelligence is affected by the environmental factors such as maternal nutrition during pregnancy. During pregnancy, fetal nerve functions are developing and brain development in the last trimester of pregnancy is particularly vulnerable to maternal dietary inadequacies. Maternal diet during pregnancy includes long-term effects on IQ and cognitive development of children (32–34). Studies by Freitas et al. and Vilela et al., have shown that children whose mothers ate more fruits and vegetables during pregnancy compared to children whose mothers ate more meats, white breads and coffees during pregnancy had higher IQs at the school age (35,36). Furthermore, early years of life play important roles in neurodevelopmental processes of the brain. Environmental factors such as breastfeeding and type of infant feeding early in life affect these processes (37). Studies showed that infants who were breastfed in the early years of life, had 2–5 higher IQ scores than children who were not breastfed in the early years of life (38,39). Their results showed that these factors included long-term effects on the cognitive ability of teenagers. Based on the studies and the lack of relationships between IQ and DII scores in adolescence in the present study, it seems that factors such as maternal nutritional status during pregnancy, breastfeeding and type of early life nutrition include higher effects on improving IQ and cognitive function of the adolescents, compared to diet alone during adolescence (40–43). This study was limited to only two districts of Tehran. In addition, cross-sectional design of the study, sampling in girls alone, dependence of nutritional information on the memory of participants and online sampling due to the prevalence of Covid-19 and school closures were other limitations of this study. As far as the authors know, this is the first study which assessed relationships between DII and IQ in adolescents. Furtheremore, sampling from two districts of Tehran with different economy and cultur statuses was another strenght of the current study.

CONCLUSION

Results of the present study showed that no significant associations between DII score and IQ score is adolescent female students. Prospective controlled studies are warranted to investigate these associations in adolescents. Genetic and environmental factors such as maternal nutrition during pregnancy and early life nutrition affecting intelligence should be addressed in these studies.

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