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The association between dietary intake of omega-3 and cognitive abilities among Saudi female university students

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Abstract
Background: Omega-3 polyunsaturated fatty acids (n-3 PUFAs) are dietary factors that have received significant research attention in relation to their beneficial effects on cognitive decline. The main n-3 PUFAs used in the body are docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) and are mostly obtained from oily fish or dietary supplementation. DHA and EPA can also be synthesized from α-linolenic acid (ALA) obtained from plant oils. The main aim of this study was to establish a relationship between n-3 PUFAs consumption and cognitive abilities.
Methods: A cross-sectional study was conducted using a sample of 100. The participants were selected using convenience sampling. A well-organized and valid questionnaire was administered, which covered variables related to socioeconomic status, health history, lifestyle, anthropometric measurement and food consumption. Omega-3 fatty acids were estimated by using food frequency questionnaire (FFQ) then analyzed by ESHA software. Cognitive abilities tests; digit span subscale (Forward & Backward) and digit cancellation scale for assessing visual attention were applied. The collected data were analyzed using IBM SPSS Statistics version 25. Descriptive statistics, Chi-Square test and Pearson correlation coefficient were used in the analysis.
Results: The median score of speed of attention (minutes) among the three levels of DHA/EPA dietary intake (< 0.25, 0.25-0.5 and > 0.5 gm) were 213, 209 and 192 respectively (P= 0.046). Furthermore, the significant positive association was found between white fish and cashew with speed of attention (p = 0.031 and 0.015 respectively); nut with accuracy of attention (p =0.009); almond with working memory (p = 0.021); and olive oil with memory direct (p = 0.025).
Conclusion: The present study provides further experimental evidence that n-3 PUFAs exert positive effects on cognitive abilities in healthy late adolescents. Therefore, improvement of dietary intake of n-3 PUFAs may lead to improvement in mental and cognitive abilities.

Keywords: omega-3, memory, attention, cognitive, food frequency questionnaire, university students, Saudi Arabia

Introduction

Recently, it has been developed and increasing interest in the health benefits of long-chain polyunsaturated fatty acids (LCPUFAs)**.** Omega-3 polyunsaturated fatty acids are vital to many functions in the body and the most beneficial types are Docosahexaenoic acid (DHA) and Eicosapentaenoic acid (EPA) found mostly in a fatty fish such as salmon fish and other types of sea mammals. Fish oil also, it can be taken as supplement. Many benefits has been shown in brain function, metabolism, inflammation, heart which can reducing the risk of heart disease and developing adverse coronary outcomes which make it recommended to be taken daily EPA and DHA, and the European Food Safety Authority recommends to take 0.25g/day [1]. The major components of neuronal membranes, which is polyunsaturated fatty acids that have a wide range of functions, from modulating synaptic plasticity and neurochemistry, to neuroimmune-modulation and neuroprotection [2].

The prevalence of mild cognitive impairment (MCI) and dementia in Saudi Arabia were higher than developed and developing countries. This high prevalence of MCI despite the included relatively young elderly population is related to the high level of illiteracy and the high prevalence of risk factors of dementia. There is a need to control risk factors of cognitive impairment in Saudi Arabia such as diabetes, hypercholesterolemia, and hypertension; otherwise the prevalence of dementia could increase significantly in the country as the aging population increases (Alkhunizan *et al*., 2018) [26].

The benefits of n-3 fatty acids has become interest of many athletics, pregnant, mothers to their child and even scholar because of their wide health benefits such as reducing the risk of cardiovascular disease (CVD), anti-inflammatories, improving infant cognitive function, reducing risk of Alzheimer disease in geriatric [3].

Omega-3 Polyunsaturated fatty acids can be important in young adult in which of special benefits [5]**.** During adolescence, the brain, especially the PFC, undergoes development which continues until after twenty [6]. Moreover, dietary intake of ω-3 polyunsaturated fatty had effects on mental health and brain function through enhancement and inflection of cerebral hemodynamics also may help the previously experiential attenuation in cognitive failure during normal ageing, may result as improved cognitive activity also in young adult [7].

In younger individuals, EPA-rich supplementation enhanced neurocognitive function, suggesting that the brain will a reduced the amount of function that had healthier cognitive performance, DHA meaningfully enhanced response times of working memory in men and episodic memory in young girls. Consequently, ω-3 Polyunsaturated fatty

supplementation performance role in support and intensify the mental capacity health [8]. Omega -3 polyunsaturated fatty acids tend to increase the process of adult neurogenesis in areas related to memory and emotions and support enhanced cognitive performance also behavioral improvement through an increase of neurogenesis, acting on the control of emotions and memory and clarify mechanisms of action of n-3 polyunsaturated fatty acids on the main brain functions [9].

The exposure to n-3 fatty acids enhances adult hippocampal neurogenesis associated with cognitive and behavioural processes, promotes synaptic plasticity by growing long-term potentiation and modulates synaptic protein expression to stimulate the dendritic arborization and new spines formation [14]. Therefore, the current study aimed to explore the association between dietary intake of omega-3 and cognitive abilities among Saudi female university students.

Materials and Methods

A cross sectional study was conducted in a sample of (N=100) female students from Imam Abdulrahman Bin Faisal University (IAU) divided into two groups (n=70) from the college of applied medical science students and (n= 30) from the college of applied studies and community services students were selected using convenience sampling from IAU. The sample size was calculated according to https://www.surveysystem.com.

Students who doesn't take omega-3 supplementation or any cognitive enhancing medication, age from 19 years old to 24 years and Body Mass Index (BMI) ranged from 18.5-30 kg/m2 were included in the study. A pilot study with 23 samples was performed to measure the reliability and validity of the questionnaire. After obtaining the informed consent, study participants were interviewed regarding their socio-demographic background, anthropometric measurements (Body weight, body height and BMI calculated according to Nuttall, 2015) [24] and food habits. Omega 3 intake was estimated by using food frequency questionnaire (FFQ) which was based on omega-3content of different 37 food items, divided into 2 groups (High contents=14 food items and moderate content=23 food items) according to Canada, (2018), Foodstandards.gov.au. (2018) and Sciencedirect.com. (2018).

The 24 hours' dietary recall for three days (two weekdays and a weekend) were collected then analyzed by food processor software. Cognitive abilities tests; Digit Span Test: Prepared by Wechsler, It is one of sub-scales of Wechsler memory scales (WMS). Digit Span (DS) is measured for forward and reverse-order (backward) recall of digit sequences. Digit sequences are presented beginning with a length of four digits (forward) and three (backward) and two trials are presented at each increasing list length. Thus, there are two scores of the test, the first part is forward digit span that measures short-term memory (and the instructions of this part "I will tell you some numbers and after finishing them directly, I want you to repeat this numbers exactly") and the second part is the trend and measures the working memory this part is backward digit span (and the instructions of this part "I'll read you a series of numbers and after I finish them, I want you to repeat these numbers but in a backward, For example: if I told you 5-9-1, you would say 1-9-5"). The test stops when the participant fails to remember two trials for the same sequence. The score is calculated by the sum of the correct trials (Millis *et al*. 1999) [22].

Digit Cancellation Test: Prepared by Taha (1997) [23], on a sample of the university's 200 students (102 males and 98 females). The average age is 20.67 years with a standard deviation of 2.04 and their intelligence is normal. It measures visual attention and consists of 323 randomly recorded numbers on printed paper. It requires the participant to write off a number 3 preceded by an even number, and each number 7 preceded by an odd number. Two scores of this test are extracted: Speed Score = time taken by the participant in the test performance. Calculates time in seconds, Accuracy Score = number of errors + numbers that should have been written off 16. These two tests were used, a meeting was done with a clinical psychologist to get the cognitive ability test, know how to apply it on the participants, and how to confirm and calculate the result. With an uncluttered. The collected data was analyzed statistically using IBM SPSS Statistics 25. Frequency table for demographic data and FFQ and descriptive statistics for cognitive abilities were presented. The correlation analysis was done with Pearson correlation coefficient and Chi-square test. The approval of this study had taken from Imam Abdulrahman Bin Faisal University, Institutional Review Board (IRB): serial Number (IRB-2019-086-CAMS).

Results

Table 1: Demographic data of study participants.

Characteristics	Number of participants
Age in years	
19	16
20	22
21	35
22	15
>=23	12
Mother education	
Post graduate	6
Graduate	37
High school	33
Elementary school	13
Primary school	9
Uneducated	2
Father education	
Post graduate	9
Graduate	49
High school	29
Primary school	9
Father occupation	
Professional	31
Manager	6
Technician	12
Business	22
Retired	29
Marital status	
Married	28
Unmarried	72
Husband job, if married.	
Graduate	19
High School	3
Monthly income (Saudi Riyals)	
Less than 5000	13
5000-10000	27
More than 10000	60
Housing	
Owned	82
Rented	16

Table 2: Food Frequency Questionnaire data.

Total sample = 100				
Food Items	**Consumers n=**		**Nonconsumers n=**	
	Quantitative absolute value	**Percentage value of the consumer's food**	**Quantitative absolute value**	**Percentage value of the consumer's food**
Caviar	9	0.75%	91	4.15%
Salmon	40	3.31%	60	2.74%
Herring	21	1.74%	79	3.60%
Sardine	15	1.24%	85	3.88%
White Fish	59	4.89%	41	1.87%
Mackerel	8	0.66%	92	4.20%
Flaxseed	36	2.98%	64	2.92%
Walnut	88	7.29%	12	0.55%
Cashew	85	7.04%	15	0.68%
Soybean	29	2.40%	71	3.24%
Canola Oil	25	2.07%	75	3.42%
Vegetables Oil	93	7.71%	7	0.32%
Soya Oil	93	7.71%	7	0.32%
Trout	11	0.91%	89	4.06%
Tuna	53	4.39%	47	2.14%
Greasy Grouper	54	4.47%	46	2.10%
Squid	5	0.41%	95	4.33%
Shrimp	66	5.47%	34	1.55%
Crab	10	0.83%	90	4.10%
Tilapia fish	6	0.50%	94	4.29%
Swordfish	2	0.17%	98	4.47%
Red Fish	7	0.58%	93	4.24%
Milk Fortified With DHA	26	2.15%	74	3.37%
Nutmeg	30	2.49%	70	3.19%
Pecans	44	3.65%	56	2.55%
Shea Seeds	36	2.98%	64	2.92%
Hazelnut	76	6.30%	24	1.09%
Almond	82	6.79%	18	0.82%
Sardine Oil	6	0.50%	94	4.29%
Herring Oil	1	0.08%	99	4.51%
Margarine	58	4.81%	42	1.92%
Walnut Oil	10	0.83%	90	4.10%
Salmon Oil	4	0.33%	96	4.38%
Olive Oil	19	1.57%	81	3.69%

Table 2 describes both the consumer's and non-consumer's Quantitative absolute value of total samples consuming omega-3 containing edibles and Percentage value of the consumer's food for each item.

Table 3: Summary statistics of Cognitive abilities

Cognitive ability	Min	Max	Mean	SD
Speed of attention	124	383	217.4	55.7
Accuracy of attention	0	32	6.6	7.9
Immediate memory	8	60	35.4	14.1
Working memory	0	50	23.5	12.8

Association between food intake of omega 3 and cognitive abilities

The correlation between omega 3 and cognitive abilities were measured using Pearson correlation coefficient and it was found that there was statistically significant positive correlation between ALA (%) with accuracy of attention ($r=0.244$, $P<0.014$).

Table 4: Correlation between Omega 3 food intake and Cognitive abilities

Omega 3 food intake	Speed of attention		Accuracy of attention		Memory Direct		Memory Worker	
	r	p	r	p	r	p	r	p
Total Consumption per day (g)	-.017	.869	.170	.092	.017	.867	.042	.680
DHA/EPA (%)	-.073	.471	.015	.883	-.040	.694	.138	.171
ALA (%)	-.013	.899	.244	.014	.081	.425	.089	.379

Table 5: Comparison of speed of attention among Selected Food items

Consumption of food items		Speed of Attention		p. value
		Fast	Slow	
		n(%)	n(%)	
White Fish	Low	47(58)	34(42)	.033*
	Moderate	16(84)	3(16)	
Cashew	Low	28(51)	27(49)	.015*
	Moderate	32(80)	8(20)	
	High	3(60)	2(40)	

Olive oil	Low	43(48.9)	45(51.1)	.025
	Moderate	10(83.3)	2(16.7)	
Almond	Low	38(59.4)	26(40.6)	.021
	Moderate	27(79.4)	7(20.6)	

From Table 5 it can be found that there is a significant association between white fish and cashew with speed of attention (p value =.033, 015 respectively; nut with accuracy of attention (p value=.009); almond with speed of attention (p value=0.021). There was not any significant relationship between DHA/EPA and ALA consumption with the other food items in the FFQ. Also, there is a significant relationship between olive oil consumption with immediate memory (P=0.025*) and almond consumption with working memory (P=0.021*).

Table 2 describes both the consumer's and non-consumer's Quantitative absolute value of total samples consuming omega-3 containing edibles and Percentage value of the consumer's food for each item.3

Discussion

This cross-sectional study established a relationship between n-3 PUFAs consumption and cognitive abilities among the study participants. Whilst, the performance of cognitive functions for the participants was within the typical range, the study presents evidence for reduced performance in the attention domain within participants with the lower Omega-3 intake. Omega-(n)-3 polyunsaturated fatty acids are main components of the neuronal membranes and key modulators of oxidative stress, neurogenesis and neuroinflammation.

Omega-3 polyunsaturated fatty acids (n-3 PUFA), especially eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA) and docosahexaenoic acid (DHA), may exercise advantageous and neuroprotective impacts on the aging brain [1, 2]. Steadily, rodent studies have shown that n-3 PUFA supplementation enhances synaptogenesis and neurogenesis, learning abilities and executive functions, while n-3 PUFA deficiency have been correlated with impaired hippocampal plasticity and memory deficits [1, 3-5].

Omega-3 fatty acids known to be main components of the neuronal membranes, with very small amounts of EPA present comparing to the long-chain docosahexaenoic acid comprising more than 50% of the PUFAs in neuronal cell membranes [6]. As DHA demonstrated to be essential for normal brain functioning as well as brain development, Adequate DHA levels throughout life are required for common brain functions such as vision, synaptic plasticity and neurotransmission [7]. Omega-3 fatty acid supplementation confidently showed positive impacts on certain aspects of cognition, such as attention and memory [6]. The present results strongly corroborate the effect of omega-3 rich food consumption in relation to cognitive function including immediate memory, working memory and speed of attention as well as accuracy of attention was assessed, the speed of attention was high in the group who consume > 0.5 gm of DHA/EPA daily, moderate consumption of white fish and cashew. In the current study, the results revealed a positive correlation between consumption of omega 3 and accuracy of attention. These results agreed with those previously reported studies. On the other hand, a similar study about omega-3 relation with cognitive function showed an interestingly similar result concerning EPA and improvement in speed of attention which was similar outcome of this study indicating the importance of this result [8]. [22] in the current research the omega -3 fatty acids rich in DHA and EPA during pregnancy has been found to increase the progeny's neurocognitive function by Li *et al* (2020)

Importantly, in the present results asserted a significant correlation between consumption of fish and speed of attention. These findings agree with those of Handel and *et al*., (2017) [9] who concluded that the fatty fish is the primary dietary source of omega-3 LCPUFAs also containing other important micronutrients for brain function and development [9]. In addition, it may be explained by Calder (2017) [10] who demonstrated that omega-3 FAs are vital to many functions in the body and the most beneficial types are DHA and EPA found mostly in salmon as a fatty fish and other types of sea mammals or it can be taken as supplement derivate from fish oil [10]. EPA and DHA has shown many benefits in brain function, metabolism, inflammation, heart and thus reducing the risk of heart disease and developing adverse coronary outcome which make it recommended to be taken daily as the European Food Safety Authority recommends to take 0.25g/day from EPA and DHA. The present findings were in the same line with those reported by [11] who recommended that use of fish and its products as dietary sources is linked with decrease the risk of cognition weakening.

Numerous processes of action have been intended to explain the relationship between cognitive function and omega-3 PUFA. Animal studies have stated evidence that omega-3 PUFA amasses in areas of the brain involved in memory and attention, involving the hippocampus and the cerebral cortex [12, 13]. A recent research in rodents with diabetes indicated that administration of low doses of omega-3 PUFAs may possibly be associated with enhanced cognitive-behavioral performance, and protect against neuronal damage in the hippocampus reduced inflammatory indications in type 2 diabetes [14].

Additionally, it is recognized that omega-3 PUFA has an important role in maintaining membrane fluidity and integrity, and neuronal functioning has been proven to be affected by omega-3 PUFA through a decline in inflammatory pathways [10, 14, 15]. Lately, it has been suggested that DHA and EPA increases serotoninergic transmission by increasing neuronal membrane fluidity and reducing prostaglandin levels [16].

Finally, Results have also been found on dopaminergic neurotransmission, in particular, the mesocortical pathway has been linked in memory, attention, and executive functions [15, 17, 18]. If these dopaminergic systems have been modified over low omega-3 PUFA, deficiency in this nutrient may impact to reduce cognitive function. PUFAs are recognized to expedite effects on gene expression, in particular the central nervous system [10, 19-21].

Limitation

One limitation of this study is that we could not take blood samples for testing the participants levels of omega-3.

Strength
This is the first study conducted among university students in Kingdom of Saudia Arabia.

Conclusion
The present study provides further experimental evidence that n-3 PUFAs exert positive effects on cognitive abilities in healthy late adolescents. Therefore, improvement of dietary intake of n-3 PUFAs may lead to improvement in mental and cognitive abilities.

List of Abbreviations
n-3 PUFAs: Omega-3 polyunsaturated fatty acids
DHA: Docosahexaenoic acid
EPA: Eicosapentaenoic acid
ALA: α-linolenic acid
FFQ: food frequency questionnaire
LCPUFAs: long-chain polyunsaturated fatty acids
BMI: Body Mass Index

Declarations
Funding
There is no funding support for this study.

Conflict of interest statement
The authors declare that they have no competing interests.

Ethics approval
The study was approved by the Institutional Review Board of Imam Abdulrahman Bin Faisal University (IRB Number: IRB-UGS-2018-03-265, Approval date: 12/12/2018).

Consent to participate
The informed consent was obtained from all the study participants.

Consent to publication
Not applicable

Availability of data and material
The dataset will not be available for publishing online since further research has been planned.

Code availability
Not applicable

Authors' contributions
RTA supported the proposal writing, data collection and writing of the article. NSA supported the proposal writing, data collection and writing of the article. FHA supported the proposal writing, data analysis and writing of the article**.** ZAA supported the proposal writing, data analysis and writing of the article**.** RSM was responsible for performing all stages of the study, supported the proposal writing and collaborated with the revision of the final version of the article. AAA supported the data collection and collaborated with the revision of the final version of the article. OIA supported the proposal writing and collaborated with the revision of the final version of the article. TS supported the statistical analysis and writing of the article. All authors read and approved the final manuscript.

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References
1. Luchtman DW, Song C. Cognitive enhancement by omega-3 fatty acids from child-hood to old age: findings from animal and clinical studies. Neuropharmacology,2013:64:550-65. Epub 2012/07/31. Doi: 10.1016/j.neuropharm.2012.07.019. PubMed PMID: 22841917.
2. Denis I, Potier B, Heberden C, Vancassel S. Omega-3 polyunsaturated fatty acids and brain aging. Current opinion in clinical nutrition and metabolic care,2015:18(2):139-46. Epub 2014/12/17. Doi: 10.1097/mco.0000000000000141. PubMed PMID: 25501348.
3. Hooijmans CR, Pasker-de Jong PC, de Vries RB, Ritskes-Hoitinga M. The effects of long-term omega-3 fatty acid supplementation on cognition and Alzheimer's pathology in animal models of Alzheimer's disease: a systematic review and meta-analysis. Journal of Alzheimer's disease: JAD,2012:28(1):191-209. Epub 2011/10/18. Doi: 10.3233/jad-2011-111217. PubMed PMID: 22002791.
4. Denis I, Potier B, Vancassel S, Heberden C, Lavialle M. Omega-3 fatty acids and brain resistance to ageing and stress: body of evidence and possible mechanisms. Ageing research reviews,2013:12(2):579-94. Epub 2013/02/12. doi: 10.1016/j.arr.2013.01.007. PubMed PMID: 23395782.
5. Maruszak A, Pilarski A, Murphy T, Branch N, Thuret S. Hippocampal Neurogenesis in Alzheimer's Disease: Is There a Role for Dietary Modulation? Journal of Alzheimer's disease, 2013, 38.
6. Robinson JG, Ijioma N, Harris W. Omega-3 fatty acids and cognitive function in women. Women's health (London, England),2010:6(1):119-34. Epub 2010/01/22. Doi: 10.2217/whe.09.75. PubMed PMID: 20088735; PubMed Central PMCID: PMCPMC2826215.
7. McCann JC, Ames BN. Is docosahexaenoic acid, an n-3 long-chain polyunsaturated fatty acid, required for development of normal brain function? An overview of evidence from cognitive and behavioral tests in humans and animals. The American journal of clinical nutrition,2005:82(2):281-95. Epub 2005/08/10. doi: 10.1093/ajcn.82.2.281. PubMed PMID: 16087970.
8. Patan MJ, Jackson PA. Shining a light on the effects of omega-3 polyunsaturated fatty acids on the brain: The relationship between cerebral blood flow parameters and cognition. Lipid Technology,2016:28(12):197-9. Doi: 10.1002/lite.201600052.
9. Handeland K, Oyen J, Skotheim S, Graff IE, Baste V, Kjellevold M *et al*. Fatty fish intake and attention performance in 14-15 year old adolescents: FINS-TEENS - a randomized controlled trial. Nutrition journal,2017:16(1):64. Epub 2017/10/04. doi: 10.1186/s12937-017-0287-9. PubMed PMID: 28969711; PubMed Central PMCID: PMCPMC5625698.
10. Calder PC. Omega-3: The good oil. Nutrition Bulletin,2017:42(2):132-40. Doi: 10.1111/nbu.12261.
11. Zhang Y, Chen J, Qiu J, Li Y, Wang J, Jiao J *et al*.

Intakes of fish and polyunsaturated fatty acids and mild-to-severe cognitive impairment risks: a dose-response meta-analysis of 21 cohort studies1–3. The American journal of clinical nutrition,2015:103(2):330-40. Doi: 10.3945/ajcn.115.124081.
12. Chung WL, Chen JJ, Su HM. Fish oil supplementation of control and (n-3) fatty acid-deficient male rats enhances reference and working memory performance and increases brain regional docosahexaenoic acid levels. The Journal of nutrition,2008:138(6):1165-71. Epub 2008/05/22. Doi: 10.1093/jn/138.6.1165. PubMed PMID: 18492851.
13. Gamoh S, Hashimoto MM, Yanagimoto K, Katakura M, Abdul HM, Shido O *et al*. Krill-derived Phospholipids Rich in n-3 Fatty Acid Improve Spatial Memory in Adult Rats. Journal of Agricultural Science,2011:3(4). Doi: DOI:10.5539/jas.v3n4p3.
14. Diaz-Gerevini GT, Dain A, Pasqualini ME, Lopez CB, Eynard AR, Repossi G *et al*. Diabetic encephalopathy: beneficial effects of supplementation with fatty acids omega3 and nordihydroguaiaretic acid in a spontaneous diabetes rat model. Lipids in health and disease,2019:18(1):43. Epub 2019/02/10. Doi: 10.1186/s12944-018-0938-7. PubMed PMID: 30736810; PubMed Central PMCID: PMCPMC6368734.
15. Calder PC. Mechanisms of action of (n-3) fatty acids. The Journal of nutrition,2012:142(3):592s-9s. Epub 2012/01/27. Doi: 10.3945/jn.111.155259. PubMed PMID: 22279140.
16. Patrick RPA BN. Vitamin D and the omega-3 fatty acids control serotonin synthesis and action, part 2: relevance for ADHD, bipolar disorder, schizophrenia, and impulsive behavior, 2015. Doi: https://doi.org/10.1096/fj.14-268342.
17. Chalon S. Omega-3 fatty acids and monoamine neurotransmission. Prostaglandins, leukotrienes, and essential fatty acids,2006:75(4-5):259-69. Epub 2006/09/12. Doi: 10.1016/j.plefa.2006.07.005. PubMed PMID: 16963244.
18. Nieoullon A. Dopamine and the regulation of cognition and attention. Progress in neurobiology,2002:67(1):53-83. Epub 2002/07/20. Doi: 10.1016/s0301-0082(02)00011-4. PubMed PMID: 12126656.
19. Kuperstein F, Eilam R, Yavin E. Altered expression of key dopaminergic regulatory proteins in the postnatal brain following perinatal n-3 fatty acid dietary deficiency. Journal of neurochemistry,2008:106(2):662-71. Epub 2008/04/16. Doi: 10.1111/j.1471-4159.2008.05418.x. PubMed PMID: 18410511.
20. Kitajka K, Sinclair AJ, Weisinger RS, Weisinger HS, Mathai M, Jayasooriya AP *et al*. Effects of dietary omega-3 polyunsaturated fatty acids on brain gene expression. Proceedings of the National Academy of Sciences of the United States of America,2004:101(30):10931-6. Epub 2004/07/21. Doi: 10.1073/pnas.0402342101. PubMed PMID: 15263092; PubMed Central PMCID: PMCPMC503722.
21. Rojas CV, Greiner RS, Fuenzalida LC, Martinez JI, Salem N, Jr Uauy R *et al*. Long-term n-3 FA deficiency modifies peroxisome proliferator-activated receptor beta mRNA abundance in rat ocular tissues. Lipids,2002:37(4):367-74. Epub 2002/05/28. doi: 10.1007/s1145-002-0904-4. PubMed PMID: 12030317.
22. Millis SR, Malina AC, Bowers DA. Confirmatory factor analysis of the Wechsler Memory Scale-III. Journal of Clinical and Experimental Neuropsychology, 1999:21(1):87-93.
23. Taha IA. Differences in the efficiency of abstract thinking at different levels of attention. Master thesis submitted to the. Department of Psychology, Faculty of Arts, Cairo University, 1997.
24. Nuttall F. Body Mass Index. Nutrition Today, 2015:50(3):117-128.
25. Li Y, Freedman R. Prospects for improving future mental health of children through prenatal maternal micronutrient supplementation in China. PEDIATRIC INVESTIGATION,2020:4(2):118-126.
26. Alkhunizan M, Alkhenizan A, Basudan L. Prevalence of Mild Cognitive Impairment and Dementia in Saudi Arabia: A Community-Based Study. *Dement Geriatr Cogn Dis Extra*,2018:8(1):98-103. Published 2018 Mar 20. doi:10.1159/000487231