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ORIGINAL RESEARCH

Low Cognitive Function Is Strongly Associated with The Intake of EPA and DHA in Adolescent Female Football Players in North Sumatra, Indonesia

Sangkot Paridah[1], Raisya Keumala Putri[1], Dina Keumala Sari[2], Christoforos D Giannaki[3], George Aphamis[3], Dairion Gatot[4], Cut Adeya Adella[5]

[1]Undergraduate Medical Study Program, Faculty of Medicine, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia; [2]Department of Nutrition, Faculty of Medicine, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia; [3]Department of Life and Health Sciences, University of Nicosia, Nicosia, Cyprus; [4]Department of Internal Medicine, Faculty of Medicine, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia; [5]Department of Obstetrics and Gynecology, Faculty of Medicine, Universitas Sumatera Utara, Medan, North Sumatra, Indonesia

Correspondence: Dina Keumala Sari, Clinical Nutrition, Faculty of Medicine, Universitas Sumatera Utara (USU), Jl. Dr. Mansur, No. 5, USU Campus, Padang Bulan, Medan, Indonesia, Tel +6281397177693, Email dina@usu.ac.id

Background: Cognitive function refers to an individual's ability to process information, influenced by several factors, including genetics, the environment, and key nutrients such as omega-3 fatty acids—specifically Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA).

Objective: The purpose of this study was to examine the relationship between EPA and DHA intake on cognitive function of amateur female adolescent football players in North Sumatra in 2024.

Methods: The research design used was observational analytic involving cross-sectional design. The total sample that participated was 79 amateur female youth football players by filling out the Montreal Cognitive Assessment (MOCA) questionnaire as a cognitive assessment and filling out the Food Recall for assessing EPA and DHA intake. The analysis used SPSS 29.0 software and the analysis of EPA and DHA food recall used the NutriSurvey application.

Results: The results of this study indicate that there is a strong positive correlation between EPA and DHA intake and the cognitive function of amateur female adolescent football players, with a strong correlation value of r = 0.676 ($p < 0.001$).

Conclusion: Eicosapentaenoic Acid and DHA intakes are strongly correlated with cognitive function in amateur female adolescent football players. Focusing on increasing daily EPA and DHA intakes is expected to improve cognitive function, especially in female adolescent athletes.

Keywords: youth, nutrition intake, sport, thinking process, omega 3

Introduction

Cognitive beliefs, shaped by thought processes, are influenced by various factors, including genetics, environment, and essential nutrients, and this is very important especially in youth.[1,2] This process includes the acquisition and manipulation of knowledge through various activities like remembering, analyzing, understanding, evaluating, imagining, and using language.[1–3] Referring to data published by the World Population Review in October 2022, it was noted that the mean Intelligence Quotient (IQ) scores of countries around the world had been measured.[4,5] From these results, Indonesia with mean IQ was 78.49, which put it in place in position 130 from 199 countries which surveyed.[4,5] Besides that results, Indonesia is at in order most lower between ten member countries of the Association of South East Asian Nations (ASEAN).[4,5]

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There are at least three main factors that can influence cognitive functioning, starting from the aspect of individual nutritional intake, genetics, and environment, such as exercise.[6,7] The cognitive function can be improved in growth period, several studies have shown that exercise can improve brain function, including memory, attention, and problem-solving skills.[8–10] This is because exercise can increase blood flow to the brain, which brings more oxygen and nutrients, and can stimulate the production of neurotrophic factors that play a role in the growth and maintenance of nerve cells.[11,12] However, not all youth do the exercise for improved cognitive function apart from their health.[13,14]

Besides exercise, presence elements nutrition essential as the fundamental nutrients that the body requires for proper growth and development such as amino acids and essential fatty acids, it also become an important element in maintaining cognitive function, especially in the context of omega-6 fatty acids, unsaturated fatty acids, and omega-3 fatty acids, as represented in Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA), which are included in the category of micronutrients.[15–17] The presence of sufficient EPA and DHA describes their main role is in stimulating the activity of Peroxisome Proliferator-Activated Receptors (PPARs) in the hippocampus, an important part of the brain responsible for synaptic plasticity. In addition, they also function as guards against the process of neuronal apoptosis through increasing phosphatidylserine on layer outside membrane cell.[12,18,19] There are various other nutrients besides EPA and DHA in omega 3 such as Alpha-Linolenic Acid (ALA), Docosapentaenoic Acid (DPA), Astaxanthin, and phospholipid but this study focused on EPA and DHA content. This is because these two elements provide support action for cognitive function.

This study is about correlation intake EPA and DHA to cognitive function of amateur female youth football players in North Sumatra has never been published, so in-depth research is needed to examine this topic. Assessing cognitive function in women athletes is crucial due to several physiological, psychological, and performance-related factors that influence their sports performance and recovery due to hormonal fluctuations. The hypothesis of this research was that there is a correlation between EPA and DHA intake and cognitive function.

The implementation of the research goes through a data collection and analysis scheme related to EPA and DHA intake and sees its correlation with cognitive function in amateur female youth football players in North Sumatra in 2024. The parameters used are the amount of EPA and DHA intake and cognitive function based on the questionnaires.

Materials and Methods

The research design used was observational analytic involving cross-sectional design, the aim of this study was to find the correlation between two variables. Primary data were collected by visiting a football club in North Sumatra. Slovin's formulation was used for sample size calculation, the sample size was 79 amateur female teenage football players.[20] The Slovin's formula calculation is used to determine the sample size in a survey research when the population is finite or known.[20] Slovin's formula helps researchers obtain a representative sample of the population, minimizing sampling error while optimizing data collection efficiency.[20]

Participants

All participants consciously agreed to participate in this study. The subjects of this study provided written informed consent before being included in this study. Written consent was obtained from all subjects and was officially recorded in a statement sheet after explanation. During the study, no therapy or intervention was performed, and the subjects were not charged any fees for this study. Subject selection is done with an approach and explanation of this research, all of the research subjects voluntarily become research subjects. No one refused to be a research subject, for that when the number of subjects has been reached and has passed the inclusion and exclusion criteria, the data collection process can begin.

This research has been conducted in four places spread across North Sumatra, namely, North Medan Football Club, Red and White Football Club, Brimo Football Club, Garuda Club spread across North Sumatra. The sampling method used is the simple random sampling method to select samples from the research population. Sampling with this method benefits researchers because of limited resources and time.

Data Collection Tools

Data was collected through a survey method using Food Recall and Montreal Cognitive Assessment (MOCA) questionnaires (link: https://mocacognition.com/permission/).[21] The Montreal Cognitive Assessment test is a test used to

assess whether there is cognitive impairment or not, this test consists of seven exercises that test various cognitive abilities such as short-term memory, memory, attention, executive function, visuospatial ability, language ability, and orientation of time and place.[21] The MOCA Test assessment done by giving a score based on the number of errors made, with a score range of 0–30. A score of 26 or more is considered normal, while a score below 26 indicates mild cognitive impairment.[21–23]

Food recall questionnaire serves to collect quantitative data on food and beverages consumed by individuals, to process data from food recall researchers use the NutriSurvey application (link: https://www.nutrisurvey.de/) to collect EPA and DHA intake data.[24] In this method, each subject was asked to remember the food that has been consumed during the previous 1×24 hours and is done twice, which were on one working day and one holiday.[24]

There are three stages carried out, first, asking the subject when, where, and what food the subject eats in 24 hours on weekdays and holidays. Second, carefully recording all food and drinks consumed including how to cook them.[24] Third, asking the subject the estimated amount of all food and drinks consumed using household size with the help of a food model as a guide to help the subject's memory. Furthermore, the data obtained in household size is converted into grams using a list of exchange food ingredients and entered into the Nutrisurvey application.[24]

Data Analysis

This research is a correlational analytical research conducted to determine whether there is a relationship between the variables. Data analysis was performed using the non-parametric Spearman Rho test. All statistical data were tested for normality and significance tests along with correlation tests. The entire data was inputted into a central table and analyzed using Statistical Package for The Social Sciences (SPSS) software. Numerical data exhibiting a normal distribution was presented as mean±SD (standard deviation), whereas data not following a normal distribution was shown in median (minimum-maximum) values. Categorical data were depicted in quantities (percentages). The assessment of normality involved the application of the Kolmogorov–Smirnov test (for sample sizes exceeding 50). The correlation between the independent and dependent variables was determined using the Pearson test when the data adhere to a normal distribution, whereas the Spearman test was utilized for non-normally distributed data, two-tailed $p < 0.05$ was considered statistically significant.

Ethical Approval

The study was conducted in Medan, North Sumatra, Indonesia, in accordance with the Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects, Good Clinical Practice and all applicable local regulatory requirements and laws. This study was approved by The Health Research Ethics Committee, Ministry of Education, Culture, Research, and Technology at the Universitas Sumatera Utara. This study was conducted in accordance with established guidelines, and all procedures involving study participants were approved by the Ethics Committee of the Universitas Sumatera Utara, No. 800/KEPK/USU/2024, date July 4th, 2024.

Results

This study aims to examine the correlation between EPA and DHA intake with cognitive function in amateur female adolescent football players in North Sumatra in 2024. The population included were amateur female adolescent football players who were members of football schools in North Sumatra. Research subjects were amateur female teenage football players with an age range of 12–18 years, where the majority of amateur female teenage football players were 16–18 years old, which was 48 people (60.8%). The research subjects can be categorized into three groups based on their last educational background, namely Elementary School, Junior High School, and Senior High School, where the majority of amateur female teenage football players were junior high school students, which was 60 people (75.9%), followed by elementary school students as many as 18 people (22.8%), and the minority were high school students, which was only one person (1.3%) (Table 1).

Based on the history of the disease, it can be classified into no history of disease, history of acute disease, history of chronic disease, family history of disease, and medical procedures, where the majority of research subjects did not have a history of disease, namely 51 people (65.6%), then followed by a history of acute disease such as sports injuries and

Table 1 Subject Characteristics

Variable	Characteristics	Frequency	Percentage (%)
Age	12–15 years	31	39.2
	16–18 years	48	60.8
Education	Elementary School	18	22.8
	Junior High School	60	75.9
	Senior High School	1	1.3
History of disease	No There is	51	64.6
	Disease I	21	26.6
	Chronic disease	4	5,1
	Disease family	2	2.5
	Medical procedures	1	1.3
Body Mass Index	Underweight	22	27.8
	Normal	43	54.4
	Overweight	6	7.6
	Obesity	8	10.1
	Total	79	100

also ARI as many as 21 people (26.6%), while the minority had a history of medical procedures such as surgery as many as 1 person (1.3%) (Table 1).

For the characteristics of Body Mass Index (BMI) is classified into four categories, namely thin, normal, overweight, and obesity where the majority of BMI of the research subjects is normal, which were 43 subjects (54.4%) followed by underweight which were 22 subjects (27.8%), obese which were 8 subjects (10.1%) and overweight were 6 subjects (7.6%) (Table 1).

Based on the sports activities carried out, researchers divided sports activities based on exercise frequency, exercise intensity, exercise time, and exercise type, where the recommended frequency in sports is 3–5 times/week, from the table it can be seen that most of the research subjects exercise with a frequency of 3 times/week as many as 53 people (67.1%). A small portion exercise with a frequency of 4 times/week as many as 1 person (1.3%) (Table 2), for exercise intensity measured by Rating Perceived Exertion (RPE), from the results of the data collection obtained the majority of physical activity of the research subjects was moderate as many as 54 subjects (68.4%) followed by light activity 18 subjects (22.8%) and heavy activity as many as 7 subjects (8.9%) (Table 2).

Characteristics based on exercise time, the majority of research subjects exercised for 150 minutes/week as many as 21 subjects (26.6%), followed by an exercise time of 90 minutes/week as many as 20 subjects (25.3%), for the shortest exercise time, namely 30 minutes/week as many as 3 subjects (3.8%) (Table 2). The type of exercise is divided into several types such as aerobic, anaerobic, agility training, strength training, balance training, and others. In the table, it is known that the majority of subjects do aerobic exercise types as many as 34 subjects (43%) followed by aerobic and strength training as many as 33 subjects (41.8%). The type of exercise that is least often done by the research subjects is aerobic and swimming exercise and aerobic and gymnastics exercise, each of which is one subjects (1.3%) (Table 2).

The intake of EPA and DHA was measured using the food recall instrument, where based on the results of the food recall that has been distributed to the research subjects, an average value of 1468 mg/day was obtained (sufficient intake is 2000–3000 mg/day). Based on the results of this study, it was found that the majority of the EPA and DHA intake of

Table 2 Characteristics of Sport Patterns

Variable	Characteristics	Frequency	Percentage (%)
Frequency exercise	1 time/week	2	2.5
	2 times/week	23	29.1
	3 times/week	53	67.1
	4 times/week	1	1.3
Intensity exercise	Light	18	22.8
	Medium	54	68.4
	Heavy	7	8.9
Time exercise	30 minutes / week	3	3.8
	60 minutes / week	2	2.5
	90 minutes / week	20	25.3
	120 minutes / week	19	24.1
	130 minutes / week	1	1.3
	135 minutes / week	2	2.5
	150 minutes / week	21	26.6
	180 minutes / week	11	13.9
Type of exercise	Aerobics	34	43
	Aerobics + strength exercises	33	41.8
	Aerobics + swimming	1	1.3
	Aerobics + gymnastics	1	1.3
	Exercise strength	10	12.7
	Total	79	100

the research subjects was lacking, namely 42 subjects (53.2%) and with sufficient intake was 37 subjects (46.8%) (Table 3). As for the cognitive function measured by MOCA, the research subjects obtained an average MOCA value of 23.85 (26–30) where this value shows that the majority of research subjects had cognitive disorders, namely 46 subjects (58.2%) and research subjects without cognitive disorders were 33 subjects (41.8%) (Table 3).

The Spearman's rho non-parametric correlation test was used because based on the normality test that had been carried out, it was found that the data were not normally distributed, and the variables in this study were ordinal. Based

Table 3 Characteristics of Subjects Based on EPA-DHA Intake and Cognitive Function

	Characteristics	Frequency	Percentage (%)
EPA and DHA intake	Insufficient	42	53.2
	Sufficient	37	46.8
Cognitive Function	Cognitive Disturbance	46	58.2
	Normal	33	41.8
	Total	79	100

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Table 4 Test Correlation of EPA and DHA Intake With Cognitive Function

EPA and DHA Intake	Cognitive Function			*p value*	*r*
	Cognitive Disturbance	Normal	Total		
	n (%)	n (%)	n (%)		
Insufficient	35 (44.3%)	7 (8.9%)	42 (53.2%)	<0.001	0.676
Sufficient	11 (13.9%)	26 (32.7%)	37 (46.8%)		
Total	46 (58.2%)	33 (41.8%)	79 (100%)		

on the Spearman's rho correlation test, a significance value of p value <0.05 was obtained with a correlation coefficient value of r = 0.676, which means that there is a strong positive correlation between EPA and DHA intake and the cognitive function of female adolescent football players in North Sumatra in 2024 (Table 4).

Discussion

This study is a preliminary study to assess the correlation between EPA and DHA intake with cognitive abilities of amateur female adolescent football ballers in North Sumatra. In this study, the subjects taken were female adolescents, with the majority aged 16–18 years. This is in accordance with the previous research where the age phase of 15 or 16 years is the age at which training services can be provided by football academies or football clubs up to the age of 18 years.[25,26] The training program for the students was focused on developing technical, tactical, physical, and mental skills.[3,25]

In this study, all research subjects were students with the majority of their last education being junior high school, which is in line with the previous research which obtained the high interest of junior high school students. The majority of research subjects did not have a medical history and followed by a history of acute illness, this is in accordance with other previous research, where injuries when playing football are often experienced by adolescent girls when they are menarche and one year after menarche, this is also in accordance with the previous epidemiology of disease and injury in football players.[27–29]

This study also assessed the characteristics based on the intensity of the sport where the majority of the intensity is moderate which is in line with the previous research, where the average weekly training volume of athletes is moderate to heavy intensity.[30–32] Most of the intensity of children doing sports or physical activities were in the moderate to heavy category.[32] The data from this study showed that the majority of the body mass index of amateur female teenage football players is normal which is in accordance with previous research, most amateur female football players have a normal BMI.[33–38] Previous research on BMI in amateur female teenage football players showed that intense physical activity in this sport plays a significant role in maintaining their nutritional status and health.[38] Body mass index is an indicator used to assess a person's nutritional status by comparing body weight and height.[12,38] In adolescents, BMI assessment is adjusted for age and gender, considering changes in body composition during growth.[39]

Eicosapentaenoic Acids (EPA) and DHA intake was found to be lacking in more than half of sample size research subjects, where this insufficient intake was very inconsistent with the recommended EPA and DHA intake of 1600–2000 mg/day.[12,40] The data in this study showed that the majority of cognitive abilities of the study subjects were cognitively impaired. This is in accordance with the previous research that the results of the Omega-3 Index (O3I), it was found that the low O3I scored group significantly lower in attention than in the middle O3I score group. The results of this test indicate that O3I scores with a low category are more dominant in women, but still within normal range. in addition to cognitive function.[40]

At a young age, EPA and DHA are required due to their very important functions, the functions of EPA include its role in cell membranes, where EPA integrates into the phospholipid bilayer of cells, including nerve cells, aiding in maintaining membrane fluidity and integrity.[41,42] Healthy membranes are crucial for proper nerve function as they influence how nerve cells communicate, signal transmission, and the opening or closing of ion channels.[35,41]

Additionally, EPA plays a role in signal transmission regulation, affecting neurotransmission.[35,43] Omega-3 fatty acids help regulate the release of neurotransmitters and receptor responses at synapses, which can influence mood and cognitive function (Table 5).[19,44]

Docosahexaenoic Acids' function is vital for brain development during the growth phases of children and adolescents.[35,41] During this period, DHA supports the growth and regeneration of dendrites and axons, which are key components of neural tissue.[18,19] Another role of DHA is neuroprotection; DHA helps protect neurons from damage caused by oxidative stress and inflammation.[45] This facilitates the production of neuroprotective substances, such as neuroprotectin D1, which have strong anti-inflammatory and neuroprotective properties.[45] Another cognitive-related function is synaptic function, and this involves regulating neurotransmission, enhancing the release of important neurotransmitters such as serotonin and dopamine, which affect cognitive and emotional functions.[40] DHA's role is crucial in synaptic plasticity, a process that enables learning and memory (Table 5).[40]

As for cognitive intelligence and emotional intelligence of adolescents greatly influence each other in supporting the performance of playing football.[38,40,46,47] Previous research showed that adolescents with high intellectual intelligence are at risk of having a high level of angry emotions compared to adolescents who have low intellectual intelligence.[11,40] In this study, a strong and highly significant positive correlation was found between EPA and DHA intake and cognitive ability, indicating that EPA and DHA intake fully play a role in the cognitive function of female adolescent football players in North Sumatra.

Omega-3 docosahexaenoic acid is a major component of neuronal membranes and, together with other long-chain omega-3 fatty acids from fish such as eicosapentaenoic acid, it has been shown to have a variety of beneficial effects on neuronal function, inflammation, oxidation and cell death.[48–50] The anti-inflammatory action of omega-3 in sports can be explained through reduction of pro-inflammatory cytokines and mediator mechanisms that benefit athletes and physically active individuals. Omega-3 fatty acids, particularly EPA (Eicosapentaenoic Acid) and DHA (Docosahexaenoic Acid), play a crucial role in reducing inflammation caused by intense exercise (Table 5).[40,48] Previous study showed that EPA and DHA are important for proper fetal development, including nerve, retinal, and immune function.[48–50] However, this is not in accordance with the previous research which states that the correlation between omega 3 fatty acid intake and cognitive abilities showed a very weak positive correlation and there was no significant relationship between omega 3 intake and cognitive abilities.[18,51,52] This could be caused by differences in research subjects and also data collection methods.

A suggestion based on this research is that omega-3 supplementation is beneficial for athletes as it helps enhance cognitive function, reduce inflammation, speed up recovery, improve endurance, and protect joints. The best sources

Table 5 Mechanism of EPA/DHA Action

No.	Mechanism	EPA/DHA Action
1	Reduction of Neuroinflammation	EPA and DHA reduce pro-inflammatory cytokines (TNF-Œ±, IL-6) and lower neuroinflammation, protecting brain cells.
2	Enhanced Synaptic Plasticity	DHA enhances synaptic plasticity by increasing brain-derived neurotrophic factor (BDNF), essential for learning and memory.
3	Improved Blood Flow to the Brain	Omega-3 improves cerebral blood flow, increasing oxygen and nutrient delivery to neurons, supporting cognitive function.
4	Neuroprotection and Anti-Oxidative Effects	Acts as an antioxidant, reducing oxidative stress and preventing neurodegeneration, which is crucial for brain aging.
5	Regulation of Neurotransmitter Function	EPA and DHA support serotonin and dopamine regulation, improving mood stability, focus, and cognitive clarity.
6	Support for Myelin Sheath Integrity	DHA is a key component of myelin sheaths, ensuring faster neural communication and reducing cognitive decline.

include fatty fish (such as salmon, mackerel, and sardines), fish oil supplements, krill oil, algal oil (for vegetarians), and plant-based sources like flaxseeds and chia seeds, though these have a lower conversion rate to active forms.[40,42]

These were limitations in this study. This research was a single-center study with a small sample size, limited by the research duration, rendering the necessity of a larger sample size and multi-center study to increase the validity of this research. The other weakness of this study was that it assessed food recall over two days, but to get a more accurate food intake, it would be better to assess it over three days. Nutritional assessment also becomes the weakness of this study, BMI is not so reliable at least a kinantropometry would be used.

Conclusion

There is a strong positive correlation between EPA and DHA intake and the cognitive function of amateur female adolescent football players in North Sumatra. Further research is needed to further assess the correlation between EPA and DHA intake and cognitive function with a wider and more evenly distributed research subject, considering other factors that may influence the results, and for further research can include population variations, such as players from various regions or other sports, to expand understanding of the relationship between EPA and DHA intake and cognitive function. In addition, various micronutrients that function to support cognitive function such as beta-carotene and creatine can also be proposed to explore.

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Author Contributions

Each author has made substantial contributions to this study, encompassing various areas such as conceptualization, study design, implementation, data collection, analysis, and interpretation. All authors have been involved in drafting, revising, and critically reviewing the article. They have provided their final approval for the version to be published and have participated in the decision regarding the choice of journal for submission. Furthermore, all authors agree to take responsibility for every aspect of the work.

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