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Omega-3 Fatty Acids: Key Players in Cognitive Function and Brain Health

Wiktoria Wesołowska:

Poznan University of Medical Sciences, Collegium Maius, Fredry 10, 61-701 Poznan, Poland

wesolowskawiktoria21@gmail.com

ORCID:https://orcid.org/0009-0000-9112-9288

Emilia Bachoń:

Clinical Hospital in Poznan, Przybyszewskiego 49, 60-355 Poznan, Poland

emiliabachon98@gmail.com

ORCID: https://orcid.org/0000-0003-3676-7708

Michalina Doligalska:

Medical Hospital in Garwolin, Lubelska 50, 08-400 Garwolin, Poland

michalina.doligalska1@gmail.com

ORCID: https://orcid.org/0009-0002-1480-0677

Aleksandra Stremel:

Centre of Postgraduate Medical Education, Orłowski Hospital, Czerniakowska 231, 00-416, Warsaw, Poland

ola.stremel@gmail.com

ORCID: https://orcid.org/0009-0005-1055-3818

Agnieszka Leszyńska:

Poznan University of Medical Sciences, Collegium Maius, Fredry 10, 61-701 Poznan, Poland

agaleszyn@gmail.com

ORCID: https://orcid.org/0009-0005-9568-5659

Julia Linke

Specialist Hospital Wejherowo, dr Alojzego Jagalskiego 10, 84-200 Wejherowo, Polska

julialinke719@gmail.com

ORCID: https://orcid.org/0009-0009-1122-3625

Zuzanna Bałoniak:

Warsaw Southern Hospital, Witolda Pileckiego 99, 02-781, Warsaw, Poland

zuzannabaloniak@gmail.com

ORCID: https://orcid.org/0009-0006-6968-8781

Dominika Kozłowska

Faculty of Medicine, Poznań University of Medical Sciences, Poznań, Poland

dominikakozl98@gmail.com

ORCID: https://orcid.org/0009-0002-3541-6076

Julia Bałoniak

Faculty of Medicine, Poznań University of Medical Sciences, Poznań, Poland

Jj.baloniak@gmail.com

ORCID: https://orcid.org/0009-0002-8843-2117

Weronika Tuszyńska

University Clinical Center of the Medical University of Warsaw, Banacha 1a Street, 02-097 Warsaw, Poland

weron.stud28@gmail.com

ORCID: https://orcid.org/0000-0002-2395-6748

Abstract

Introduction:

Omega-3 fatty acids, particularly DHA and EPA, are crucial for brain health. Modern diets, often lacking in omega-3, highlight their importance in combating cognitive decline, neurodegenerative diseases, and mental disorders.

Purpose of research:

This study explores the roles of omega-3 fatty acids in brain health and cognitive functions, including their mechanisms of action and potential in preventing and alleviating neurodegenerative diseases.

Materials and methods:

This study involves a comprehensive review of scientific literature on the impact of omega-3 fatty acids on brain health and cognitive functions. The literature search was conducted using PubMed and Google Scholar, focusing on peer-reviewed articles, clinical trials, and meta-analyses relevant to omega-3 fatty acids, brain health, cognitive functions, and mental health outcomes.

Results and conclusions:

Research shows that DHA and EPA supplementation can significantly improve memory and learning, especially in older individuals and those with cognitive impairments. Omega-3s also show potential in reducing the risk of neurodegenerative diseases like Alzheimer's through their anti-inflammatory and antioxidant properties. In mental health, omega-3s can help reduce symptoms of depression and schizophrenia, although effectiveness depends on dosage and the EPA to DHA ratio. Omega-3s are essential for brain health and cognitive functions. Their supplementation, combined with cognitively stimulating activities, offers substantial benefits, especially in aging populations. Further research is needed to fully understand omega-3s' mechanisms, optimal dosing, and their use in preventing and treating neurological disorders.

Keywords: Omega-3 fatty acids; DHA (Docosahexaenoic acid); EPA (Eicosapentaenoic acid), Long-chain polyunsaturated fatty acids (LCPUFAs) ;Brain health; Cognitive functions; Neurodegenerative diseases; Alzheimer's disease (AD); Mental health; Depression; Schizophrenia

Introduction

Omega-3 fatty acids, especially docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), play a vital role in brain health. These essential nutrients, found mainly in marine and plant sources, are key to the structure and function of brain cells [1,2]. Modern diets often lacking in omega-3 fatty acids, highlight the importance of these nutrients in preventing cognitive decline, neurodegenerative diseases, and mental health problems [1,2,3].

Omega-3 fatty acids influence brain functions through multiple mechanisms [1,2]. They improve neuronal membrane fluidity, optimize synaptic connectivity, and modulate inflammatory processes [4].

As life longevity rises, the incidence of age-related non-communicable diseases also grows. This results in more complex healthcare needs. Brain DHA levels diminish with age, and low levels are linked to cognitive decline. Adequate intake of DHA and EPA can help maintain brain health, improve quality of life, and potentially reduce healthcare costs for the elderly population [2].

Research shows that omega-3 fatty acids may not only help preserve memory and learning abilities but also slow the progression of Alzheimer's disease and other neurodegenerative conditions [1,3,5]. Their benefits are not just for older adults, they also help brain development and offer protection against psychiatric disorders like depression and schizophrenia [6,7].

The objective of this study is to examine the various roles of omega-3 fatty acids in brain health and cognitive functions. This includes investigating their mechanisms of action, their effects on neuroplasticity and neurogenesis, and their potential in preventing and alleviating neurodegenerative diseases. By exploring these factors, we aim to show the importance of adequate omega-3 intake for maintaining cognitive health and preventing cognitive decline, especially in the aging population.

1. Mechanism of Action of Omega- 3 Fatty Acids

Omega-3 fatty acids are important substances that our bodies need for various essential functions. The main types of omega-3 fatty acids are eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and alpha-linolenic acid (ALA). These fatty acids play a crucial role in regulating many body functions, including the nervous system, blood pressure, sugar levels, and inflammation [1]. The body does not produce them sufficiently, so it is important to obtain them through diet or supplements.

EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) are particularly important for brain health. They are key components of brain cell membranes, increasing their fluidity, which aids in signal transmission and gene activity. This is essential for cognitive processes and overall brain health [8,9]. DHA is found in high amounts in the brain, making up about 40% of the brain's polyunsaturated fatty acids. It enhances membrane fluidity, which in turn improves neurotransmission and synaptic plasticity, leading to better memory and learning ability [10]. EPA, although present in smaller amounts, helps produce anti-inflammatory substances, protecting brain cells from damage [8]. The right balance of DHA and EPA is crucial for proper brain function and the prevention of brain diseases [11].

Omega-3 fatty acids also support brain plasticity and the growth of new brain cells. DHA promotes the growth and differentiation of brain stem cells, which is crucial for brain development and recovery after injuries [10]. Both DHA and EPA aid in the formation of synapses by increasing levels of synapsin and glutamate receptors, which are essential for synaptic function [9]. They also enhance the production of brain growth factors such as brain-derived neurotrophic factor (BDNF), which supports the survival and growth of brain cells [9]. Additionally, omega-3 fatty acids reduce pro-inflammatory substances, thereby decreasing brain inflammation commonly associated with brain diseases [8,11].

To sum up, omega-3 fatty acids, especially DHA and EPA, are crucial for keeping brain cell membranes healthy, improving synaptic plasticity, and promoting the growth of new brain cells. These activities contribute to the proper functioning of the brain and emphasize the importance of omega-3 fatty acid intake for brain health and disease prevention.

2. Impact of Omega-3 Fatty Acids on Cognitive Functions and Brain Health

2.1 Impact on Memory and Learning

Memory and learning are key cognitive functions affected by diet and lifestyle.Recent studies have explored the potential benefits of long-chain polyunsaturated fatty acids (LCPUFAs) for cognitive health. LCPUFAs are a group of fatty acids that include omega-3 and omega-6 fatty acids, which are essential for various bodily functions. The effects of these nutrients on memory and learning have been described in several studies [5,10,12,13]

A study conducted by Toshiaki Sueyasu et al. examined how LCPUFAs affect memory in older Japanese people with memory problems. The study included randomized, double-blind, placebo-controlled trials. Participants took supplements with arachidonic acid, docosahexaenoic acid, and eicosapentaenoic acid for 24 and 12 weeks. Memory functions

were assessed using Cognitrax (computerized cognitive function test) before and after each trial period. The results showed that LCPUFAs did not significantly improve memory in healthy, older adults with memory complaints. However, those with memory difficulties showed better memory function [12].

Omega-3 fatty acids, like EPA and DHA, are important elements of many healthy diets and are linked to better memory and learning. Research by Loong et al. explored the connection between omega-3 levels, brain volume, and cognitive functions in older adults. The study found that higher levels of omega-3 fatty acids were associated with improved information processing speed and better memory. It also showed changes in brain structure, such as a thicker entorhinal cortex and the more white matter [5].

Combining cognitively stimulating leisure activities (CSLAs) with LCPUFA intake may provide more benefits than using these methods separately. A study by Tokuda et al. looked at the effects of combining these two approaches on cognitive function in elderly Japanese. The results show that frequent participation in CSLA combined with high arachidonic acid intake lowered the risk of cognitive decline. Additionally, it was found that a high intake of DHA, along with regular CSLA, improved memory, especially in people who initially had low levels of DHA and EPA[13].

As previously mentioned, DHA is vital for various stages of neurogenesis, including the proliferation, migration, differentiation, and synaptogenesis of brain cells. Research indicates that DHA accumulates in brain regions associated with learning and memory. Lack of DHA can lead to problems with cognitive function and developmental disorders such as dyslexia, autism spectrum disorders, ADHD, and schizophrenia. These observations show the necessity of sufficient DHA intake for optimal brain development and function [10].

In conclusion, research suggests that adequate supplementation with DHA and EPA can help improve learning abilities, especially in older adults and people with cognitive problems. A diet with these fatty acids, along with doing mind-stimulating activities, can greatly benefit brain health.

2.2 Impact on Neurodegenerative Diseases

Omega-3 fatty acids, particularly docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), are being investigated for their potential benefits in neurodegenerative diseases such as Alzheimer's disease (AD) and other forms of dementia. These essential fatty acids play a crucial role in brain health and function, making them a significant focus in research on memory loss and dementia [14,15].

Higher intake of omega-3 fatty acids, particularly DHA, has been linked to a lower risk of dementia by 10-20%. This protective effect is likely due to the anti-inflammatory and antioxidant properties of DHA and EPA, which help keep the brain healthy. Additionally, structured forms of these fatty acids, like triglycerides and phospholipids, have shown better absorption and stronger effects compared to other forms of omega-3 acids [3,16].

DHA is crucial for brain health and has been extensively studied for its potential to reduce Alzheimer's disease (AD). It is incorporated into brain phospholipids and forms potent lipid mediators that help reduce inflammation and oxidative stress. Studies have demonstrated that DHA can decrease amyloid-beta plaques and tau tangles, which are key pathological markers of AD. In animal models, DHA supplementation has been shown to improve memory and reduce AD pathology. Additionally, DHA-enriched phosphatidylserine (DHA-PS) has been found to significantly enhance cell structure and promote the restoration of neural network integrity [15,17].

Research has also highlighted the connection between omega-3 blood markers and brain glucose uptake, which is significant for proper brain function. Higher levels of alpha-linolenic acid (ALA), a type of omega-3 fatty acid, have been linked to increased glucose uptake in brain regions affected by Alzheimer's disease (AD), particularly in individuals carrying the apolipoprotein E ε4 (APOE ε4) allele. This suggests that omega-3 fatty acids may enhance brain energy metabolism, which is often compromised in neurodegenerative diseases [14].

Omega-3 fatty acids also play an important role in maintaining cognitive function. High-dose supplements of omega-3 and omega-6 polyunsaturated fatty acids, along with antioxidant vitamins, have been shown to significantly improve cognitive function and functional capacity in older adults with mild cognitive impairment (MCI). The study found a 15% improvement in cognitive scores and a 20% improvement in functional capacity in the supplemented group compared to the placebo group [18].

Moreover, combining mentally stimulating activities with high intake of arachidonic acid (ARA) and DHA has been found to significantly reduce the risk of cognitive decline. Participants who engaged in frequent mentally stimulating activities and had high DHA intake showed a 30% lower risk of cognitive decline compared to those with low DHA intake and low activity levels [13].

In summary, omega-3 fatty acids, especially DHA and EPA, have a big effect in reducing the risk of cognitive decline, dementia, and Alzheimer's disease. Their benefits are enhanced when combined with lifestyle changes, such as mentally stimulating activities.

These results underscore the importance of a holistic approach to brain health, including dietary and lifestyle changes aimed at reducing the risk of developing and progressing neurodegenerative diseases.

2.3 Impact on Mental Health

Omega-3 fatty acids have been researched for their potential positive effects on mental health, especially in relation to conditions like schizophrenia and depression. This overview explains how omega-3 fatty acids impact mental well-being [4,7]

Schizophrenia is a serious mental illness with symptoms such as hallucinations, delusions, and cognitive impairments. Studies have found that individuals with schizophrenia often have lower levels of polyunsaturated fatty acids (PUFAs), especially docosahexaenoic acid (DHA), in both their blood and brain tissues [7]. These deficiencies are believed to affect the development of the disorder, influencing the severity of psychotic symptoms and thinking problems.

Clinical trials examining the impact of omega-3 supplementation on schizophrenia have produced diverse outcomes. Some studies have shown significant improvements in both positive and negative symptoms, as well as overall functioning, especially in teenagers and young adults at high risk of developing psychosis. The benefits of omega-3 supplementation appear to depend on initial LCPUFAs levels, with people who start with lower levels showing greater improvements [7]. This suggests that omega-3 supplements could be more effective for some patients, and further studies are needed to confirm these

Depression is another mental health condition in which omega-3 fatty acids have shown potential benefits. Many studies suggest that EPA and DHA have antidepressant effects. These benefits are believed to come from their ability to influence neuroinflammatory processes, neurotransmitter function and neuroplasticity. However, clinical trials have produced variable results; some have reported significant reductions in depressive symptoms, while others have shown little or no benefit [4]

The efficacy of omega-3 supplementation in treating depression may depend on factors such as dosage, the ratio of EPA to DHA, and the patient's baseline nutritional status. For instance, EPA doses ranging from 1 g per day to less than 2 per day have been associated with significant reductions in depression severity, whereas higher doses (2 per day or more) have not shown substantial therapeutic effects [19]. Additionally, formulations containing at least 60% EPA have been more effective than those with higher DHA content in alleviating depressive symptoms [20].

Omega-3 fatty acids may be used as an additional treatment for depression, especially with conventional antidepressant medications. Studies indicate that omega-3 supplementation could help alleviate residual depressive symptoms in individuals with bipolar disorder [4].

The effects of omega-3 fatty acids on anxiety have also been studied, although the evidence is not as strong as it is for depression and schizophrenia. One study found a significant reduction in anxiety severity with a daily dose of 2.1 g of EPA (with an EPA to total EPA + DHA ratio of 85.6%) compared to a placebo. These results highlight the need for more research to better understand the anxiety-reducing potential of omega-3 fatty acids.

In summary, omega-3 fatty acids, especially EPA and DHA, have demonstrated potential benefits for mental health conditions like schizophrenia, depression, and anxiety. The effectiveness of omega-3 supplementation seems to depend on initial PUFAs levels, dosage, and the EPA to DHA ratio. Although the current evidence is promising, additional research is necessary to develop standardized guidelines for using omega-3 fatty acids in the treatment of mental health disorders [4,7,19].

3. Supplementation and diet

Taking supplements and eating the right foods are important for getting enough omega-3 fatty acids, which are essential for brain health and cognitive function. Omega-3 fatty acids, especially EPA and DHA, are mostly found in fish and fish oil, but they can also be found in plant oils. Main sources of these acids include fish like salmon, mackerel, sardines, and herring, which are rich in EPA and DHA. Plant oils such as flaxseed, chia seeds, and walnuts contain ALA, which can be converted into EPA and DHA, but not very effectively. The body usually converts less than 10% of ALA to EPA and DHA, making it difficult to obtain sufficient amounts of these important fatty acids from plant sources alone [21,22,23].

To get benefits for the brain from omega-3 fatty acids, it is recommended to eat fatty fish at least twice a week. For example, a portion of salmon (about 100 grams) contains approximately 1.5 grams of EPA and DHA combined. Therefore, consuming two portions of fatty fish per week can provide around 3 grams of EPA and DHA, which aligns with general recommendations for brain health [21,23]. For vegetarians or vegans, omega-3 supplements can be a good alternative. It is important to choose high-quality supplements that provide sufficient EPA and DHA and are free from contaminants like mercury [23]. Fish oil supplements are the most common form, available in liquid, capsule, or softgel forms. Algal oil supplements are a plant-based alternative, suitable for vegetarians and vegans, and they also provide DHA and EPA [22]. For general brain health, a daily intake of 1-2 grams of EPA

and DHA is often recommended, as it positively affects cognitive function, especially in older adults. In the context of Alzheimer's disease, some studies have shown that around 2 grams per day of EPA and DHA can yield promising results [19,23,24].

Research shows that omega-3 supplements, especially from fish, are beneficial for brain health. Increased fish consumption is linked to a lower risk of cognitive problems and Alzheimer's disease. Higher fish intake, up to 150 grams per day, reduces the risk of cognitive issues. EPA and DHA supplements improve cognitive function, particularly in individuals with mild cognitive impairment. General recommendations suggest 0.25–0.5 grams per day of EPA and DHA for overall health, with higher doses (1 to 4 grams per day) for specific conditions like dementia and Alzheimer's disease. In a study, individuals with mild to moderate Alzheimer's who took 2 grams of DHA daily for 18 months did not show significant overall cognitive improvements compared to a placebo. However, a subgroup without the APOE ε4 gene exhibited a slower rate of cognitive decline. This suggests that consuming fish and taking DHA supplements may benefit certain groups, but further research is needed [21,25,26,27].

The EFSA (European Food Safety Authority) states that up to 5 grams per day of combined EPA and DHA can be taken for general health, including brain health. This is more than other health organizations suggest. Higher omega-3 intake can reduce inflammation and improve neuronal function, which is crucial for brain health. Omega-3 fatty acids are also important for mental health. Studies indicate that EPA-rich supplements, especially those with EPA constituting $\geqslant$ 60% of total EPA + DHA and doses between 1-2 grams per day, significantly reduce depression symptoms. There are also potential anxiety-reducing effects of EPA, though further research is needed. Omega-3 supplements have shown promise in aiding individuals with schizophrenia and other mental health conditions. For instance, a study on recent onset psychosis found that participants treated with 740 mg of EPA and 400 mg of DHA daily, along with risperidone, experienced significant improvements in depression-anxiety symptoms compared to the placebo group. These findings underscore the potential of omega-3 fatty acids as an adjunctive treatment in mental health disorders, highlighting the need for more research to optimize their use and understand their mechanisms of action [19,28,29].

Interestingly, a review of randomized controlled trials suggested that lower doses of omega-3 fatty acids (<1.73 g/day) might be more effective at preventing cognitive decline compared to higher doses. This indicates that smaller amounts could be more beneficial in maintaining cognitive function [30].

In summary, adequate intake of omega-3 fatty acids is crucial for brain health and cognitive function. The optimal approach to achieve this is through diet and supplementation. Consuming 1-2 grams of EPA and DHA daily is recommended for optimal results. The EFSA states that up to 5 grams daily can provide additional benefits for the brain and overall health. By incorporating omega-3-rich foods or high-quality supplements into their diet, individuals can enhance brain function, reduce the risk of cognitive decline, and support brain development. Omega-3 fatty acids are also vital for mental health, aiding in the reduction of anxiety and depression symptoms.

4. Future Directions for Research on Omega-3 and Brain Health

Research on omega-3 fatty acids, especially DHA, shows they are very beneficial for brain health, including cognitive function, brain cell growth, and stress management. Although the results are promising, further study is needed.

Future research should look at how omega-3 affects brain functions at a small level. It is important to understand how DHA helps brain connections and brain cell growth in the hippocampus [11,25]. Long-term studies are needed to clearly show the benefits of omega-3 supplements in stopping and treating brain disorders like Alzheimer's disease [26].

Studies should also look at how omega-3 works with other diet and lifestyle factors to better understand how these fatty acids can be best used for public health. It is important to study how different groups of people, including those of different ages and health statuses, respond to omega-3 supplements. This could help create more personalized diet recommendations [1,11,23].

Omega-3 fatty acids also have potential benefits for mental health, especially in conditions like schizophrenia and depression. Research has shown that patients with schizophrenia often have low levels of polyunsaturated fatty acids (PUFA), especially DHA, in their blood and brain tissues [4,7]. Omega-3 supplements can help reduce symptoms of depression, especially at the right doses of EPA and DHA [4,31]. Studies, like the one by Sublette et al. (2011), have shown that higher doses of EPA compared to DHA may be more effective in reducing depressive symptoms. This suggests that the specific mix of omega-3 supplements could be very important for their effectiveness. Future research should focus on finding the best doses and ratios of EPA to DHA for mental health benefits [31]. It is also necessary to study how omega-3 supplements affect different groups of patients, including those with various types of mental disorders and different levels of symptom severity.

In studies on mild cognitive impairment (MCI), like those by Mengelberg et al. (2022), DHA supplements can have different effects based on the APOE genotype. In their study, 72 older adults with MCI took a DHA supplement or a placebo for 12 months. The results showed no significant effect on cognitive function, but APOE ε4 carriers had better moods and lower blood pressure [26]. These findings suggest that future research should look at the APOE genotype when studying omega-3 supplements. In a study on recent psychosis, people who took 740 mg of EPA and 400 mg of DHA daily, along with risperidone, had better moods and less anxiety compared to the placebo group [29]. These results suggest that omega-3 supplements may help with depression and anxiety in people with recent psychosis, but more research is needed to confirm this. These studies may also help to see if omega-3 can be a good addition to standard psychotic treatment, especially for improving mood and anxiety.

In summary, while there is strong evidence that omega-3 is good for brain health, more research is needed to fully understand how it works and how to best use it to prevent and treat brain disorders. Future studies should look at how omega-3 works at a molecular level, conduct long-term clinical trials, and examine its interactions with diet and lifestyle to fully utilize its potential for improving brain health.

5. Conclusions

Omega-3 fatty acids, especially EPA and DHA, are very important for brain health and cognitive function. These fatty acids help keep brain cell membranes healthy, improve connections between brain cells, and support the growth of new brain cells. DHA helps with learning and memory by making cell membranes more fluid and improving communication between brain cells. EPA helps reduce inflammation and protects brain cells from damage.

Research shows that omega-3 fatty acids are very beneficial for cognitive function. Taking DHA and EPA supplements can improve memory and learning, especially in older adults and individuals with cognitive impairments. Combining these fatty acids with activities that stimulate the brain can be highly advantageous. Higher levels of omega-3s are associated with better memory, faster cognitive processing, and healthier brain structure.

Omega-3 fatty acids can also help reduce the risk of cognitive decline, dementia, and Alzheimer's disease. Their anti-inflammatory and antioxidant properties help maintain brain health and reduce the formation of amyloid-beta plaques and tau tangles, which are key markers of Alzheimer's disease. The benefits of omega-3s are even greater when combined

with brain-stimulating activities. This approach combines dietary and lifestyle changes to improve brain health.

In mental health, omega-3 fatty acids can help with conditions like schizophrenia, depression, and anxiety. The effectiveness of omega-3 supplements depends on factors like the levels of fatty acids in the body, the dose, and the ratio of EPA to DHA. More research is needed to create guidelines for using omega-3s in mental health treatment. Personalized approaches to supplementation, considering individual nutritional status and health conditions, are important.

Getting enough omega-3 fatty acids through diet and supplements is essential. For the best results, it is recommended to consume 1-2 grams of EPA and DHA daily, with higher doses of up to 5 grams per day suggested for better brain and overall health. Eating foods rich in omega-3s or taking high-quality supplements can support brain development, reduce the risk of cognitive decline, and improve brain function. This shows the importance of diet in keeping the brain healthy and preventing neurodegenerative diseases.

Future research should focus on understanding how omega-3s work in the brain, conducting long-term studies, and exploring how they interact with diet and lifestyle. Considering the APOE genotype as a factor in the effects of omega-3 supplements could lead to more personalized and effective treatments for brain health. This will help develop better interventions for brain health.

In conclusion, omega-3 fatty acids are very important for brain health and cognitive functions. Their potential benefits in preventing and treating neurodegenerative diseases and mental health conditions highlight the importance of getting enough omega-3s through diet or supplements. More research is needed to fully understand their benefits and optimize their use in clinical practice. The findings of this study show the significant role of omega-3 fatty acids in brain health and provide a strong foundation for future research and clinical applications.

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Authors' Contribution:

Conceptualization: Wiktoria Wesołowska, Emilia Bachoń, Michalina Doligalska, Aleksandra Stremel

Methodology: Wiktoria Wesołowska, Aleksandra Stremel, Julia Linke, Dominika Kozłowska, Weronika Tuszyńska

Investigation: Wiktoria Wesołowska, Emilia Bachoń, Michalina Doligalska, Agnieszka Leszyńska, Julia Bałoniak

Software: Aleksandra Stremel, Zuzanna Bałoniak, Julia Bałoniak, Weronika Tuszyńska

Formal analysis: Michalina Doligalska, Aleksandra Stremel, Dominika Kozłowska,Weronika Tuszyńska

Writing: Wiktoria Wesołowska, Emilia Bachoń, Michalina Doligalska, Aleksandra Stremel, Agnieszka Leszyńska, Julia Bałoniak

Resources: Zuzanna Bałoniak, Julia Linke, Dominika Kozłowska

Supervision: Wiktoria Wesołowska, Emilia Bachoń, Aleksandra Stremel

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