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The Impact of Omega-3 Fatty Acids on the Onset and Management of Alzheimer's Disease

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Abstract

Introduction and Purpose: Alzheimer’s disease (AD) is a progressive neurodegenerative disorder, whose etiology remains complex. Research suggests that dietary factors, particularly omega-3 fatty acids, may play a role in modulating neuroinflammation and amyloid-beta pathology—key hallmarks of AD. Omega-3 acids have been linked to improved neuronal function and reduced cognitive decline in aging populations. This review explores their impact on the progression and management of Alzheimer’s disease.
Materials and Methods: This article is a comprehensive review based on articles obtained from scientific databases like PubMed, selected for their importance to the subject.
Results: The relationship between omega-3 fatty acids and cognitive impairment, including Alzheimer’s disease, has been widely studied. Research suggests that docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) may support brain health by reducing neuroinflammation, enhancing synaptic function, and potentially slowing cognitive decline. Although some studies show cognitive benefits, others report mixed results due to variations in dosage, duration, and patient characteristics. While omega-3s are not a cure, their neuroprotective potential underscores the need for further research to optimize their clinical application.
Conclusion: Although research indicates possible cognitive benefits, particularly in early Alzheimer's disease or mild cognitive impairment, findings remain inconsistent. While omega-3s are not a definitive treatment, their neuroprotective properties highlight the need for further scientific investigation in the field. Future research is required to determine the optimal dosage of omega-3 fatty acids and to identify patient-specific factors that influence their therapeutic efficacy.

Keywords: omega-3, Alzheimer’s disease, diet, supplementation, inflammation, cognitive decline

Introduction

A balanced diet for a healthy individual should meet the body's requirements for energy as well as all other essential nutrients necessary for growth, maintaining vital functions, and preserving health[1]. Research suggests that diet plays a crucial role in the onset and progression of Alzheimer's disease. A diet high in saturated fats, refined sugars, and processed foods may contribute to chronic inflammation and oxidative stress, both of which are linked to neurodegeneration. In contrast, consuming omega-3 fatty acids, antioxidants, B vitamins, and polyphenols—found in fruits, vegetables, and nuts—can support cognitive function and potentially slow neurodegenerative processes[2]. Diets, which emphasize healthy fats, fiber, and anti-inflammatory compounds, have been associated with a lower risk of dementia and improved brain health.The most concentrated source of energy in the human diet comes from fats, providing an average of 9 kcal for every gram consumed. Fats are a source of fatty acids, including essential unsaturated fatty acids (EUFA), as well as fat-soluble vitamins such as A, D, E, and K. These nutrients are utilized by the body for the synthesis of hormones, proteins, and other biologically active substances, and they also contribute to the formation of cellular organelles that make up tissues and organs. In dietary fats, fatty acids are classified based on their chemical structure into saturated fatty acids (SFA), monounsaturated fatty acids (MUFA)—which contain one double bond in their molecule—and polyunsaturated fatty acids (PUFA), which are highly desirable and contain more than one double bond in their molecule. PUFA cannot be synthesized by the human body and must therefore be obtained through diet[1]. Omega-3 fatty acids (also referred to as n-3 or ω-3 fatty acids) belong to the group of polyunsaturated fatty acids[1][2]. In their molecular structure, the last double bond in the carbon chain is located at the third carbon atom from the end. This group includes the following compounds, which play crucial roles in the human body: Eicosapentaenoic acid (EPA), Docosahexaenoic acid (DHA) and α-Linolenic acid (ALA). The primary dietary sources of omega-3 fatty acids include plants and plant-based products, such as vegetable oils (e.g., rapeseed oil, flaxseed oil, soybean oil, walnut oil, and macadamia oil) as well as foods like walnuts, almonds, chia seeds, soybeans, sprouted grains, rapeseed, and flaxseeds[1]. Additionally, algae are a significant source of omega-3s. Moreover, the main dietary sources of DHA and EPA—two key omega-3 fatty acids—are fatty marine fish, such as salmon, herring, sole, and cod, particularly those that are wild-caught, as well as seafood[1].

Role of Omega-3 fatty acids

Unsaturated fatty acids obtained from food can undergo enzymatic transformations, leading to the production of physiologically essential substances such as eicosanoids. These are tissue hormones with a broad spectrum of activity, including: prostaglandins (PG), prostacyclins (PGI), thromboxanes (TXA) and non-cyclic compounds such as leukotriens (LT) and lipoxins (LX). Eicosanoids play a regulatory role in the cardiovascular system, blood pressure, blood clotting, intravascular clot formation, and the control of inflammatory and immune processes. Additionally, they contribute to the formation of phospholipids and cholesterol esters, which are essential components of membrane structures in virtually all human cells.

The dietary precursor of omega-3 is primarily metabolized into DHA (docosahexaenoic acid) or EPA (eicosapentaenoic acid) in the liver, with a smaller portion being processed in the brain's endothelium and astrocytes. From these sites, the resulting compounds are transported to neurons. DHA is integrated into the phospholipids of neuronal membranes, providing them with structural and physicochemical properties that are crucial for synaptic function. High levels of DHA enhance the fluidity of plasma membranes, which facilitates the efficient transport of neurotransmitters[2]. Because of these characteristics, DHA is now recognized as a significant factor in both the prevention and management of neurodegenerative diseases. DHA is the predominant omega-3 fatty acid in the brain, where it is essential for preserving neuronal structure and function [2][3].Its neuroprotective effects are believed to arise from multiple mechanisms, such as modulating synaptic plasticity, mitigating neuroinflammation, and improving the fluidity of neuronal membranes[3]. Experimental studies have demonstrated that DHA protects neurons from oxidative stress, particularly by maintaining the organization of cytoskeletal microtubules. Additionally, multiple studies suggest that increased DHA supplementation supports neuronal maturation and development, especially in the hippocampus, thereby improving synaptic function. These effects may enhance signal transmission, promote neurogenesis, and inhibit apoptosis, potentially slowing the progression of cognitive decline in conditions like Alzheimer's disease and mild cognitive impairment[3]. Growing evidence from epidemiological and animal studies highlights DHA's role in reducing cognitive decline, underscoring its potential as a focus for clinical research.

Cognitive impairment

Neurodegenerative diseases are defined by the gradual loss of neuronal function in the brain, leading to cognitive decline and motor impairments. While these conditions arise from multifactorial interactions, nutrition plays a critical role in their development and progression [4]. A systematic review of the literature was conducted, focusing on studies that examined the impact of the nutritional interventions, EPA and DHA, and vitamins on memory and cognitive decline. The findings revealed that malnutrition and a low body mass index (BMI) are associated with an increased risk of dementia and higher mortality rates.

Cognition refers to the process of acquiring, storing, and utilizing information to guide behavior. It encompasses the ability to perceive, process, and interpret information, as well as to make sound decisions and develop effective behavioral responses. In essence, stronger cognitive abilities enable individuals to better understand their surroundings and interact with them in a safe and efficient way. Certain aspects of cognitive functioning, such as attention, often decline with mental illness[5]. Some conditions lead to difficulties with concentration, while others may result in a complete inability to focus. Typically, each disease affects specific cognitive domains, leading to distinct disruptions in mental functioning.

Cognitive impairment and dementia impact tens of millions of individuals globally, creating substantial emotional strain for both patients and their caregivers. Cognitive impairment refers to a decline in cognitive abilities that affects memory, thinking, reasoning, and other mental functions[5]. It can range from mild to severe and may interfere with daily activities and quality of life. The term is used to describe difficulties with one or more cognitive functions, such as: memory (forgetting recent events or important information), language (trouble finding words or understanding speech), attention (difficulty in focusing on a particular task), executive function (troubles with planning or decision-making) or visuospatial skills (difficulty recognizing faces or familiar places).

There are several types of cognitive impairments, from mild form to severe. We can distinguish Mild Cognitive Impairment (MCI), dementia and age connected cognitive decline. MCI is a transitional stage between normal age-related cognitive decline and more serious conditions like dementia. Patients with MCI may experience noticeable memory or thinking problems, but these do not significantly interfere with daily life. Not everyone with MCI progresses to dementia; some remain stable or even improve [5][6]. Dementia is a more severe form of cognitive impairment that significantly impacts daily functioning, common types include Alzheimer's disease, vascular dementia, Lewy body dementia, and frontotemporal dementia. It is progressive and irreversible, though some symptoms can be managed with treatment[6]. Age-related cognitive decline is characterized by slower processing speed and mild memory lapses and is a normal part of the aging process.

Cognitive impairment can eventuate from wide range of factors, including: neurodegenerative diseases, infections (e.g. meningitis, encephalitis) ,vascular issues (stroke or small vessels disease), traumatic brain injuries, mental health disorders (chronic stress, depression), nutritional deficiencies (lack of essential nutrients, such as vitamin B12, vitamin D, or omega-3 fatty acids), certain medications (sedatives, anticholinergics, or chemotherapy) or lifestyle factors (poor sleep hygiene, smoking, lack of physical activity, social isolation).

Symptoms vary depending on the severity and underlying cause but may include: memory loss, language problems, disorientation, difficulty concentrating or mood changes [7]. Cognitive impairment can be diagnosed through clinical evaluation, cognitive testing (tests like Mini-Mental State Examination (MMSE) or Montreal Cognitive Assessment (MoCA)) [8], blood tests, brain imaging or other specialized tests (e.g. lumbar puncture or PET scans to assess biomarkers like amyloid-beta or tau in suspected Alzheimer's cases). Early diagnosis and intervention are crucial for managing symptoms and slowing progression. Lifestyle factors play a significant role in both prevention and treatment [8].

Alzheimer's disease

Alzheimer's disease, the leading cause of dementia, is rapidly emerging as one of the most costly, deadly, and burdensome diseases of the 21st century. Its growing prevalence places an immense strain on healthcare systems, families, and societies, both financially and emotionally, while its progressive and incurable nature makes it a significant public health challenge[9]. It can be described as a gradually progressive neurodegenerative disorder marked by the presence of neuritic plaques and neurofibrillary tangles (Figure 1.) [10]. These pathological features arise from the accumulation of amyloid-beta peptides (Aβ) in key regions of the brain, particularly the medial temporal lobe and neocortical structures, which are among the most severely affected areas [10].

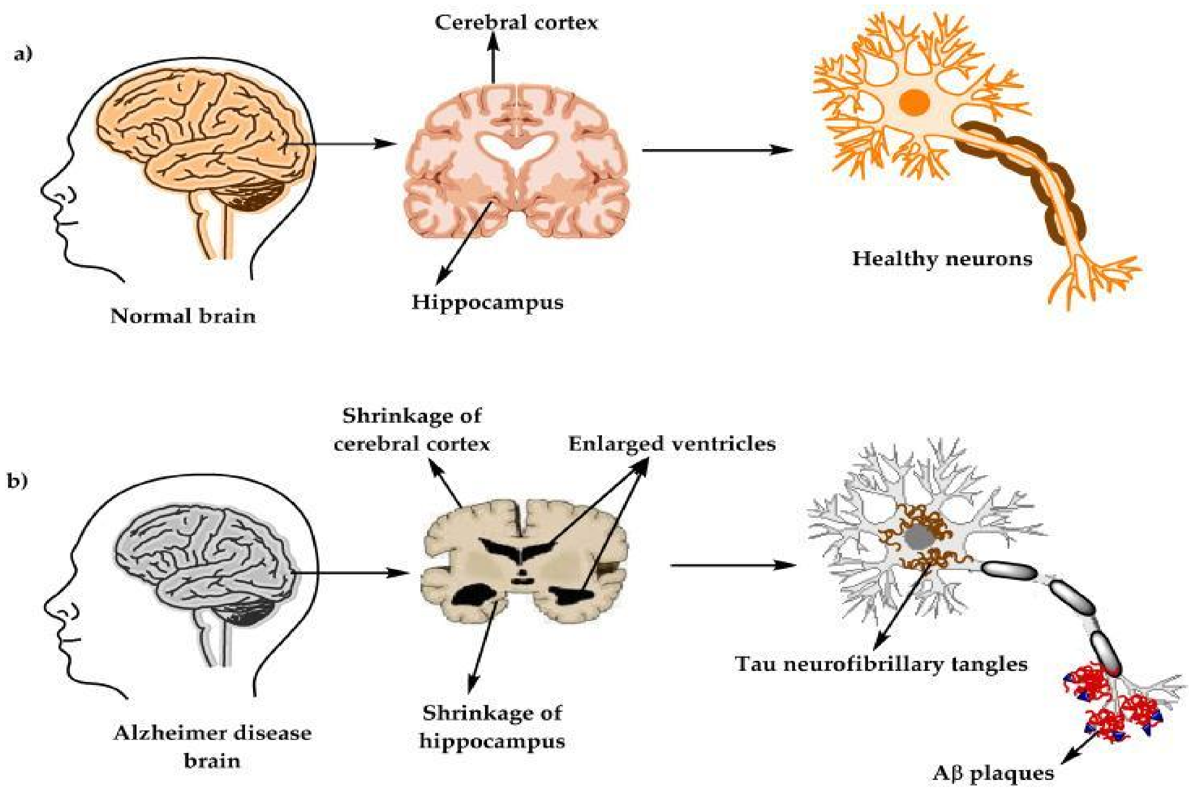

Figure 1. The physiological structure of the brain and neurons in (a) healthy brain and (b) Alzheimer's disease (AD) brain. Adapted from Breijyeh Z, Karaman R. Comprehensive Review on Alzheimer's Disease: Causes and Treatment. *Molecules*. 2020;25(24):5789. Published 2020 Dec 8. doi:10.3390/molecules25245789 [10]

A small proportion of Alzheimer's disease (AD) cases are caused by dominant genetic mutations in three genes: APP (amyloid precursor protein), PSEN1 (presenilin 1), and PSEN2 (presenilin 2). These mutations are typically associated with early-onset Alzheimer's, where clinical symptoms manifest before the age of 65. However, the majority of patients develop late-onset Alzheimer's disease (LOAD), which occurs later in life and is generally sporadic rather than hereditary. While LOAD does not have a single genetic cause, research has identified several genetic risk factors. The most significant of these is the E4 allele of the ApoE (apolipoprotein E) gene, which is present in approximately 16% of the population and strongly correlates with increased disease risk [11]. Additionally, lifestyle factors such as an unhealthy diet and lack of physical activity, along with environmental and metabolic

conditions like diabetes, cerebrovascular disease, head trauma, and chronic stress, are commonly associated with a higher likelihood of developing the disease [10][11].
One of the first alternative hypotheses for the development of this disease was the cholinergic changes. Acetylcholine is one of the key neurotransmitters in the human brain, playing a vital role in various regions, including the cerebral cortex, basal ganglia, and forebrain. Its functions are multifaceted: acetylcholine is involved in neuroplasticity, which is the brain's ability to adapt and reorganize itself based on experiences and learning throughout life. Additionally, it contributes to neuronal synchronization, a process that ensures effective communication between neurons. This synchronization is crucial for proper signal transmission, which underpins cognitive functions such as memory, attention, and learning. Initial studies on patients with Alzheimer's disease revealed that disruptions in cholinergic conductivity, observed even in the early stages of the disease, were primarily presynaptic rather than postsynaptic. Further research demonstrated that these changes in neural signaling involve both nicotinic (ionotropic) and muscarinic (metabotropic) receptors in the cerebral cortex. In the early stages of Alzheimer's, there is a significant loss of cholinergic neurons in the basal nucleus and the cingulate cortex. As the disease progresses, the loss of cholinergic neurons becomes more pronounced, particularly in the basal nucleus, where over 90% of the cells in this region may be affected. This widespread neuronal loss leads to a reduction in the binding capacity of cholinergic receptors, contributing to the neuropsychiatric symptoms commonly seen in Alzheimer's patients.

The articles discuss various mechanisms involved in the development of Alzheimer's disease. These include issues like selective autophagy (a process that helps clear damaged cells), mitochondrial dysfunction (problems with the energy-producing parts of cells), the role of NLRP3 inflammasome activation (a pathway linked to inflammation), and the impact of insulin and insulin resistance on the brain [11]. A large amount of research and scientific studies indicate inflammatory processes as the mechanism most often present in the development of Alzheimer's disease. A complex network of cells, including astrocytes, microglia, and proteins such as cytokines and chemokines, triggers neuroinflammation. This inflammatory response damages the neuronal environment, leading to neuron injury and contributing to the development of oxidative stress or even cell apoptosis. These processes ultimately result in the onset of symptoms characteristic of Alzheimer's disease (Figure 2.) [12]

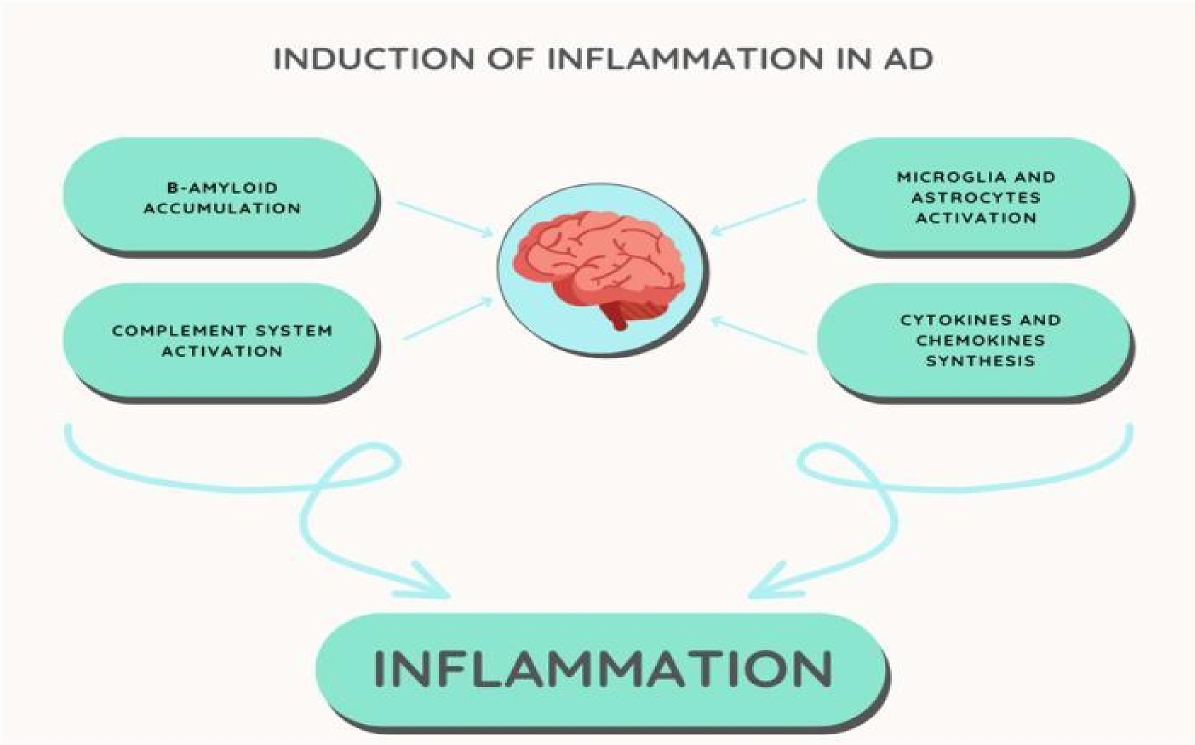

Figure 2. The primary inducers of inflammation in Alzheimer's Disease. Adapted from Twarowski B, Herbet M. Inflammatory Processes in Alzheimer's Disease-Pathomechanism, Diagnosis and Treatment: A Review. *Int J Mol Sci*. 2023;24(7):6518. Published 2023 Mar 30. doi:10.3390/ijms24076518 [12]

The most significant risk factors for Alzheimer's disease are advanced age (typically over 65, though this isn't a strict cutoff) and having at least one APOE ε4 allele. Additionally, women are more likely than men to develop Alzheimer's, particularly after the age of 80 [9][11]. Research also shows that women tend to have higher levels of tau protein in their brains, even when their amyloid β burden is similar to men's. Beyond genetics and gender, cardiovascular risk factors (like high blood pressure and cholesterol) and an unhealthy lifestyle (such as poor diet, lack of exercise, and smoking) are also linked to a higher risk of dementia. According to the Lancet Commission on Dementia Prevention, around 40% of dementia cases worldwide can be attributed to modifiable risk factors, highlighting the importance of prevention through lifestyle changes [13].

Alzheimer's disease diagnosing process

Diagnosing Alzheimer's disease (AD) is a complex process that requires a multidisciplinary approach, it involves a combination of clinical evaluation, cognitive testing, imaging, and sometimes biomarker analysis. Early and accurate diagnosis is crucial for timely intervention and management of symptoms[14]. The main symptoms of Alzheimer's disease (AD) typically develop gradually and worsen over time. They can be categorized into cognitive, behavioral, and functional symptoms. Beyond memory concerns, patients with symptomatic AD may present for the evaluation of changes in mood, anxiety, irritability or word-finding difficulty [14].

Clinical evaluation should consist of asking about detailed medical history (especially about symptoms and their progression) and physical examination with the strongest emphasis on neurological exam (assesses reflexes, coordination, and sensory function to identify any neurological abnormalities)[13]. Another important part of the process of diagnosing AD is

cognitive and neuropsychological testing including tools like the Mini-Mental State Examination (MMSE), Montreal Cognitive Assessment (MoCA), or Clock Drawing Test and more detailed neuropsychological assessments to measure specific cognitive domains affected by Alzheimer's, such as episodic memory, executive function, and visuospatial skills [13].Brain imaging is also an essential component of diagnosing process, the most important ones are: MRI, functional imaging (PET or SPECT), amyloid PET imaging or Tau PET imaging. To make the diagnosing evaluation complete it is also crucial to check biomarkers analysis such as cerebral fluid analysis (can measure levels of amyloid-beta, tau, and phosphorylated tau in the CSF. Low amyloid-beta and high tau levels are indicative of Alzheimer's) and blood tests (emerging blood-based biomarkers, such as phosphorylated tau (p-tau) and neurofilament light chain (NfL), are being developed for easier and less invasive diagnosis). Biomarkers and imaging can detect Alzheimer's pathology years before symptoms appear, allowing for early intervention[14][15].
There are three stages of Alzheimer's symptoms, they can be divided into: early stage (subtle memory lapses, difficulty with complex tasks and mild mood changes), middle stage (confusion about time and place, difficulty recognizing family and friends, increased behavioral changes) and late stage (loss of ability to communicate coherently, complete dependant on others, difficulty walking, sitting or swallowing and increased susceptibility to infections) [14].

Alzheimer's disease treatment

Alzheimer's disease undoubtedly poses a significant clinical challenge for healthcare professionals tasked with caring for affected patients . The complexity of the disease requires a thorough understanding of the underlying mechanisms driving its progression, as well as the use of appropriate diagnostic tools to assess the patient's condition accurately. Once a diagnosis is established, the next critical step is to select an effective treatment strategy tailored to the individual's needs[14]. Recent research indicates a strong correlation between the onset and progression of Alzheimer's disease (AD) and various lifestyle factors, particularly diet. Nutritional interventions have emerged as a promising strategy for delaying neurocognitive decline and potentially reducing the risk of AD development[14][15]. Maintaining a well-balanced diet rich in plant-based foods, probiotics, nuts, and omega-3 polyunsaturated fatty acids while minimizing the consumption of saturated fats, animal-derived proteins, and refined sugars has been associated with a lower likelihood of neurocognitive impairment. These dietary components contribute to brain health by modulating inflammation, supporting synaptic plasticity, and enhancing neuronal resilience. Given the growing body of evidence linking diet to cognitive function, further investigation into specific nutritional strategies may provide valuable insights into preventing or slowing the progression of AD [15].
The primary goal of Alzheimer's disease treatment is to slow the progression of the disease and delay the onset of severe symptoms. Pharmacotherapy aims to enhance the patient's overall health, improve their quality of life, and increase their ability to function independently in daily activities. However, it is important to note that the benefits of such pharmacotherapy are time-limited and do not halt the disease entirely[15]. Current pharmacological treatments for AD primarily target two key areas. The first one is modulation of enzymatic activity- some drugs aim to influence enzymes involved in the production of abnormal proteins, such as amyloid-beta and tau, which play a central role in the pathogenesis of Alzheimer's. Second one is enhancement of neurotransmission, which focuses on improving cholinergic neurotransmission, which is critical for memory and cognitive function. This is achieved by increasing the availability of acetylcholine, a neurotransmitter often depleted in AD patients. The aim of such pharmacotherapy is to improve the general health of

the patient and their well-being and to increase the comfort of functioning in everyday life. It should be emphasized that the effect of this type of pharmacotherapy is limited in time [16].
Acetylcholinesterase inhibitors (AChEIs) are widely utilized in modern medicine. Acetylcholinesterase is an enzyme responsible for breaking down the neurotransmitter acetylcholine at cholinergic synapses . By inhibiting this enzyme, AChEIs prevent the degradation of acetylcholine, thereby enhancing cholinergic neurotransmission and slowing the progression of Alzheimer's disease (AD). In the European Union, including Poland, the AChEIs approved for AD treatment are donepezil, rivastigmine, and galantamine . However, galantamine is rarely used in practice due to a lack of reimbursement. Additionally, AChEIs are thought to have a stabilizing effect on the course of Alzheimer's disease, slowing cognitive decline and potentially improving the quality of life for patients. Among other applied medications are: memantine (which regulates the activity of glutamate), antidepressants and antipsychotics. Treatment plans often include a combination of pharmacological and non-pharmacological approaches, such as cognitive therapy, lifestyle modifications, and support for caregivers, to maximize patient outcomes[16].
Current treatments for Alzheimer's disease focus on enhancing patients' quality of life rather than addressing the root causes of the condition. While existing therapies provide symptomatic relief, they do not offer a cure [17]. Numerous drugs and innovative treatment methods are still undergoing clinical trials, and their eventual approval for use in AD therapy could mark a significant breakthrough in the field, potentially transforming how the disease is managed.

Omega-3 acids impact on cognitive functions

Omega-3 polyunsaturated fatty acids (omega-3 PUFAs) are assumed to have a beneficial effect on the function of the brain. It has been suggested that they might improve or delay decline in memory and ability to carry out everyday tasks in people with dementia. High blood omega-3 (n3-PUFA) levels in older adults have been shown to be associated with better cognitive performance, less brain atrophy and lower white matter lesions which coincides with a decreased risk for dementia, including Alzheimer's[19]. PUFAs are known for their anti-inflammatory properties, whereas Omega-6 fatty acids tend to promote inflammation. Maintaining a proper balance between these two types of fatty acids is crucial for a healthy diet. However, over the past three decades, the Western diet has seen a significant shift, with a marked increase in Omega-6 consumption and a corresponding decrease in Omega-3 intake. This imbalance can contribute to chronic inflammation, which, when left unchecked, plays a key role in the development of neurodegenerative disorders. Omega-6/3 PUFA ratio should be targeted for the modulation of low-grade inflammation, as well as for the prevention of immune dysregulation and complications of uncontrolled inflammation triggered by infections, development, and progression of autoimmune disorders, and the consequences of oxidative stress due to aging[19].
Research shows that supplementation with *n*-3 LC PUFAs during the infancy phase of development has its foundation in the longstanding research on the advantages of breastfeeding for cognitive development. Research conducted during infancy has shown a positive association between PUFA supplementation and improvements in both cognitive and visual functions. This is largely attributed to the accumulation of PUFAs in fetal brain tissue and retinal tissue. Studies on infant supplementation have primarily focused on DHA, often combined with EPA and AA (arachidonic acid), due to their critical roles in various neural processes. These include synapse maturation, processing speed, and the structural integrity of neuronal membranes[20].

Fatty acids affect white matter tracts in terms of myelination and fiber integrity, thereby influencing neural signaling. Docosahexaenoic acid, (DHA) has received the most extensive attention throughout extant research, since it has the highest concentration in the brain; however, studies have also addressed eicosapentaenoic acid (EPA), alpha-linolenic acid (ALA), arachidonic acid (AA/ARA), and the importance of LC PUFA ratios. The frontal lobe, where complex cognitive processes occur, has a high concentration of DHA, which has a significant role in membrane fluidity and signal transmission. DHA is the most abundant omega-3 fatty acid in the brain, where it plays a critical role in maintaining neuronal structure and function[19][20]. Its neuroprotective properties are thought to stem from several mechanisms, including the regulation of synaptic plasticity, the reduction of neuroinflammation, and the enhancement of neuronal membrane fluidity. These effects may contribute to improved signal transmission and neurogenesis, as well as the inhibition of apoptosis, which could collectively slow the progression of cognitive decline in conditions such as Alzheimer's disease and mild cognitive impairment.

Conclusions

The link between Omega-3 fatty acids and cognitive impairment, including Alzheimer's disease, has been extensively studied, and research suggests that Omega-3s, particularly DHA and EPA, may play a protective role in brain health and potentially reduce the risk or slow the progression of Alzheimer's disease [2][20]. A deficiency in DHA has been linked to neuronal dysfunction and cognitive decline, both of which are hallmarks of Alzheimer's disease. What is more, chronic neuroinflammation is a key feature of Alzheimer's disease. Omega-3 fatty acids, particularly EPA, have potent anti-inflammatory properties. They inhibit the production of pro-inflammatory molecules and promote the synthesis of anti-inflammatory mediators. By reducing inflammation, Omega-3s may help protect neurons from damage and slow disease progression [20]. Also DHA, in particular, enhances the function of synaptic proteins and promotes the growth of dendritic spines, which are essential for neuronal communication [19]. DHA supplementation has shown cognitive benefits in some studies, particularly in improving memory and preserving hippocampal volume in individuals with early-stage cognitive decline. However, other studies have reported minimal effects, especially in cases of advanced Alzheimer's disease. The review highlighted differences in study design, dosage, duration of intervention, and population characteristics as potential reasons for the inconsistent results across trials. Despite these mixed findings, DHA's favorable safety profile and potential for early intervention in at-risk groups make it a promising option for clinical use. Higher dietary intake of Omega-3 fatty acids has been associated with a reduced risk of cognitive decline and Alzheimer's disease in older adults. Some studies have shown that Omega-3 supplementation improves cognitive function in individuals with mild cognitive impairment (MCI) or early-stage Alzheimer's, but on the other hand others have reported mixed results [2][3]. The benefits may depend on factors such as dosage, duration of supplementation, and the stage of the disease. Omega-3s show promise, they are not a cure for Alzheimer's disease. Their effectiveness may be limited in later stages of the disease when significant neuronal damage has already occurred. More research is needed to determine the optimal dosage, timing, and combination of Omega-3s (e.g., DHA + EPA) for maximum benefit [18][19]. Future research should focus on determining the most effective timing and therapeutic dose of DHA for different stages of cognitive decline, considering factors such as age, baseline cognitive status, and genetic risk factors like APOE ε4 allele presence[19]. The effectiveness of omega-3 supplementation can be influenced by various factors, including diet, lifestyle, and genetic predisposition [21]. When designing and conducting clinical trials, it is essential to account for these factors and acknowledge their potential impact on the outcomes.

To gain a comprehensive understanding, it is important to examine each variable individually, as well as the interactions between them.

Disclosures

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