

**MENTAL FATIGUE AND COGNITIVE LONGEVITY: THE EMERGING ROLE OF
NUTRITIONAL SUPPLEMENTATION IN HEALTHY BRAIN AGING*****Maria Gisele dos Santos**

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DOI: <https://doi.org/10.5281/zenodo.21698391>**How to cite this Article:** *Maria Gisele dos Santos. (2026). Mental Fatigue And Cognitive Longevity: The Emerging Role Of Nutritional Supplementation In Healthy Brain Aging. World Journal of Pharmaceutical and Medical Research, 12(8), 238-245. This work is licensed under Creative Commons Attribution 4.0 International license.

Article Received on 23/06/2026

Article Revised on 13/07/2026

Article Published on 01/08/2026

ABSTRACT

Mental fatigue and cognitive decline have become increasingly relevant concerns in modern society. Rapid technological advancement, continuous exposure to information, chronic stress, inadequate sleep, and population aging have created a complex environment that challenges cognitive health across all stages of life. As a result, growing attention has been directed toward strategies capable of preserving brain function, supporting mental performance, and promoting healthy aging. Mental fatigue is no longer viewed simply as a temporary consequence of intense intellectual activity. Instead, it is increasingly recognized as a multifactorial condition that can influence attention, memory, emotional regulation, productivity, and overall well-being. At the same time, the rising prevalence of neurodegenerative disorders, particularly Alzheimer's disease, has reinforced the need for preventive approaches that address the long-term preservation of cognitive function. Among the factors associated with brain health, nutrition has emerged as a promising area of investigation. Scientific evidence indicates that nutritional status influences several biological processes involved in neuronal communication, neuroplasticity, energy metabolism, oxidative balance, and inflammatory regulation. Consequently, specific nutritional compounds and dietary supplements have attracted growing interest for their potential role in supporting cognitive resilience and reducing risk factors associated with cognitive decline. This narrative review examines the relationship between mental fatigue, cognitive health, brain aging, and nutritional supplementation. Particular emphasis is placed on evidence regarding omega-3 fatty acids, creatine, vitamin D, magnesium, B-complex vitamins, and curcumin. Current findings suggest that, when combined with healthy lifestyle habits, evidence-based nutritional strategies may contribute to the preservation of cognitive function and the promotion of healthy brain aging.

KEYWORDS: Mental Fatigue; Cognitive Health; Brain Aging; Nutritional Supplementation; Alzheimer's Disease; Neuroprotection; Quality of Life.**1. INTRODUCTION**

The human brain is remarkably adaptable. Throughout life, it continuously responds to new experiences, environmental demands, and physiological changes, allowing individuals to learn, remember, communicate, and interact with the world around them. However, the conditions that characterize contemporary society have introduced unprecedented challenges to cognitive well-being. Increasing professional demands, constant digital connectivity, information overload, chronic stress, and insufficient sleep have become common aspects of everyday life, placing sustained pressure on cognitive resources.

In recent decades, concerns regarding mental health have expanded beyond emotional disorders alone to include cognitive performance and long-term brain health. Many individuals report persistent difficulties related to concentration, mental clarity, memory, and decision-making. These experiences are frequently associated with mental fatigue, a condition that can emerge when cognitive demands consistently exceed the brain's capacity for recovery and adaptation.

Unlike physical fatigue, which is often immediately recognized, mental fatigue may develop gradually and remain unnoticed for extended periods. Its effects, however, can be substantial. Reduced attention, impaired

memory performance, decreased motivation, and emotional exhaustion may negatively affect academic achievement, workplace productivity, and overall quality of life. As modern lifestyles continue to intensify cognitive demands, understanding the mechanisms underlying mental fatigue has become increasingly important.

Simultaneously, advances in healthcare and living conditions have contributed to a significant increase in life expectancy worldwide. While longer life represents a major achievement for public health, it has also been accompanied by a growing prevalence of age-related cognitive decline and neurodegenerative disorders. Alzheimer's disease, in particular, has become one of the most significant health challenges of aging populations, affecting millions of individuals and generating profound social, emotional, and economic consequences.

These developments have stimulated considerable scientific interest in identifying strategies capable of supporting cognitive health throughout the lifespan. Among the various factors investigated, nutrition has emerged as a key determinant of brain function. Nutrients influence multiple physiological processes involved in neuronal communication, neurotransmitter synthesis, cellular energy production, inflammatory regulation, and protection against oxidative damage. Consequently, nutritional interventions have attracted growing attention as potential tools for preserving cognitive performance and promoting healthy aging.

Within this context, nutritional supplementation has become an increasingly important area of research. Although supplements cannot replace healthy dietary habits, certain compounds have demonstrated promising neuroprotective and cognitive-supportive properties. Understanding their potential role may contribute to the development of more comprehensive strategies aimed at reducing mental fatigue, preserving cognitive function, and supporting brain longevity.

Therefore, the purpose of this narrative review is to explore the relationship between mental fatigue, cognitive health, brain aging, and evidence-based nutritional supplementation. By examining current scientific knowledge in these areas, this article seeks to contribute to the growing discussion surrounding preventive approaches for cognitive preservation and healthy aging in contemporary society.

REVIEW

2. MENTAL FATIGUE IN CONTEMPORARY SOCIETY

Mental fatigue has become an increasingly visible feature of modern life. Although often perceived as a temporary consequence of demanding cognitive tasks, growing evidence suggests that it represents a more complex phenomenon influenced by psychological, physiological, behavioral, and environmental factors. In

contemporary society, where attention has become a highly valuable and continuously challenged resource, understanding the mechanisms underlying mental fatigue is essential for promoting cognitive health and overall well-being.

The modern environment differs substantially from that experienced by previous generations. Advances in digital technology have transformed communication, education, healthcare, and professional activities, creating unprecedented opportunities for productivity and access to information. At the same time, however, these developments have dramatically increased cognitive demands. Individuals are routinely exposed to continuous streams of information, frequent interruptions, multitasking requirements, and prolonged periods of screen engagement. As a result, the brain is often required to maintain sustained attention for extended periods without adequate opportunities for recovery.

From a neurophysiological perspective, mental fatigue may arise when prolonged cognitive effort alters the efficiency of neural networks involved in attention, executive control, motivation, and decision-making. Over time, the continuous allocation of cognitive resources may lead to a subjective perception of exhaustion accompanied by measurable declines in cognitive performance. Individuals experiencing mental fatigue commonly report difficulties maintaining concentration, reduced mental clarity, slower information processing, and diminished motivation to perform cognitively demanding tasks.

Importantly, mental fatigue does not occur in isolation. It is frequently influenced by lifestyle factors that have become increasingly common in modern societies. Inadequate sleep, irregular work schedules, emotional stress, sedentary behavior, and poor dietary habits may all contribute to the development and persistence of cognitive exhaustion. These factors often interact with one another, creating a cycle in which recovery becomes progressively more difficult and cognitive performance gradually declines.

Sleep deserves particular attention within this discussion. Adequate sleep is essential for memory consolidation, neural restoration, metabolic regulation, and maintenance of cognitive function. Nevertheless, sleep disturbances affect a substantial proportion of the global population. Reduced sleep duration and poor sleep quality have been consistently associated with impairments in attention, learning capacity, emotional regulation, and executive function. When combined with chronic cognitive demands, insufficient sleep may significantly amplify the effects of mental fatigue.

Psychological stress also plays a central role. Exposure to persistent stressors activates physiological mechanisms that are initially adaptive but may become

detrimental when maintained over long periods. Elevated levels of stress-related hormones, particularly cortisol, have been associated with alterations in brain regions involved in learning, memory, and emotional processing. Consequently, chronic stress may not only intensify perceptions of fatigue but also contribute to long-term cognitive vulnerability.

An important aspect of mental fatigue is that its consequences often extend beyond cognitive performance alone. Academic achievement, professional productivity, interpersonal relationships, emotional well-being, and quality of life may all be affected. Individuals frequently describe a reduced capacity to engage in complex reasoning, solve problems efficiently, or maintain motivation for activities that previously seemed manageable. These experiences highlight the multidimensional nature of mental fatigue and its relevance to both individual and public health.

In recent years, researchers have increasingly emphasized the concept of cognitive resilience, defined as the ability to maintain or recover cognitive function despite exposure to stressors, aging processes, or adverse environmental conditions. This perspective shifts attention away from fatigue as merely a symptom and toward understanding the factors that support adaptation and recovery. Nutrition, physical activity, sleep quality, stress management, and social engagement have all emerged as important contributors to cognitive resilience.

Given the growing prevalence of cognitive overload in contemporary society, mental fatigue should be viewed not simply as an unavoidable consequence of modern life but as a significant health-related issue requiring preventive attention. Developing effective strategies to preserve cognitive resources and promote brain resilience may play an essential role in supporting mental performance, emotional well-being, and healthy aging throughout the lifespan.

3. COGNITIVE AGING AND THE GROWING CHALLENGE OF ALZHEIMER'S DISEASE

Aging is an inevitable and natural part of the human experience. Throughout life, the body undergoes a series of physiological adaptations that reflect the passage of time, and the brain is no exception. Although aging is often associated with decline, it is important to recognize that many cognitive abilities can be preserved well into later life. Indeed, a growing number of older adults remain intellectually active, socially engaged, and functionally independent for decades. Nevertheless, advancing age remains one of the strongest risk factors for cognitive impairment and neurodegenerative disease.

The distinction between normal cognitive aging and pathological cognitive decline is essential. Healthy aging may involve subtle changes in processing speed, reaction time, and the retrieval of stored information. These

changes are generally mild and do not significantly interfere with daily activities. In contrast, neurodegenerative disorders are characterized by progressive deterioration of cognitive functions that ultimately compromise independence, communication, reasoning, and quality of life.

Among these disorders, Alzheimer's disease represents the most common cause of dementia worldwide. The condition is characterized by a gradual loss of neurons and synaptic connections, resulting in progressive impairments in memory, learning, language, and executive function. Although Alzheimer's disease has been extensively studied for decades, its exact causes remain incompletely understood. Current evidence suggests that the disease results from a complex interaction between genetic predisposition, biological aging, environmental influences, lifestyle factors, and metabolic alterations.

Several pathological mechanisms have been implicated in the development of Alzheimer's disease. These include the accumulation of amyloid-beta plaques, abnormal aggregation of tau proteins, chronic neuroinflammation, mitochondrial dysfunction, oxidative stress, vascular impairment, and disturbances in neuronal communication. Rather than acting independently, these processes appear to interact over many years, gradually reducing the brain's capacity to maintain normal cognitive function.

The growing prevalence of Alzheimer's disease reflects one of the most significant consequences of population aging. Improvements in healthcare, sanitation, nutrition, and disease prevention have substantially increased life expectancy across the globe. While this achievement represents a remarkable public health success, it has simultaneously led to a larger number of individuals living long enough to experience age-related neurological disorders.

The impact of Alzheimer's disease extends far beyond the affected individual. Families often experience emotional distress, financial strain, and caregiving burdens that may persist for years. Healthcare systems face increasing demands for specialized services, long-term care, and supportive interventions. Consequently, Alzheimer's disease is now widely recognized not only as a medical condition but also as a major social and economic challenge.

Despite these concerns, contemporary research offers reasons for cautious optimism. Scientific understanding of brain aging has evolved considerably over the past two decades. Researchers increasingly recognize that cognitive health is influenced by a combination of genetic and modifiable factors. While aging itself cannot be prevented, many factors associated with cognitive decline can be addressed through preventive strategies implemented throughout life.

Regular physical activity, cognitive stimulation, social interaction, cardiovascular health management, stress reduction, adequate sleep, and balanced nutrition have all been associated with improved cognitive outcomes. These findings have contributed to a shift in scientific thinking, moving from a predominantly treatment-oriented perspective toward one that emphasizes prevention, resilience, and healthy aging.

Within this framework, the concept of brain resilience has gained particular relevance. Brain resilience refers to the capacity of the nervous system to adapt, compensate, and maintain function despite aging-related changes or pathological processes. Individuals with greater cognitive reserve often demonstrate a higher ability to preserve daily functioning even in the presence of underlying neurological alterations.

Nutrition has emerged as a particularly promising component of this preventive approach. The growing recognition that dietary patterns and nutritional status influence inflammation, oxidative stress, vascular health, and neuronal metabolism has stimulated extensive research into nutritional interventions capable of supporting cognitive longevity. Rather than focusing exclusively on disease treatment, current scientific efforts increasingly seek to identify strategies that may help preserve brain health long before clinical symptoms emerge.

As populations continue to age worldwide, promoting cognitive health will remain a central objective of public health and preventive medicine. Understanding the mechanisms that contribute to both healthy aging and neurodegenerative disease is essential for developing interventions that support autonomy, dignity, and quality of life throughout the lifespan.

4. NUTRITION, BRAIN HEALTH, AND NEUROPROTECTION

The relationship between nutrition and brain health has attracted increasing scientific attention over recent decades. Once viewed primarily as a source of energy and essential nutrients for basic physiological functions, nutrition is now recognized as a key factor influencing cognitive performance, neurological resilience, and healthy aging. Emerging evidence suggests that dietary habits can affect not only physical health but also the structural and functional integrity of the brain throughout the lifespan.

The human brain is one of the most metabolically active organs in the body. Despite representing only a small proportion of total body weight, it consumes a substantial amount of the body's energy resources. This continuous demand reflects the complexity of neuronal communication, neurotransmitter synthesis, synaptic plasticity, and cellular maintenance processes that occur every moment of life. Consequently, adequate nutritional

support is essential for sustaining optimal cognitive function and preserving neurological health.

In recent years, researchers have increasingly recognized that the brain responds dynamically to nutritional influences. Nutrients, bioactive compounds, and dietary patterns can affect multiple biological pathways involved in cognition, including energy metabolism, inflammatory regulation, antioxidant defense systems, vascular function, and neuronal signaling. These interactions have contributed to a growing understanding of nutrition as a modifiable factor capable of influencing long-term cognitive outcomes.

One of the principal mechanisms linking nutrition to brain health involves oxidative stress. Due to its high oxygen consumption and intense metabolic activity, the brain is particularly vulnerable to oxidative damage. When the production of reactive oxygen species exceeds the body's antioxidant defenses, cellular structures may become compromised, potentially contributing to neuronal dysfunction and accelerated aging. Over time, cumulative oxidative damage has been associated with cognitive decline and the development of neurodegenerative disorders.

Inflammation represents another critical component of this relationship. While acute inflammatory responses are essential for protecting the body against injury and infection, chronic low-grade inflammation may have detrimental effects on neurological function. Persistent inflammatory activity has been implicated in the progression of several age-related conditions, including cardiovascular disease, metabolic disorders, and neurodegenerative diseases such as Alzheimer's disease. Nutritional factors capable of modulating inflammatory pathways may therefore play an important role in preserving cognitive health.

Vascular health also contributes significantly to brain function. The brain relies on a continuous supply of oxygen and nutrients delivered through an intricate network of blood vessels. Conditions that impair vascular function may reduce cerebral blood flow and compromise neuronal performance. Dietary patterns rich in fruits, vegetables, whole grains, healthy fats, and antioxidant compounds have consistently been associated with improved cardiovascular health, which in turn supports optimal brain function.

Beyond these physiological mechanisms, nutrition directly influences neurotransmitter production and neuronal communication. Several vitamins, minerals, amino acids, and fatty acids serve as essential substrates for the synthesis of neurotransmitters involved in mood regulation, attention, learning, and memory. Nutritional deficiencies may therefore contribute to cognitive disturbances, emotional imbalance, and reduced mental performance.

An important shift has occurred in the scientific understanding of nutrition and brain health. Rather than focusing solely on the treatment of disease, researchers increasingly emphasize the importance of lifelong nutritional strategies aimed at promoting cognitive resilience and delaying age-related decline. This preventive perspective recognizes that brain health is influenced by cumulative exposures and lifestyle choices across many decades.

Within this context, the concept of neuroprotection has gained substantial relevance. Neuroprotection refers to strategies capable of preserving neuronal structure and function while reducing vulnerability to injury, aging, and disease. Nutrition represents one of the most accessible and modifiable components of neuroprotective care. Although no single nutrient can eliminate the risk of cognitive decline, a consistent pattern of healthy dietary behaviors may contribute significantly to maintaining brain vitality and cognitive independence throughout life.

As scientific knowledge continues to evolve, nutrition is increasingly viewed not merely as a supportive factor but as a central component of comprehensive approaches to cognitive health. This growing body of evidence provides a strong foundation for exploring the role of specific nutritional supplements that may further support brain function, mental performance, and healthy aging.

5. EVIDENCE-BASED SUPPLEMENTS FOR COGNITIVE FUNCTION AND BRAIN LONGEVITY

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6. SUPPLEMENTATION, MENTAL FATIGUE, AND COGNITIVE PERFORMANCE

Mental fatigue has become an increasingly common experience in contemporary society. Whether associated with academic demands, professional responsibilities, emotional stress, or continuous exposure to digital information, cognitive overload affects millions of individuals worldwide. While occasional mental fatigue is a normal response to sustained cognitive effort, persistent exhaustion may compromise performance, well-being, and long-term brain health.

In recent years, scientific interest has expanded beyond understanding the causes of mental fatigue to exploring strategies capable of improving cognitive resilience and supporting recovery. Within this context, nutritional supplementation has emerged as a promising area of investigation. Rather than functioning as a substitute for healthy lifestyle habits, nutritional support may help optimize physiological processes involved in energy production, neuronal communication, and cognitive adaptation.

One of the central mechanisms associated with mental fatigue involves the increasing demand placed on neural systems responsible for attention, executive function, memory, and decision-making. Sustained cognitive effort requires continuous energy expenditure, efficient neurotransmitter activity, and adequate metabolic support. When these systems are challenged repeatedly without sufficient recovery, individuals may experience reductions in concentration, mental clarity, motivation, and overall cognitive efficiency.

Several nutrients appear capable of supporting these processes. Creatine, for example, has demonstrated potential benefits in situations characterized by elevated cognitive demand. By contributing to cellular energy availability, creatine may help support brain function

during periods of prolonged mental effort, sleep restriction, or psychological stress. Although responses vary among individuals, the growing body of evidence suggests that its benefits extend beyond physical performance and may include cognitive applications.

Omega-3 fatty acids also play an important role within this framework. Their contribution to neuronal membrane integrity and synaptic communication may help support efficient information processing and cognitive flexibility. Similarly, magnesium participates in mechanisms associated with neurotransmission, stress regulation, and sleep quality, all of which influence mental performance and resilience.

The B-complex vitamins contribute through their involvement in energy metabolism and neurotransmitter synthesis. Adequate levels of these nutrients are essential for maintaining normal neurological function and supporting cognitive processes that depend on efficient cellular activity. Likewise, vitamin D has attracted attention due to its influence on neuroimmune regulation and brain function, highlighting the interconnected nature of nutrition and cognitive health.

However, it is important to emphasize that mental fatigue is rarely caused by a single factor. Sleep deprivation, chronic stress, sedentary behavior, poor dietary habits, emotional overload, and insufficient recovery often interact in complex ways. Consequently, supplementation should be understood as one element within a broader strategy aimed at promoting cognitive well-being rather than as a standalone solution.

The concept of cognitive resilience provides a useful framework for understanding this relationship. Cognitive resilience refers to the ability of the brain to maintain performance and adapt effectively in the presence of challenges, stressors, or age-related changes. Nutritional status appears to influence this adaptive capacity by supporting physiological processes involved in neuronal protection, repair, and communication.

From a practical perspective, the combination of balanced nutrition, regular physical activity, restorative sleep, stress management, cognitive engagement, and evidence-based supplementation may offer the most comprehensive approach to supporting mental performance. Rather than seeking short-term enhancement alone, these strategies aim to preserve cognitive resources and promote long-term neurological health.

As scientific understanding continues to evolve, the relationship between nutrition, mental fatigue, and cognitive performance is likely to become increasingly important. Future research may help clarify which interventions are most effective for different populations and life stages, ultimately contributing to more

personalized approaches for maintaining cognitive vitality in an increasingly demanding world.

7. CONCLUSION

The growing interest in cognitive health reflects one of the most important public health challenges of the twenty-first century. As populations age and modern lifestyles become increasingly demanding, preserving brain function throughout the lifespan has emerged as a priority for researchers, healthcare professionals, and policymakers alike. In this context, understanding the factors that influence cognitive resilience is essential for promoting healthy aging and improving quality of life.

The evidence discussed throughout this review highlights the complex and multifactorial nature of cognitive health. Mental fatigue, cognitive decline, and neurodegenerative disorders do not arise from a single cause but rather from the interaction of biological, environmental, behavioral, and lifestyle-related factors. Consequently, effective preventive strategies must adopt a comprehensive perspective that recognizes the interconnected nature of these influences.

Nutrition has emerged as one of the most promising modifiable determinants of brain health. Beyond its traditional role in supporting basic physiological functions, nutritional status appears to influence processes directly involved in neuronal communication, energy metabolism, inflammatory regulation, oxidative balance, and neuroplasticity. These mechanisms are increasingly recognized as central components of cognitive preservation and healthy brain aging.

The growing body of evidence surrounding omega-3 fatty acids, creatine, vitamin D, magnesium, B-complex vitamins, and curcumin suggests that nutritional supplementation may provide meaningful support for cognitive function when incorporated within a broader framework of healthy lifestyle practices. Although supplementation should not be viewed as a substitute for balanced nutrition, physical activity, restorative sleep, or stress management, it may represent a valuable complementary strategy for enhancing cognitive resilience and supporting neurological well-being.

Importantly, the concept of brain health should extend beyond the prevention of disease. Preserving cognitive function is fundamentally linked to maintaining autonomy, independence, emotional well-being, social participation, and overall quality of life. The ability to think clearly, learn continuously, make decisions, and remain actively engaged with society represents an essential component of healthy aging and human flourishing.

As scientific knowledge continues to advance, future research will likely provide increasingly personalized approaches to cognitive health, integrating nutritional science, preventive medicine, genomics, and precision

healthcare. Such developments may contribute to more effective strategies for identifying individuals at risk and implementing interventions before significant cognitive decline becomes clinically evident.

Ultimately, promoting cognitive longevity is not solely a scientific objective but also a societal responsibility. In an era characterized by longer life expectancy and unprecedented cognitive demands, investing in brain health has the potential to benefit not only individual well-being but also families, communities, and healthcare systems worldwide. Supporting cognitive vitality across the lifespan represents an investment in human potential, reinforcing the importance of evidence-based nutritional strategies as part of a broader commitment to healthy aging and lifelong quality of life.

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