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Micronutrients and mental well-being: Implications for cognitive function and psychological health

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Abstract
Micronutrients, though required in minute quantities, play a fundamental role in maintaining optimal physical health, psychological well-being, and cognitive functioning. Vitamins and minerals act as essential cofactors in enzymatic reactions, neurotransmitter synthesis, antioxidant defense, immune regulation, and gene expression. Increasing evidence from nutritional epidemiology, clinical trials, and neurobiological studies highlights the strong association between micronutrient status and mental health outcomes such as depression, anxiety, stress, cognitive decline, and neurodevelopmental disorders. This review provides a comprehensive overview of the role of key micronutrients in psychology and human health, emphasizing their physiological functions, mechanisms of action in the brain, effects of deficiency and excess, and implications for mental health across the life course. The review also discusses public health relevance, vulnerable populations, and future research directions, underscoring the importance of adequate micronutrient intake for holistic health.

Keywords: Micronutrients, mental health, psychology, vitamins, minerals, cognitive function

Introduction

Micronutrients include vitamins and minerals that are required in small amounts but are indispensable for normal growth, development, metabolism, and mental functioning (Arif *et al*., 2024) [4]. Unlike macronutrients, micronutrients do not provide energy; instead, they facilitate biochemical and physiological processes essential for life (Taşğın, 2017) [14]. In recent decades, the field of nutritional psychiatry has emerged, recognizing nutrition as a modifiable factor influencing mental health and psychological well-being (Horovitz, 2025) [17]. The human brain, despite constituting only about 2% of body weight, consumes approximately 20% of total energy and depends heavily on a continuous supply of micronutrients to sustain neurotransmission, neuroplasticity, and neuroprotection (Bourre, 2006) [9].

Micronutrient deficiencies remain a major global public health concern, particularly in low- and middle-income countries, but also among vulnerable groups in high-income nations (Bailey *et al*., 2015) [7]. Deficiencies in iron, iodine, zinc, vitamin D, B-complex vitamins, and antioxidants have been associated with impaired cognitive development, mood disorders, reduced stress tolerance, and poor quality of life (Brown, 2025) [10]. This review aims to critically examine the role of micronutrients in psychology and human health, integrating evidence from biological, clinical, and population-based studies.

Classification of Micronutrients

Micronutrients are broadly classified into two categories:

1. Vitamins

Micronutrients are broadly classified into two major categories based on their chemical nature and physiological functions: vitamins and minerals (Awuchi *et al*., 2020 [6]). Vitamins are organic compounds required in small quantities to regulate metabolic processes, support growth and development, and maintain normal physiological and psychological functions (Huskisson *et al*., 2007) [19]. Based on their solubility, vitamins are further classified into fat-soluble and water-soluble groups. The fat-soluble vitamins—vitamins A, D, E, and K—are absorbed along with dietary fats, stored in body tissues, and play crucial roles in vision, bone health, antioxidant defense, and blood coagulation (Andrès *et al*., 2024) [3]. In contrast, water-soluble vitamins, which include vitamin C and the B-complex vitamins (B1, B2, B3, B5, B6, B7, B9, and B12), are not stored in large amounts and must be consumed regularly (Hrubša *et al*., 2022) [18]. These vitamins are particularly important for energy metabolism, neurotransmitter synthesis, cognitive functioning, and stress regulation, highlighting their critical role in maintaining both physical health and psychological well-being (Muscaritoli, 2021) [28].

2. Minerals

Minerals are inorganic micronutrients essential for a wide range of structural, regulatory, and catalytic functions in the human body, including skeletal integrity, fluid balance, nerve transmission, and enzymatic activity (Razzaque and Wimalawansa, 2025) [32]. Based on the quantity required by the body, minerals are classified into macrominerals and trace elements. Macrominerals, such as calcium, phosphorus, magnesium, sodium, potassium, and chloride, are needed in relatively larger amounts and are vital for bone formation, muscle contraction, nerve impulse transmission, and maintenance of acid–base balance (Malik *et al*., 2023) [26]. In contrast, trace elements, including iron, zinc, iodine, selenium, copper, manganese, chromium, and molybdenum, are required in minute quantities but play disproportionately critical roles in oxygen transport, thyroid hormone synthesis, antioxidant defense, and metabolic regulation. Adequate mineral status is particularly important for brain development, emotional regulation, neurotransmitter function, and mental resilience, as both deficiencies and imbalances can adversely affect cognitive performance, mood stability, and overall psychological health (Delvin and Levy, 2020) [13].

Micronutrients and Brain Physiology

Micronutrients influence brain function through multiple mechanisms, including energy metabolism, neurotransmitter synthesis, myelination, synaptic plasticity, and antioxidant defense (Huskisson *et al*., 2007) [19]. The blood–brain barrier regulates micronutrient transport, ensuring a controlled supply to neural tissues. Any imbalance in micronutrient status can disrupt neuronal signaling and cognitive performance (Tiani *et al*., 2019) [37].

For example, B-vitamins are essential for glucose metabolism in the brain, iron is required for oxygen transport and dopamine synthesis, and zinc modulates synaptic transmission. Antioxidant vitamins protect neurons from oxidative stress, a key contributor to neurodegenerative and psychiatric disorders (Kennedy, 2016) [21].

Role of B-Complex Vitamins in Psychology

1. Vitamin B1 (Thiamine)

Thiamine is essential for carbohydrate metabolism and neuronal energy production. Deficiency impairs glucose utilization in the brain, leading to neurological and psychological symptoms such as irritability, memory loss, and confusion. Severe deficiency can result in Wernicke–Korsakoff syndrome, characterized by profound cognitive impairment (Dhir *et al*., 2019) [15].

2. Vitamin B6 (Pyridoxine)

Vitamin B6 is a cofactor in the synthesis of neurotransmitters including serotonin, dopamine, gamma-aminobutyric acid (GABA), and norepinephrine. Inadequate intake has been associated with depression, anxiety, and reduced stress tolerance (Demelash, 2017) [14].

3. Folate (Vitamin B9) and Vitamin B12

Folate and vitamin B12 are crucial for one-carbon metabolism and DNA methylation, processes vital for brain development and neurotransmitter regulation. Deficiencies are linked to depression, cognitive decline, and increased risk of neurodegenerative disorders, particularly in older adults (Anderson *et al*., 2012) [2].

Vitamin D and Mental Health

Vitamin D functions as a neurosteroid hormone, with receptors widely distributed in the brain (Groves *et al*., 2014) [16]. It regulates neurotrophic factors, neuroimmune responses, and calcium homeostasis. Low vitamin D levels have been consistently associated with depression, seasonal affective disorder, schizophrenia, and cognitive impairment. Supplementation studies suggest potential benefits in improving mood and reducing depressive symptoms, particularly in deficient individuals (Kiraly *et al*., 2006) [22].

Antioxidant Vitamins (A, C, and E)

Antioxidant vitamins A, C, and E play a crucial role in protecting the brain from oxidative stress, which is a key contributor to the pathophysiology of several mental and neurodegenerative disorders. The brain is particularly vulnerable to oxidative damage due to its high oxygen consumption and abundance of polyunsaturated fatty acids (Bourre, 2004) [8]. Vitamin A is essential for vision, neurodevelopment, and regulation of gene expression involved in neuronal differentiation and synaptic plasticity, thereby influencing cognitive and behavioral outcomes. Vitamin C participates in the synthesis of neurotransmitters such as dopamine and norepinephrine and functions as a powerful water-soluble antioxidant that protects neurons from oxidative injury while supporting mood regulation (Kocot *et al*., 2017) [23]. Vitamin E, a lipid-soluble antioxidant, safeguards polyunsaturated fatty acids in neuronal cell membranes from lipid peroxidation, maintaining membrane integrity and neural signaling; its adequate intake has been linked to a slower progression of cognitive decline. Overall, sufficient consumption of antioxidant vitamins is associated with improved cognitive performance, enhanced psychological well-being, and a reduced risk of neurodegenerative diseases (Rao and Balachandran, 2002) [31].

Iron and Psychological Functioning

Iron is essential for hemoglobin synthesis, oxygen transport, and neurotransmitter metabolism. Iron deficiency, particularly during pregnancy and early childhood, adversely affects cognitive development, attention, learning ability, and emotional behavior. In adults, iron deficiency anemia is associated with fatigue, poor concentration, depression, and reduced work productivity (Pivina *et al*., 2019) [30].

Iodine and Cognitive Development

Iodine is required for thyroid hormone synthesis, which is critical for brain development and mental functioning. Iodine deficiency remains the leading cause of preventable intellectual disability worldwide. Even mild deficiency during pregnancy can impair offspring IQ, attention, and academic performance (Delange, 2000) [12].

Zinc and Mental Health

Zinc plays a key role in synaptic plasticity, neurogenesis, and modulation of the glutamatergic system. Low zinc levels have been observed in individuals with depression, anxiety, and attention-deficit disorders (Wang *et al*., 2023) [38]. Zinc supplementation has shown adjunctive benefits in the treatment of depression (Lai *et al*., 2012) [24].

Selenium and Psychological Well-Being

Selenium is a component of antioxidant enzymes such as glutathione peroxidase. It protects the brain from oxidative damage and supports thyroid function. Low selenium status has been associated with poor mood, anxiety, and cognitive decline (Cardoso *et al*., 2014) [11].

Magnesium and Stress Regulation

Magnesium is involved in nerve transmission, muscle relaxation, and regulation of the hypothalamic–pituitary–adrenal (HPA) axis. Deficiency is linked to increased stress, anxiety, irritability, and sleep disturbances. Adequate magnesium intake supports emotional stability and stress resilience (Murck, 2002; Sartori *et al*., 2012) [27, 33].

Micronutrient Deficiencies Across the Life Cycle

Micronutrient requirements vary significantly across the life cycle, and deficiencies at any stage can have profound and long-lasting effects on physical health, psychological well-being, and cognitive functioning (Pettoello-Mantovani *et al*., 2025) [29]. During pregnancy and lactation, the demand for micronutrients such as iron, iodine, folate, and vitamin B12 increases substantially to support fetal brain development, maternal metabolic adaptations (Allen, 2005) [1], and prevention of neural tube defects and anemia. In childhood and adolescence, adequate intake of vitamins and minerals is critical for optimal cognitive development, learning ability, attention span, and academic performance, as this

period is marked by rapid brain growth and neuroplasticity. During adulthood, sufficient micronutrient status supports work productivity, stress management, emotional stability, and overall mental health by maintaining efficient neurotransmission and energy metabolism (Muscaritoli, 2021) [28]. In older adults, micronutrients play a protective role against age-related cognitive decline and neurodegeneration, with deficiencies contributing to memory impairment, mood disturbances, and increased susceptibility to neurodegenerative disorders. Ensuring adequate micronutrient intake throughout all life stages is therefore essential for sustaining lifelong mental resilience and quality of life (Wickramasinghe *et al*., 2020) [39].

Public Health and Clinical Implications

Addressing micronutrient deficiencies through dietary diversification, food fortification, biofortification, and supplementation is essential for improving mental health outcomes at the population level. Integrating nutritional assessment into mental health care can enhance prevention and treatment strategies (Ashraf, 2025) [17].

Future Perspectives and Research Directions

Future research should focus on personalized nutrition, nutrient–gene interactions, and the role of combined micronutrient interventions in mental health (Singar *et al*., 2024) [34]. Long-term randomized controlled trials are needed to establish causal relationships and optimal dosage strategies (Spieth *et al*., 2016) [35].

Table 1: Role of Micronutrients in Psychology and Human Health (Summary of Evidence from Previous Studies (Huskisson *et al*., 2007; Lopresti, 2020)

Micronutrient	Key Psychological / Neurological Functions	Effects of Deficiency	Evidence from Published Studies
Vitamin A	Neurodevelopment, gene expression, vision-related cognition	Impaired cognitive development, visual–cognitive deficits	Studies report its role in neuronal differentiation and brain maturation
Vitamin B1 (Thiamine)	Brain energy metabolism, nerve conduction	Memory loss, irritability, confusion, Wernicke–Korsakoff syndrome	Clinical evidence links deficiency to severe neuropsychiatric disorders
Vitamin B6 (Pyridoxine)	Neurotransmitter synthesis (serotonin, dopamine, GABA)	Depression, anxiety, reduced stress tolerance	Observational and intervention studies show mood improvement with adequacy
Folate (Vitamin B9)	DNA methylation, neurotransmitter regulation	Depression, cognitive decline, neural tube defects	Strong association with depressive disorders and cognitive impairment
Vitamin B12	Myelination, neuronal integrity, cognitive function	Memory loss, depression, dementia-like symptoms	Widely reported in geriatric and psychiatric literature
Vitamin C	Neurotransmitter synthesis, antioxidant defense	Fatigue, mood disturbances, poor stress response	Studies indicate improved mood and cognition with adequate intake
Vitamin D	Neuroimmune modulation, neuroprotection	Depression, cognitive impairment, schizophrenia risk	Meta-analyses show inverse relationship with depressive symptoms
Vitamin E	Protection of neuronal membranes, antioxidant activity	Cognitive decline, increased oxidative damage	Long-term studies link intake with reduced neurodegeneration
Iron	Oxygen transport, dopamine synthesis	Poor attention, learning difficulties, depression	Strong evidence in children, pregnant women, and anemic adults
Iodine	Thyroid hormone synthesis, brain development	Intellectual disability, low IQ, poor academic performance	Established cause of preventable cognitive impairment
Zinc	Synaptic plasticity, neurogenesis	Depression, anxiety, behavioral disorders	Clinical trials show adjunctive benefits in depression
Magnesium	Stress regulation, HPA axis modulation	Anxiety, irritability, sleep disorders	Studies support its role in stress and anxiety reduction
Selenium	Antioxidant defense, thyroid function	Mood disturbances, cognitive decline	Observational studies associate low status with poor mental health

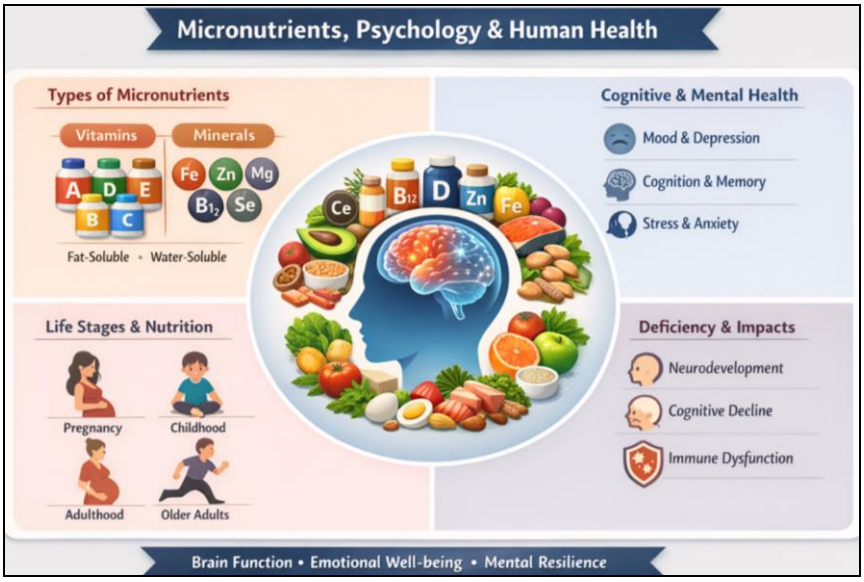

Fig 1: Role of Micronutrients in Brain Function, Psychology, and Human Health

Conclusion

Micronutrients play a pivotal role in psychology and human health by supporting brain development, cognitive function, emotional regulation, and mental resilience. Deficiencies can have profound and long-lasting effects on psychological well-being across the life span. Ensuring adequate micronutrient intake through balanced diets and public health interventions is a cost-effective strategy to promote holistic health and improve quality of life.

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