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Proceeding Paper

Precision Neuronutrition: Personalized Approaches for Optimizing Brain Health †

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Abstract: Leveraging advancements in metabolomics and other cutting-edge technologies, precision neuronutrition aims to identify personalized nutrient requirements to optimize brain health outcomes and prevent neurological disorders. The main pathological mechanisms of brain health disruption include neuroinflammation, oxidative stress, gut–brain disturbances and nutrient deficiencies. Recent studies have identified biological markers for all those mechanisms. Precision interventions for maintaining brain health and optimizing outcomes include omega-3 fatty acids, vitamin B12, vitamin D, magnesium, coenzyme q10, polyphenols, l-carnitine, prebiotics and probiotics. Precision neuronutrition offers a promising approach to optimizing brain health through personalized nutrient interventions. Continued research in this field holds great potential for improving brain health outcomes.

Keywords: neuronutrition; neurological disorders; neuronutrients; brain health

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1. Introduction

According to WHO experts, brain health is the state of proper cognitive, sensory, socio-emotional, behavioral and motor functioning, allowing a person to reach their full potential throughout time, regardless of presence or absence of disorders [1]. In the context of brain health optimization, a number of researchers [2,3] call for attention to the developing field of neuroscience–nutritional cognitive neuroscience. This scientific branch aims to investigate how nutrition impacts the brain's development, overall well-being, and the aging process [4,5]. Recently, the term neuronutrition has been used actively [6,7]. Neuronutrition is an interdisciplinary field studying the influence of various aspects of nutrition on brain health, neurological disease prevention and treatment throughout life. The brain requires specific nutrients to maintain its structural integrity, support cognitive processes, and protect against neurodegenerative diseases [8]. Assessing brain health objectively is a crucial challenge in neuroscience, particularly in detecting and diagnosing early neurocognitive changes, including those caused by nutritional deficiencies [9]. Precision neuronutrition aims to identify personalized nutrient requirements to optimize brain health outcomes and prevent neurological disorders [10,11].

2. Brain Health Status

Biomarkers indicative of brain health status reflect neuroinflammation, oxidative stress, gut–brain disturbances and nutrient deficiencies.

2.1. Neuroinflammation

The main biomarkers of neuroinflammation are C-reactive protein, interleukin-6 and tumor necrosis factor-alpha. Levels of these biomarkers are altered in a number of neurological diseases, including Alzheimer's disease (AD), Parkinson's disease (PD), epilepsy and others [12–14]. However, for a more accurate assessment of neuroinflammation, taking into account other molecular markers, such as chemokines, microglial cytokines [15,16] and angiogenesis factors [17], is necessary. However, assessing the degree of neuroinflammation poses a number of difficulties, due to the complex biology of the process, and the need for new strategies to collect and analyze relevant data [18,19].

2.2. Oxidative Stress

Oxidative stress has been proven to play a crucial part in pathogenesis of many neurodegenerative diseases, including AD, PD, amyotrophic lateral sclerosis and Huntington's disease [20–22]. The brain is particularly vulnerable to oxidative damage, and the excessive formation of reactive oxygen species (ROS) can lead to neuronal cell death [23]. Antioxidant enzymes catalase and glutathione peroxidase-1 have been quantified in plasma as indicators of oxidative stress [24]. F2-isoprostanes are stereoisomers of prostaglandin F2 and are considered the most reliable markers for monitoring oxidative stress [25,26]. 8-isoprostane is considered a marker of oxidative stress. It can be measured in various biological fluids, including urine, plasma [27], saliva [28] and exhaled air condensate [29]. Advanced oxidation protein products are the end products of the reaction between plasma albumin and chlorinated oxidants [30], and can be measured in blood plasma [24]. Protein carbonylation is an oxidative transformation induced by ROS, reactive nitrogen species, reactive halogen species and reactive aldehydes [31]. They are considered markers of oxidative stress [25] that can be measured in blood plasma. 8-hydroxy-2′-deoxyguanosine, 8-oxo-7,8-dihydroguanosine and malondialdehyde are also indicative of oxidative stress [32–34]. Many biomarkers associated with oxidative stress can be measured in biological samples using standard assays [35,36]. The ability to accurately detect free radical formation in cells and tissues is critical for the development of appropriate therapeutic antioxidant approaches to brain health [37].

2.3. Gut–Brain Disturbances

Gut microbiota and its metabolites have been shown to play a role in pathogenesis and progression of a number of neurological diseases through gut-brain axis regulation [38]. Short-chain fatty acids are metabolites that may affect brain function and are associated with some neurological disorders [38]. Indoles are involved in various neurological functions and are associated with several neurological disorders [39]. Secondary bile acids can serve as activators of bile acid receptors in the brain, and their affinity for individual receptors varies [40]. The gut-brain axis is a potential target for the development of new treatments for neurological disorders, and the role of secondary bile acids in this axis is an area of active research [41]. Serotonin, dopamine, 5-aminovaleric acid and taurine are neurotransmitters produced by intestinal bacteria that regulate neurotransmission in the brain as well as gut itself [42]. Liposaccharide binding protein, zonulin and claudin-3 are biomarkers reflecting damage to the epithelial blood-gut barrier [43–45].

2.4. Nutrient Deficiencies

Nutrient deficiencies can lead to the manifestation of neuroinflammation, oxidative stress and a wide range of neurological problems, including encephalopathy, cognitive impairment and psychiatric disorders [42,46,47]. Deficiency is most often caused by poor nutrition, including not eating enough calories, a lack of certain foods such as fruits and vegetables in diets and eating disorders, and alters vitamin and mineral absorption [48,49]. Vitamin B12 deficiency is associated with cognitive impairment, polyneuropathy and psychiatric manifestations [46]. Thiamine deficiency can cause Wernicke–Korsakoff syndrome [50]. Vitamin D deficiency can lead to neurological manifestations such as depression, cognitive impairment and multiple sclerosis [51]. Magnesium deficiency has been associated with many neurological disorders such as AD, stroke, migraine, depression and cerebellar syndrome [52–54]. Coenzyme Q10 may have neuroprotective effects in neurological diseases, including AD, PD, Huntington's disease, amyotrophic lateral sclerosis and stroke [55,56]. Neurological manifestations of carnitine deficiency include hypotension, burning pain, decreased endurance, sensory impairment, developmental delay, rigidity and myopathy [57,58]. These biomarkers could provide real-time feedback on the effectiveness of nutrient interventions.

3. Precision Nutrient Interventions

There are other crucial substances that play a significant role in brain health [59]. These substances can specifically target neuroinflammation, oxidative stress, and gut–brain disturbances. Recent research has shown that dietary polyphenols may have beneficial effects on neurological diseases by attenuating oxidative stress and reducing the risk of developing neurodegenerative diseases such as AD, stroke, multiple sclerosis, PD and Huntington's disease [60]. Polyphenols have great potential to address brain aging by simultaneously modulating the gut–brain axis [60]. Probiotics can have beneficial effects on patients with neurological diseases by reducing oxidative stress and reducing the risk of developing neurodegenerative diseases such as AD, stroke, multiple sclerosis, PD, etc. [61]. Non-digestible oligosaccharides have neuroprotection effects by modulating the gut–brain axis [62]. Consuming omega-3 fatty acids has been shown to improve learning, memory, cognitive well-being and blood flow in the brain [63]. Omega-3 supplementation may also target neuroinflammation [64], oxidative stress [65] and gut-brain disturbances [66]. A deficiency in omega-3 fatty acids increases the risk of neurodegenerative disorders [67] and accelerates brain aging [68]. Overall, omega-3 fatty acids are essential for maintaining optimal brain health (Figure 1).

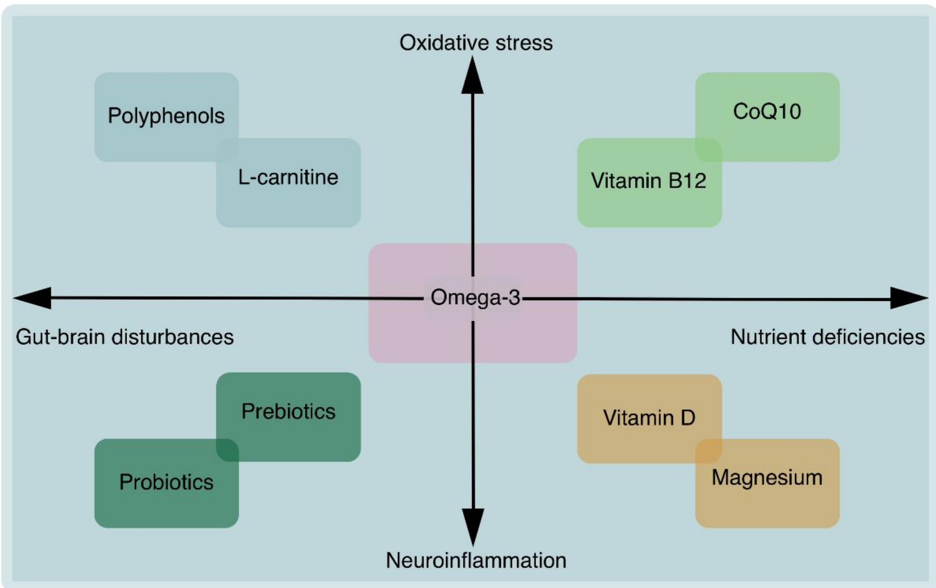

Figure 1. Overview of precision nutritional interventions for brain health.

4. Conclusions

The field of precision neuronutrition holds great promise in optimizing brain health through targeted nutrient interventions based on an individual's brain health status. In order to accurately assess brain health, a personalized approach is necessary, taking into account an individual's nutrient, biochemical and metabolic characteristics. By adapting scientific findings to each person's unique profile, brain health outcomes can effectively be optimized. Continued research in this area has the potential to revolutionize approaches to nutrition for the brain and to improve overall brain health.

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