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Review

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The Potential of MIND Diet to Improve Brain Health for American Football Players

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Abstract

Since American football is inherently a collision sport, exposure to repeated head impacts leads to increased concerns among players, especially regarding brain health. The risk of neurodegenerative diseases may rise at the later phase of life in case of the long-term continuation of brain damage induced by repetitive head impacts thereby leading to the chronicity of oxidative stress and neuroinflammation along with the blood-brain barrier disruption. Therefore, early preventive strategies are necessary to improve brain health. Nutrition is considered one of these strategies. The Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet model was designed to improve brain health. The MIND diet includes foods rich in bioactive compounds, fiber, polyunsaturated fatty acids (PUFAs) and monounsaturated fatty acids (MUFAs) with anti-inflammatory and antioxidant characteristics. Therefore, this diet model may protect the brain against the negative effects of brain damage. The potential effects of MIND diet components, including bioactive compounds, fiber, PUFAs, and MUFAs on brain health for American football players are discussed in this review.

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1. Introduction

Participation in popular and now globally played American football has been reported to decline in recent years because of increasing concerns about brain health (Cecchi et al., 2021; Stone et al., 2019). In particular, this collision sport carries a high risk of exposure to repeated head impacts and, therefore, brain damage (Marchi et al., 2013). The likelihood of being exposed to head impacts increases as the level of experience increases in American football (Choi et al., 2022). It is stated that American football players are more likely to develop neurological conditions in old age, including amyotrophic lateral sclerosis, Alzheimer's disease, and chronic traumatic encephalopathy (Hampshire et al., 2013; Kochsiek et al., 2021; Lehman et al., 2012).

The underlying reasons for the neurodegenerative diseases seen in American football players have been considered to be long-term exposure to brain damage induced by repetitive head impacts and the resulting symptomatic brain injuries such as subconcussive injuries and concussions (Kochsiek et al., 2021). Brain damage can lead to neuronal damage, increased reactive oxygen species (ROS), and proinflammatory cytokines (signalling molecules) along with an impaired blood-brain barrier (BBB), a key cellular barrier tightly controlling the microenvironment of the central nervous system (CNS) to support balanced neuronal function (Daneman & Prat, 2015; Kim et al., 2022). Exposure to long-term and severe brain damage or resulting concussion can lead to chronic oxidative stress and neuroinflammation, which, if sustained, can subsequently trigger neurodegenerative progression (Hoffman et al., 2022; Kochsiek et al., 2021).

It is thought that the risk of developing neurodegenerative disorders may be reduced by decreasing the negative effects of brain damage (Hoffman et al., 2022; Oliver et al., 2016; Zuckerman et al., 2018). Therefore, strategies to improve brain damage-induced inflammation and oxidative stress are crucial in the early stage of life (Churchill et al., 2017; Walrand et al., 2021). Lifestyle factors, such as dietary habits, can be considered as one of the strategies to support brain health in American football players (Walton et al., 2021). Consumption of processed foods deficient in nutrients can compromise the brain's resilience and flexibility and increase inflammation and oxidative stress owing to brain damage (Fesharaki-Zadeh, 2022; Mullins et al., 2022; Walrand et al., 2021). On the other hand, a diet model like the MIND diet, which includes foods rich in bioactive compounds and nutrients such as fiber, PUFAs, and MUFAs with antioxidant and anti-inflammatory properties, may improve brain health (Oliver et al., 2016; Walrand et al., 2021). Therefore, this paper will discuss the potential effects of MIND diet components including bioactive compounds, fiber, PUFAs, and MUFAs on brain health for American football.

2. MIND Diet

The MIND diet emphasizes limiting the consumption of cheese, red meat, butter, sweets, and fried foods and increasing the intake of berries, fish, green leafy vegetables, olive oil, whole grains, nuts, beans, and poultry (Morris et al., 2015). The MIND diet is designed by Morris et al. (2015) to improve certain dietary factors after the Mediterranean and DASH diets and to provide the maximum beneficial impact on brain health (Barnes et al., 2023).

The MIND diet's anti-inflammatory and antioxidant features are mostly elevated by preferred foods such as whole grain products, beans, green leafy vegetables, fish, olive oil and berries which are the source of bioactive compounds and key nutrients such as fiber, MUFAs, and PUFAs (Barnes et al., 2023). Drinking a glass of wine per day is also recommended. Wine is a drink rich in bioactive compounds. The MIND diet includes foods with these important components which may provide neuroprotective benefits (Barnes et al., 2023; Morris et al., 2015).

The following sections will elaborate on the potential effects of MIND diet components, such as bioactive compounds, fiber, PUFAs, and MUFAs on brain health.

2.1. Bioactive compounds

Bioactive compounds are substances that have physiological and biological activities. Moreover, these substances also provide health benefits over the main nutritional value of a food (Guaadaoui et al., 2014). The MIND diet provides bioactive compounds like phenolic substances including terpenoids (carotenoids and phytosterols), glucosinolates, alkaloids, and polyphenols through recommended foods such as green leafy vegetables, beans, and whole grains, besides olive oil and wine (Sorrenti et al., 2023).

Studies usually attribute the positive effects of bioactive compounds on brain health to their anti-inflammatory and antioxidant abilities thereby neuroprotective potentials.

The presence of bioactive compounds can reduce brain damage-induced ROS and proinflammatory cytokines (Kim et al., 2022). Therefore, they prevent the increase of oxidative stress and neuroinflammation and support the recovery of disrupted microglia including the plentiful inhabitant macrophages in the CNS, responsible for tissue defence and repair (Zaa etl al., 2023). Among bioactive compounds, polyphenols stand out with their strong anti-inflammatory and antioxidant capabilities (Kim et al., 2022). Foods such as green leafy vegetables, berries, and wine included in the MIND diet have abundant flavonoids and resveratrol, which are considered some of the polyphenols most researched for their potential beneficial effects on brain health (Ardekani et al., 2023; Caruana et al., 2016; Chaves et al., 2018). Some of the important polyphenols frequently found in foods included in the MIND diet are summarized in Table 1 (Manach et al., 2004).

As for flavonoids, catechin, epicatechin, and epigallocatechin-3-gallate have been shown to implement neuroprotective effects on the neurons encompassing the injured area of the brain by hindering apoptotic cell death. Besides, they can decrease the expression levels of the mRNA of proinflammatory factors like interleukin 6 (IL-6), tumor necrosis factor-alpha (TNF-α), and inducible nitric oxide synthase (iNOS) (Carecho et al., 2023). Anthocyanins can contribute to the protection from oxidative stress and apoptosis of neurons. The protective activities of anthocyanins are relatively because of their ability to trigger Nrf-2 transcription factor activation which binds to the main antioxidant response regulator (Nrf-2/antioxidant response). For example, the berries' anthocyanin cyanidin-3-glucoside induces the Nrf-2 antioxidant defence system causing a fall of oxidative stress and apoptosis within stressed cultured neurons (Zaa et al., 2023). Anthocyanins also attenuate inflammatory stress signalling via the inhibition of the nuclear factor kappa B (NF-κB) pathway giving rise to neuroinflammation, neuronal dysfunction and cell death by generating proinflammatory molecules such as TNF-α, interleukin 1 beta (IL-1β), iNOS, and ROS. Therefore they support the survival of microglial cells (Henriques et al., 2020). Luteolin has also been reported to alleviate inflammation after brain damage by decreasing IL-1 and TNF-α levels, and restoring anti-inflammatory factors such as glutathione peroxidase (GPx) activity. Apart from these, resveratrol is a non-flavonoid polyphenol abundant in wine. It may lead to decreased microglia activation with its antioxidant and anti-inflammatory properties after brain damage. In terms of the inflammation and oxidative stress-reducing capability, it has been reported that resveratrol reduces ROS, malondialdehyde, 8-hydroxy-20-deoxyguanosine protein, IL-1, IL-6, IL-12, and TNF- α, while increasing the GPx activity and IL-10 levels and improving NF-κB pathway in the affected brain tissue (Nath et al., 2022).

The bioactive compounds included in the MIND diet may help to improve brain damage, with their antioxidant and anti-inflammatory characteristics. The ability of polyphenols to interplay with various physiological processes makes them promising bioactive compounds to support brain health.

Table 1. Some of the important polyphenols frequently found in foods included in the MIND diet (Adapted from Manach et al., 2004)

Polyphenols	Food sources/serving size	Polyphenol content (mg/serving)
Anthocyanins (Cyanidin, Pelargonidin, Peonidin, Delphinidin, Malvidin)	Blackberry/100 g	100-400
	Blueberry/100 g	25-500
	Strawberry/200 g	30-150
	Red wine/100 mL	20-35
Flavonols (Quercetin, Kaempferol, Myricetin)	Curly kale/200 g	60-120
	Blueberry/100 g	3-16
	Beans, green or white/200 g	2-10
	Red wine/100 mL	0,2-3
Flavones (Apigenin, Luteolin)	Parsley/5 g	1,2-9,2
Isoflavones (Daidzein, Genistein, Glycitein)	Soybeans, boiled/200 g	40–180
Monomeric flavanols (Catechin, Epicatechin)	Beans/200 g	70–110
	Blackberry/100 g	13
	Red wine/100 mL	8–30

2.2. Dietary Fiber

Sports-related acute to chronic brain trauma induced by brain damage or repetitive head impacts can lead to gastrointestinal dysfunction by increasing intestinal permeability (Al-Ayadhi et al., 2021; Ramezani Ahmadi et al., 2020; Tillisch et al., 2013; Walrand et al., 2021). Although the exact mechanism is unknown, it is stated that brain trauma stimulates the sympathetic adrenal medullary system, leading to contraction of the gastrointestinal blood vessels, decreased blood flow, inadequate perfusion of the gastrointestinal tissue and circulatory ischemic hypoxia in the intestine (Guangliang et al., 2024; Iftikhar et al., 2020). In addition, excessive activation of the hypothalamic-pituitary-adrenal axis (HPA) and autonomic nervous system leads to partial loss of intestinal neurons (Li et al., 2020). It is thought that increased intestinal microvascular permeability due to these factors leads to disruption of the gastrointestinal mucosal barrier (Guangliang et al., 2024; Iftikhar et al., 2020; Li et al., 2020). The damaged gastrointestinal tract adversely modifies gut microbiota (the living microorganisms found in a defined environment) homeostasis leading to bacterial imbalance, called dysbiosis, which, in turn, may affect neural pathways (Al-Ayadhi et al., 2021; Ramezani Ahmadi et al., 2020; Tillisch et al., 2013; Walrand et al., 2021). Therefore, supporting the growth of beneficial bacteria in the gut microbiota by dietary fiber with prebiotic (a substrate selectively used by host microorganisms and provides health benefits) properties may be an important factor in brain injury recovery (Al-Ayadhi et al., 2021; Walrand et al., 2021).

The MIND diet includes important fibers (oligosaccharides, plant polyphenols, polyunsaturated fatty acid, conjugated linoleic acid, etc.) and fiber sources (whole grains, vegetables, beans, fruits, and nuts) that are prebiotic (Al-Ayadhi et al., 2021; Morris et al., 2015; Ramezani Ahmadi et al., 2020; Tillisch et al., 2013). Therefore, this diet model can support the proliferation of beneficial bacteria in the gut microbiota with the fibers showing prebiotic properties (Lockyer & Stanner, 2019; Nagpal et al., 2019). In this way, fibers help sustain the integrity of the gastrointestinal barrier by decreasing intestinal permeability (Al-Ayadhi et al., 2021). Furthermore, fibers support the release of neurotransmitters like brain-derived neurotrophic factor (BDNF) and gamma-aminobutyric acid (GABA), as well as the metabolites of short-chain fatty acids (SCFAs), which are produced by bacteria that consume prebiotics (Al-Ayadhi et al., 2021; Ramezani Ahmadi et al., 2020; Tillisch et al., 2013). These neurotransmitters and metabolites are involved in modulating inflammatory responses, promoting bidirectional communication among the microbiota, gut and brain called the microbiota-gut-brain axis (MGBA) thereby influencing the CNS while maintaining homeostasis in a healthy way (Poblete et al., 2023).

Since gut bacteria are involved in the metabolic processes of brain injury, maintaining MGBA homeostasis by consuming dietary fiber sources included in the MIND diet with prebiotic properties can be beneficial for improving possible negative neurological consequences induced by increased intestinal permeability.

2.3. Polyunsaturated Fatty Acids

The MIND diet includes essential PUFAs. Among these fatty acids omega-3 (ω-3) PUFAs like alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are some of the most studied and important for brain health (Nishi et al., 2023; Lăcătușu et al., 2019; Scrimgeour & Condlin, 2014). ALA, a plant-based ω-3 fatty acid, especially found high in nuts like walnuts supports neural processes such as axonal and dendritic growth, synaptogenesis, neurogenesis, and myelination, especially in terms of brain development from an early age (Chauhan & Chauhan, 2020; Nishi et al., 2023). It suppresses inflammation and oxidative stress by inhibiting nitric oxide (NO) production and proinflammatory cytokines such as IL-6, IL-1β, and TNF-α. ALA is the precursor for EPA and DHA (abundant in oily cold-water fish species) which are structural components of cell membranes, regulating membrane fluidity, flexibility, cell signalling, and mitochondrial function (Chauhan & Chauhan, 2020). DHA is also the main component of phospholipids, supporting neuronal plasma membranes (Arnoldussen & Kiliaan, 2014).

After brain damage cell membrane metabolism could be changed. Microglia has been considered the main cell regulator for the immune response of the CNS. It becomes more active than a passive state after brain damage and triggers an inflammatory cascade (Poblete et al., 2020). So proinflammatory cytokines are released (Martínez et al., 2023). In this case, BBB disruption occurs and exacerbates neuroinflammation leading to brain damage (Poblete et al., 2020; Poblete et al., 2023). Endogenous lipid mediators such as thromboxanes, prostaglandins, and leukotrienes produced from the hydrolysis of omega-6 (ω-6) rich membranes increase the infiltration of neutrophils along with disrupted BBB. These specialized pro-resolving lipid mediators (SPMs) can negatively regulate the inflammatory process thus leading to pain, fever, increased vascular permeability, and soft-tissue edema (Poblete et al., 2020). On the other hand, lipoxins which are another ω-6-derived SPMs can modulate granulocyte recruitment into injured tissue and attenuate neuroinflammation by promoting apoptosis of leukocytes (Poblete et al., 2020; Tiberi & Chiurchiù, 2021). Above all, SPMs derived from EPA and DHA ω-3 fatty acids like resolvins, protectins, and maresins take part in attenuating neuroinflammation by removing pathogens, decreasing leukocyte-infiltration, and promoting macrophage-mediated cellular debris phagocytosis. Since those SPMs having beneficial effects in alleviating neuroinflammation are mostly derived from ω-3 fatty acids, it is thought that ω-3 fatty acids protect nerve cells more than ω-6 fatty acids (Guo et al., 2016; Musto et al., 2015; Poblete et al., 2020; Scrimgeour & Condlin, 2014).

Specific to ω-3 fatty acids, there are studies conducted on American football players, in which the effects of different doses and formulas of ω-3 fatty acids supplementation on some biomarkers of brain damage and inflammation have been investigated (Heileson et al., 2021; Mullins et al. 2022; Oliver et al., 2016). Even one of these studies has found attenuation in biomarkers of brain damage (Heileson et al., 2021), others reported that ω-3 fatty acids did not mitigate the adverse effect of brain damage and inflammation (Mullins et al. 2022; Oliver et al., 2016). This indicates an inability to establish a direct consensus that ω-3 fatty acids improve brain damage in American football players. PUFAs may support brain health in general, but more clinical research is required (Derbyshire, 2018; Poblete et al., 2020).

2.4. Monounsaturated Fatty Acids

The MIND diet recommends to prefer olive oil as the primary oil. Olive oil is rich in oleic acid (ω-9), which is one of the MUFAs (Lăcătușu et al., 2019; Morris et al., 2015). It has been indicated that MUFAs have neuroprotective features and oleic acid is the primary MUFA in the brain (Bazinet & Laye, 2014; Carrillo et al.,2012). Oleic acid is contained within neuronal membranes and high levels in myelin (Bazinet & Laye, 2014).

In a human study, the oleic acid levels were elevated in the cerebrospinal fluid 48 hours after the brain injury (Pilitsis et al., 2003). It has been considered that the increase in MUFA-containing phospholipids in the brain after brain damage may trigger the activation of neuroprotective mechanisms. On the other hand, a decrease in MUFA at later stages can contribute to the neurodegeneration following amyloid deposition (Ojo et al., 2019). A diet enriched with high oleic acid has been shown to exert neuroprotective effects by increasing amyloid clearance enzymes and diminishing amyloid plaques in mice (Amtul et al., 2011). Further, oleic acid has been associated with reduced oxidative stress, increased myelination and neurotropic support (Carrillo et al., 2012; Medina & Tabernero, 2002; Ojo et al., 2019).

According to studies and recommendations, the MIND diet model including balanced consumption of foods rich in both PUFAs (especially with a higher ω-3/ω-6 fatty acids ratio) and MUFAs (mainly oleic acid) could be advantageous for supporting brain health in American football players. Figure 1 summarizes the potential beneficial effects of the MIND diet components on brain health for American football players.

3. Conclusion

The MIND diet could have been considered to support brain health in American football players because it includes foods rich in bioactive components, fiber, PUFAs, and MUFAs. These MIND diet components could help to achieve the desired neuroprotective improvements against brain damage with their anti-inflammatory and antioxidant capabilities, besides regulating intestinal homeostasis, and modulating brain cell membrane, thereby restoring BBB disruption, neuroinflammation, and other neurological imbalances.

Although the MIND diet components may have been considered to improve the outcomes of brain damage depending on head impacts, integrating this type of nutrition model into regular practice does require discipline to comply with the recommendations on food consumption frequency and preference. Restriction on the consumption frequency of some foods may not be easy to adopt. Therefore, this diet model should be explained to athletes before being adopted. Since there is no literature on applying the MIND diet model for brain health in American football players, future studies would better focus on this topic by conducting randomized controlled clinical trials.

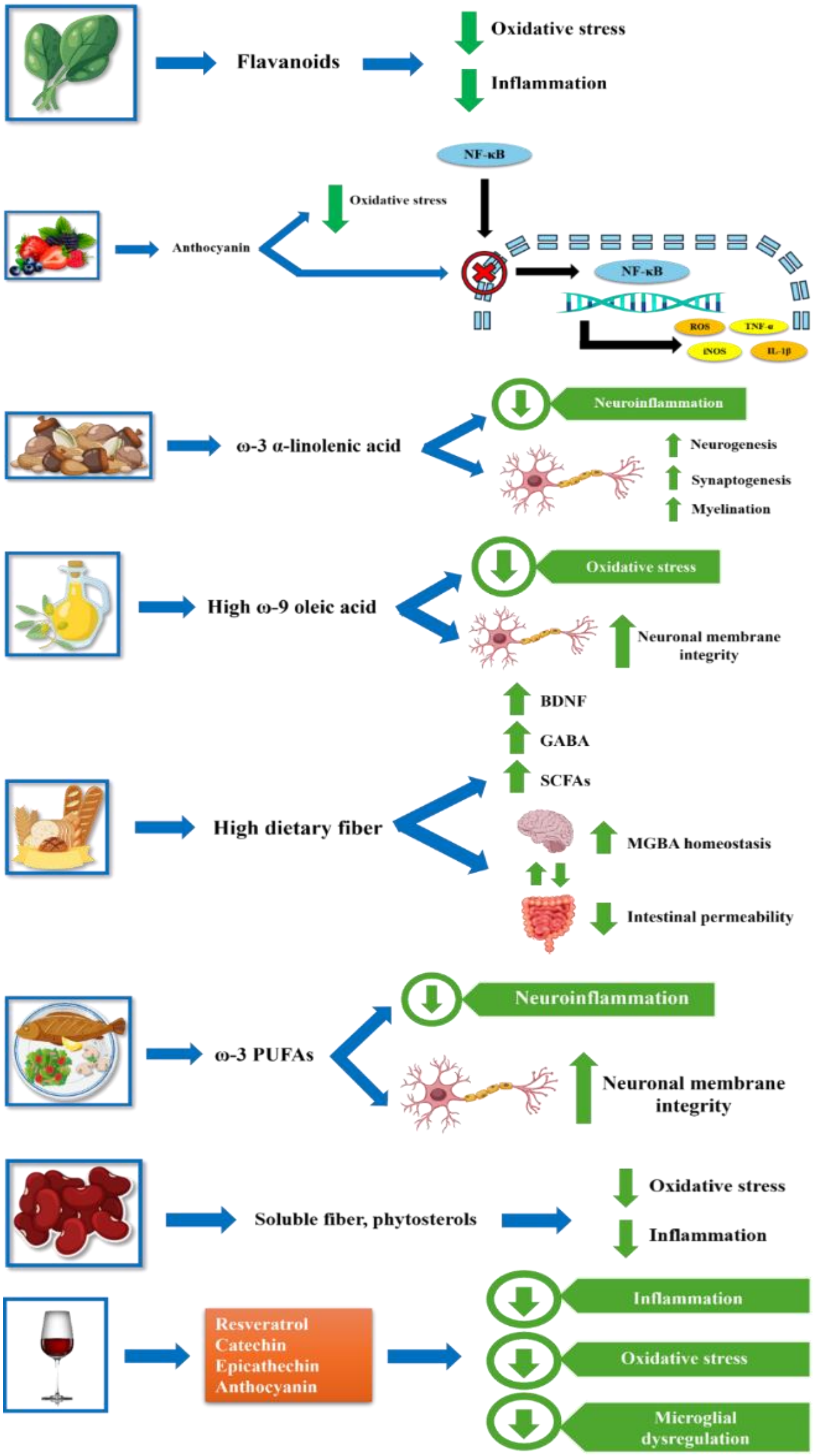

Figure 1. The Potential Effects of MIND Diet Components on Brain Health (Freepik was used for images) (Adapted from Ardekani et al., 2023)

Abbreviations: BDNF, brain-derived neurotrophic factor; GABA, gamma-aminobutyric acid; IL-1β, interleukin 1 beta; iNOS, inducible nitric oxide synthase; MGBA, microbiota-gut-brain axis; NF-κB, nuclear factor kappa B; ROS, reactive oxygen species; SCFAs, short-chain fatty acids; TNF-α, tumor necrosis factor-alpha; ω, omega.

Ethical Statement

There is no need to obtain ethics committee permission for this study due to it is review article.

Financial Support for the Study

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Presentation Information

The findings of this study have not been presented at any conference or journal.

Conflicts of Interest

The authors declare no conflicts of interest regarding this study. Any institution or organization providing funding for this research did not have any role in the design, data collection, analysis, interpretation, or publication to influence or distort the findings.

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