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REVIEW

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Examining the efficacy of the Mediterranean-DASH diet intervention for neurodegenerative delay in mitigating cognitive decline

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Abstract

Background The association between the Mediterranean-DASH (Dietary Approaches to Stop Hypertension) Diet Intervention for Neurodegenerative Delay (MIND) diet and cognitive decline has garnered substantial attention in recent research. This review aims to comprehensively analyse the existing evidence regarding the potential impact of the MIND diet on cognitive health.

Methods A literature search was conducted to identify relevant studies exploring the relationship between the MIND diet and cognitive decline. A narrative synthesis approach was employed to summarise and interpret the findings from diverse study designs.

Results The review reveals consistent evidence suggesting a positive association between adherence to the MIND diet and improved cognitive performance. Several longitudinal studies demonstrate potential preventive effects against cognitive decline, emphasising the significance of dietary habits in preserving cognitive function.

Conclusion The MIND diet's positive impact on cognitive health is well-supported by numerous studies. Additionally, the review highlights the exciting opportunity to connect research findings with practical dietary guidance and targeted interventions, particularly for high-risk populations, to enhance cognitive health promotion.

Keywords MIND diet, Cognitive decline, Cognitive performance, Mediterranean-DASH diet

Introduction

Cognitive decline has garnered increasing attention as populations worldwide experience unprecedented demographic shifts [1]. With longer lifespans, the prevalence of cognitive disorders such as Alzheimer's disease (AD) and related dementias has risen, underscoring the urgency of understanding and addressing this multifaceted challenge [2]. The societal and individual burdens imposed by cognitive decline highlight the pressing need for effective interventions to enhance cognitive resilience and mitigate its adverse effects [3]. In this pursuit, dietary interventions have emerged as a compelling avenue for promoting cognitive health. The MIND diet (Mediterranean-DASH Diet Intervention for Neurodegenerative Delay) has become an innovative and potentially impactful dietary regimen [4]. Combining principles from the Mediterranean and Dietary Approaches to Stop Hypertension (DASH) diets, the MIND diet encompasses cardiovascular benefits and emphasises foods rich in nutrients believed to safeguard cognitive function [5].

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This integration positions the MIND diet as a distinctive dietary approach with the potential to contribute significantly to cognitive health preservation [5].

The growing prevalence of cognitive decline and the increasing recognition of the role of lifestyle factors in cognitive well-being have spurred scientific inquiry into dietary interventions like the MIND diet [6]. As cognitive disorders impose substantial societal and economic burdens, identifying strategies to delay or mitigate cognitive decline has become a global health priority [7]. The exploration of the MIND diet's impact on cognitive health is particularly pertinent given its unique focus on cognitive-protective nutrients and foods [8]. Understanding this dietary approach's potential benefits and limitations can inform individual choices and guide public health strategies to promote cognitive vitality in ageing populations. This comprehensive narrative review delves into the existing body of research to critically examine the efficacy of the MIND diet in mitigating cognitive decline. Through the synthesis of studies, a meticulous evaluation of their methodologies, and the identification of avenues for further investigation, this review aims to elucidate the role of the MIND diet in bolstering cognitive resilience.

Methodology

This review synthesises existing literature concerning the efficacy of the MIND diet in mitigating cognitive decline (Table 1). The review began with a comprehensive search of electronic databases, including PubMed, MEDLINE, PsycINFO, and Web of Science. The search was conducted using a combination of keywords and phrases such as "MIND Diet", "cognitive decline", "neuroprotective nutrients", and "dietary interventions". Only studies published in peer-reviewed journals within the last 10 years were included to ensure the relevance and currency of the evidence. Initially, titles and abstracts were screened to identify studies that potentially investigated the impact of the MIND diet on cognitive health outcomes. Subsequently, full-text articles were retrieved for further assessment. Studies on the MIND diet's effects on cognitive function, cognitive decline, Alzheimer's disease, and related outcomes were included. Studies with irrelevant methodologies, populations, or interventions were excluded.

Data extraction was conducted to compile relevant information from the included studies. This process involved extracting details such as study design, sample characteristics, intervention specifics, outcome measures, and key findings. The extracted data were then organised and synthesised to facilitate a comprehensive overview of the diverse studies' findings.

The synthesised findings were categorised into themes based on the consistency and convergence of outcomes across studies. Themes encompassed the impact of the MIND diet on cognitive function, potential mechanisms underlying its effects, and any reported limitations or challenges. This categorisation aimed to provide a clear framework for understanding the collective evidence and to identify patterns or discrepancies in the reported findings.

Components of the MIND diet and their potential cognitive benefits

The MIND diet is a nutritional regimen meticulously crafted to enhance brain health and diminish susceptibility to cognitive decline and neurodegenerative disorders such as AD [9]. The MIND diet spotlights a selection of foods deemed advantageous for cognitive function through the fusion of principles derived from

Table 1 Methodology

Review process	Description
Objective	Assess the efficacy of the MIND diet in mitigating cognitive decline
Literature search	A comprehensive search of electronic databases using keywords: "MIND Diet", "cognitive decline", "neuroprotective nutrients", and "dietary interventions"
Inclusion criteria	- Studies published in peer-reviewed journals within the last ten years—focus on MIND diet's impact on cognitive health outcomes
Exclusion criteria	Studies with irrelevant methodologies, populations, or interventions were excluded
Screening	Titles and abstracts were initially screened to identify relevant studies
Full-text assessment	Full-text articles were retrieved for further evaluation, focusing on cognitive function, cognitive decline, Alzheimer's disease, and related outcomes
Data extraction	Relevant data were extracted, including study design, sample characteristics, intervention specifics, outcome measures, and key findings
Data organisation and synthesis	Extracted data were organised and synthesised to overview the study findings comprehensively
Categorisation into themes	Synthesised findings were categorised into themes based on consistency and convergence of outcomes, including the MIND diet's impact on cognitive function, potential mechanisms, and reported limitations or challenges

the Mediterranean and DASH diets [9]. This dietary approach accentuates specific food groups and nutrients linked to potential cognitive benefits [10].

Originally conceived by Morris et al. in 2015, the MIND diet was custom-tailored to safeguard cognitive vitality [11]. Drawing inspiration from the time-honoured Mediterranean and DASH dietary traditions, the MIND diet integrates refinements informed by salient insights from diet-dementia research. The dietary blueprint places paramount importance on whole, plant-derived foods, encouraging the amplification of dietary intake of berries, leafy greens, whole grains, fish, nuts, and olive oil [12]. Simultaneously, the regimen restricts consuming animal-based products and foods rich in saturated fats [11].

A recent randomised controlled trial conducted by Arjmand et al. further elucidated the constituents of the MIND diet through an exhaustive inventory [13]. This comprehensive list encompasses an array of items, including green leafy vegetables, assorted vegetables, berries, nuts, olive oil, butter, margarine, cheese, whole grains, non-fried fish, legumes, un-fried poultry, red meat and related products, fast-fried foods, pastries, sweets, and moderate wine consumption [13]. Despite the diversity of components, these can be distilled into two distinct categories: brain-healthy foods and those that pose potential detriments to cognitive well-being. Notably, red meat, butter, margarine, cheese, pastries, sweets, and fast-fried foods fall within the latter category. At the same time, the remaining items are acknowledged for their potential positive influence on brain health.

A burgeoning body of research underscores the associations between adherence to the MIND diet and cognitive prowess. Elevated MIND diet scores have been linked to improved global cognitive function [14]. Furthermore, investigations have highlighted the potential of the MIND diet to decelerate cognitive decline associated with the ageing process [11, 14, 15]. Central to the MIND diet's foundation is its robust emphasis on integrating plant-based fare into dietary habits [14]. This approach is meticulously designed to bolster brain health and mitigate the risk of cognitive decline. For instance, leafy greens such as spinach and kale contain folate, a critical B vitamin pivotal in neurotransmitter synthesis, fostering effective communication between brain cells [15]. Vitamin K in these greens contributes to maintaining brain cell membranes, promoting overall cognitive well-being [15]. Additionally, these vegetables are rich in antioxidants, pivotal in shielding brain cells from oxidative stress-induced damage, potentially enhancing cognitive function and lowering the risk of cognitive decline [15]. Another essential component is the inclusion of leguminous beans, which offer the dual benefit of being a notable plant-based protein source and a rich reservoir of dietary fibre [16]. Dietary fibre establishes a flourishing gut microbiome, an increasingly recognised influencer of cognitive function [16]. The intricate connection between a healthy gut and brain is instrumental in sustaining brain health and curbing the risk of cognitive decline [16].

Mechanisms underlying the MIND diet's potential cognitive benefits

The MIND diet represents a dietary approach with therapeutic potential for addressing cognitive dysfunction (Fig. 1). Drawing from the Mediterranean and DASH diets, this composite regimen exhibits a confluence of dietary patterns that positively affect brain health [11].

Influence on inflammation and oxidative stress

Integral to the cognitive benefits attributed to the MIND diet is the interplay of its components, culminating in mechanisms that counter inflammation and oxidative stress within the brain [17]. Oxidative stress, stemming from an imbalance between reactive oxygen species (ROS) production and the antioxidants required for their neutralisation, is pivotal in the genesis of neurodegenerative disorders like Alzheimer's [18]. Elements encompassing folate, vitamin E, lutein-zeaxanthin, and flavonoids within the MIND diet contribute anti-inflammatory and antioxidant attributes, guarding brain cells against the ravages of oxidative stress-induced damage caused by free radicals [19–21]. The diet's incorporation of anti-inflammatory foods such as omega-3 fatty acids further fortifies the brain against inflammation and the progression of neurodegenerative diseases [22].

Influence on gut microbiota and brain health

The intricate interplay between the central nervous, gut, and microbiome forms the brain–gut microbiota system (BGM), an interconnected bidirectional axis [23]. The MIND diet's constituents impact this system upon absorption in the small intestine, channelling communication through neuronal, endocrine, and immunoregulatory pathways [24, 25]. These dietary components wield substantial influence over the composition and diversity of the gut microbiota. Deprivation of these constituents disrupts the equilibrium of the BGM system, engendering dysfunctions like oxidative stress and inflammation, which are intertwined with cognitive impairment [24]. Notably, carbohydrate-rich, fatty, and polyphenol-rich foods favour the proliferation of bacteria, such as prevotella, bacteroides, Flavonifractor plautii, and others, endowed with neuroprotective attributes, encompassing anti-inflammatory and antioxidant properties [26–28].

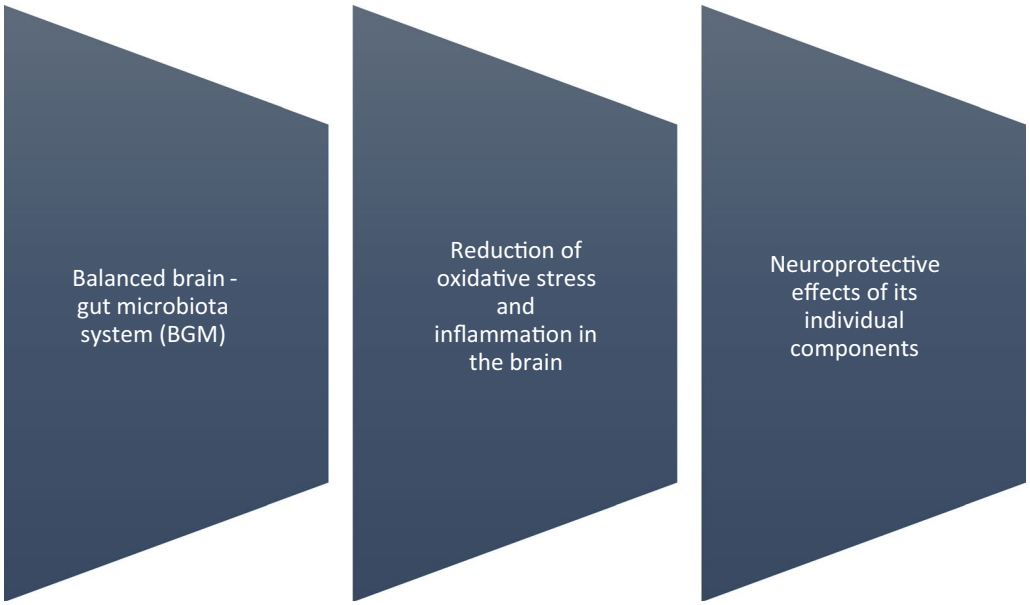

Fig. 1 Mechanisms underlying cognitive benefits of the MIND diet

Neuroprotective effects of individual diet components

Collectively, the orchestrated anti-inflammatory, antioxidant, and gut-microbiota-modulating effects inherent to the MIND diet yield neuroprotective outcomes [29]. Robust adherence to this dietary framework has demonstrated potential in treating diverse neurodegenerative conditions, including multiple sclerosis, dementia, AD, and Parkinson's disease, as documented across various studies [30, 31]. Core constituents of the MIND diet encompass green vegetables, berries, nuts, beans, olive oil, fish, red meat, poultry, and more, each contributing to a comprehensive nutritional intake [31].

Arjmand et al. randomised controlled trial, examining the impact of the MIND diet intervention on cognitive performance and brain structure in obese women, unveiled enhanced cognitive outcomes, including working memory and verbal recognition memory [13]. Magnetic resonance imaging (MRI) further revealed structural changes indicative of improved brain health [32]. Likewise, Barnes et al. trial in 2023 investigating the MIND diet's potential for preventing cognitive decline among individuals with a family history of dementia witnessed improvements in cognitive outcomes, with MRI corroborating positive changes in brain structures [32].

The MIND diet's neuroprotective effects reverberate beyond AD, as demonstrated in studies exploring multiple sclerosis and Parkinson's disease. Noormohammadi et al. investigation associated proper MIND diet adherence with reduced odds of multiple sclerosis, with distinct impacts of various dietary components [33]. Similarly, Agarwal et al. reported a connection between MIND diet adherence and delayed progression of Parkinson's disease in the elderly [15]. Numerous other studies, including seminal works by Morris et al., Liu et al., and Devranis et al., underscore the pervasive neuroprotective effects of the MIND diet [34–36].

Studies assessing the MIND diet's impact on cognitive function

Numerous studies have been conducted to investigate the potential impact of the MIND diet on cognitive function. This dietary approach, which combines elements of the Mediterranean and DASH diets, has garnered attention for its potential neuroprotective properties (Table 2). These studies provide valuable insights into the relationship between dietary choices and cognitive health, offering potential strategies for mitigating cognitive decline and promoting overall brain well-being.

Positive association between MIND diet adherence and cognitive performance

Multiple epidemiological studies provide evidence of a positive association between adherence to the MIND diet and improved cognitive performance. Hoskings et al. conducted a longitudinal study spanning 12 years involving 1220 participants. Their findings revealed a noteworthy association between adherence to the MIND diet and a reduced risk of cognitive impairment. This suggests that the MIND diet might have preventive effects against cognitive decline over the long term [37].

Cherian et al. explored the impact of the MIND diet on post-stroke cognitive deterioration [38]. Participants with

Table 2 Studies comparing MIND diet adherence and cognitive decline

Author and year	Study design	Sample size	Intervention duration	Cognitive outcome measured	Key findings
Hoskings et al., 2019	Prospective cohort study	1220	12 years	Cognitive and functional changes	In adjusted logistic regression models, the MIND diet was associated with reduced odds of 12-year cognitive impairment (OR 0.47, 95% CI 0.24, 0.91) The Mediterranean diet did not significantly correlate with the incidence of cognitive impairment in this study
Cherian et al., 2021	Observational prospective cohort study	709	6.53 years	Episodic memory, semantic memory, working memory, perceptual orientation, and perceptual speed	Participants in the highest tertile of the Dietary Approaches to Stop Hypertension (DASH) diet and Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet scores had lower rates of depressive symptoms over time compared to those in the respective lowest tertiles The Western diet was positively associated with depressive symptoms over time
Wesselman et al., 2021	Cross-sectional study	389	-	Memory, language, executive functioning, executive functioning and visuospatial functioning	Adherence to the Mediterranean and MIND diets was associated with better memory in fully adjusted models After excluding mild cognitive impairment (MCI) subjects, Mediterranean and MIND diets were also related to language functions, while associations with the "alcoholic beverages" component were attenuated but mostly remained significant

Table 2 (continued)

Author and year	Study design	Sample size	Intervention duration	Cognitive outcome measured	Key findings
Berendsen et al. 2017	Population-based prospective cohort study	16,058	6 years	Verbal memory score and composite scores of verbal memory and global cognition	Greater long-term adherence to the MIND diet was associated with a better verbal memory score Multivariable-adjusted mean differences between extreme MIND quintiles for verbal memory score: 0.04 (95% CI 0.01–0.07), *p*-trend = 0.006 There was no significant association between adherence to the MIND diet and cognitive decline over 6 years in global cognition, verbal memory, or Telephone Interview for Cognitive Status (TICS) Long-term adherence to the MIND diet showed a moderate association with better verbal memory in later life
Calil et al., 2018	Cross-sectional study	96	–	Mini-Mental State Examination (MMSE) scores Brief Cognitive Screening Battery (BCSB) Learning scores	Clinical groups (NC, mild cognitive impairment, and Alzheimer's disease) did not differ regarding body mass index or level of adherence to the diets Greater adherence to the Mediterranean and MIND diets was only associated with higher MMSE and BCSB Learning scores in the NC group Moderate adherence to the Mediterranean and MIND dietary patterns may be associated with better cognition among healthy seniors in middle to low-income countries

Table 2 (continued)

Author and year	Study design	Sample size	Intervention duration	Cognitive outcome measured	Key findings
Van Lent et.al 2021	Community-based observational study	2092	4 years	Global cognitive function, verbal memory, visual memory, processing speed, verbal comprehension/reasoning, cognitive decline	Higher MIND diet scores were associated with better global cognitive function, verbal memory, visual memory, processing speed, and verbal comprehension/reasoning Participants with higher MIND diet scores also had larger total brain volume (TBV). However, there was no significant association between MIND diet scores and other brain measures (e.g., hippocampal volume, lateral ventricular volume, white matter hyperintensity volume, and SBIs) Additionally, the MIND diet scores were not associated with cognitive decline
Morris et al., 2015	Cross-sectional study	960	4.7 years	Episodic memory, working memory, semantic memory, visuospatial ability, and perceptual speed	The MIND diet score was positively associated with slower cognitive decline in both the global cognitive score and the five cognitive domains Being in the top tertile of MIND diet scores compared to the lowest was linked to a decline rate equivalent to 7.5 years younger

Table 2 (continued)

Author and year	Study design	Sample size	Intervention duration	Cognitive outcome measured	Key findings
Munoz-Garcia et.al 2019	Prospective cohort study	806	6 years	Orientation, memory, attention/calculation, and language	The AHEI-2010 (Alternative Healthy Eating Index) and MIND (Mediterranean-DASH Intervention for Neurodegenerative Delay) diets significantly benefitted the 6-year change in STICS-m score A 1-SD (standard deviation) increase in the AHEI-2010 score was associated with a 6-year improvement of 0.25 points in the STICS-m score An increase of 1-SD in the MIND diet score was associated with a 6-year improvement of 0.27 points in the STICS-m score The Mediterranean dietary pattern (MDP), Dietary Approaches to Stop Hypertension (DASH), and pro-vegetarian diet (PVD) scores showed positive differences in their point estimates for an increase of 1-SD, but the results were not statistically significant The MIND diet appeared to modify changes in cognitive function over time

Table 2 (continued)

Author and year	Study design	Sample size	Intervention duration	Cognitive outcome measured	Key findings
Barnes et al. 2023	Two-site, randomised, controlled trial	604	3 years	Global cognition score and four cognitive domain scores derived from a 12-test battery	The MIND-diet and control-diet groups showed improvements in global cognition scores from baseline to year 3 Increases of 0.205 standardised units in the MIND-diet group and 0.170 standardised units in the control-diet group were observed There was no significant difference in cognitive performance between the MIND-diet and control-diet groups (mean difference, 0.035 standardised units; 95% confidence interval, −0.022 to 0.092; $p=0.23$) Changes in MRI-derived brain characteristics, including white-matter hyperintensities, hippocampal volumes, and total gray- and white-matter volumes, were similar in both groups
Mc Evoy et.al 2017	Population-based cross-sectional study	5907	–	Cognitive performance measured using a composite test score of global cognitive function	Participants with higher adherence to the Mediterranean and MIND diets had a lower likelihood of poor cognitive performance in fully adjusted models Higher scores in both dietary patterns were independently associated with significantly better cognitive function in a dose–response manner Greater adherence to the Mediterranean and MIND diets was independently associated with better cognitive function and a lower risk of cognitive impairment in a large, nationally representative population of older adults

Table 2 (continued)

Author and year	Study design	Sample size	Intervention duration	Cognitive outcome measured	Key findings
Krueger et.al 2022	Randomised control trial	604	–	Executive function, perceptual speed, episodic memory, and semantic memory	Age was associated with lower cognitive scores in all domains. Additionally, men had a significantly lower cognitive score in episodic memory and perpetual speed compared to women's perceptual speed However, no significant sex differences were noted in executive function and semantic memory. Education was associated with higher scores for episodic memory and semantic memory
Dhana et.al 2021	Longitudinal study	569	–	Global cognitive functioning proximate to death	A higher MIND diet score was associated with better global cognitive functioning proximate to death The association between the MIND diet and cognitive function remained significant even after controlling for common brain pathologies, including Alzheimer's disease (AD) pathology The strength and significance of the association remained relatively the same when accounting for brain pathologies The MIND diet-cognition relationship remained significant when analysing individuals without mild cognitive impairment at the baseline or in individuals diagnosed with AD based on postmortem diagnosis recommendations

Table 2 (continued)

Author and year	Study design	Sample size	Intervention duration	Cognitive outcome measured	Key findings
Cornelis et.al 2023	Observational study	120,661	–	Prospective memory (PM), fluid intelligence (FI, verbal-numerical reasoning), pairs matching (pairs, visual memory) and reaction time (RT) tests	Higher adherence to the MIND diet was associated with a small but significant worsening in performance on five out of seven cognitive tests The associations were strongest among highly educated participants. However, overall, MIND adherence was not associated with incident dementia There was an inverse association among females between MIND adherence and incident dementia, indicating a lower risk of dementia in females who adhered to the MIND diet
Arjmand et.al 2022	Randomised control trial	40 participants (37 completed the study)	3 months	Change in cognitive performance assessed with a comprehensive neuropsychological test battery, including working memory, verbal recognition memory, and attention	The MIND diet group showed significant improvements in working memory, verbal recognition memory, and attention compared to the control group Brain MRI results indicated an increase in the surface area of the inferior frontal gyrus in the MIND diet group The MIND diet intervention demonstrated the potential to reverse the negative effects of obesity on cognition and brain structure when combined with modest calorie restriction

Table 2 (continued)

Author and year	Study design	Sample size	Intervention duration	Cognitive outcome measured	Key findings
Elsayed et.al, 2022	Parallel randomised clinical trial (Experimental Group: Moderate-intensity treadmill exercise three times/week for three months with MIND diet Control Group: MIND diet only)	68	3 months	Cognitive functions Functional levels	The experimental group showed highly significant changes ($p < 0.01$) in sex hormones, cognitive functions, and functional levels compared to the control group ($p < 0.05$) after the intervention No correlation was found between the measured variables in both groups after the intervention ($p > 0.05$) Aerobic exercise combined with the MIND diet improves cognitive and functional levels and substitutes sex hormone deficiency in postmenopausal women, contributing to brain health longevity
Cherian et al., 2019	Community cohort study	106	5.9 years	Cognitive decline in five cognitive domains	The study found that high adherence to the MIND diet was associated with a slower rate of cognitive decline after stroke Participants in the top tertile of MIND diet scores had a slower rate of global cognitive decline compared to those in the lowest tertile, even after adjusting for age, sex, education, APOE-ε4 status, caloric intake, smoking, and participation in cognitive and physical activities

Table 2 (continued)

Author and year	Study design	Sample size	Intervention duration	Cognitive outcome measured	Key findings
de Crom et al., 2022	Prospective cohort study	5375 participants at baseline I and 2861 participants at baseline II	15.6 years from baseline I and 5.9 years from baseline II	Risk of all-cause dementia	The study found that higher adherence to the MIND diet was associated with a lower risk of dementia within the first 7 years of follow-up from baseline I However, associations disappeared over longer follow-up intervals, suggesting possible reverse causality and residual confounding by lifestyle Similarly, at baseline II, a higher MIND diet score was associated with a lower risk of dementia over every follow-up interval, but associations slightly attenuated over time The MIND diet score at baseline II showed a stronger association with the risk of dementia than the MIND diet score at baseline I

a history of stroke were examined using cognitive assessments and a food frequency questionnaire. Higher adherence to the MIND diet was correlated with mitigated cognitive deterioration post-stroke. These findings hint at the potential of the diet to aid stroke recovery and warrant further investigation into underlying mechanisms. In a study involving 389 participants, including those with mild cognitive impairment and Alzheimer's disease, Wesselman et al. assessed the relationship between the MIND diet, cognitive functioning, and dietary patterns [39]. Their investigation revealed that increased adherence to MIND and Mediterranean diets was associated with improved memory function. These positive effects were observed even in participants without cognitive impairment, suggesting potential cognitive benefits for the broader elderly population.

Berendsen et al. investigated cognitive function and cognitive decline in 16,058 older women. Their findings demonstrated that better verbal memory scores were linked to increased long-term adherence to the MIND diet over 6 years [40]. While the study did not find an association with cognitive decline, the improvement in verbal memory suggests potential cognitive enhancement with sustained MIND diet adherence. Calil et al. examined elderly individuals with varying cognitive profiles and their adherence to the MIND and Mediterranean diets [41]. Notably, higher adherence correlated with higher cognitive scores in the normal control group. This suggests that adherence to these diets might improve cognition, particularly in individuals without cognitive impairment. A study conducted in Malaysia assessed dietary patterns and their impact on cognitive risk [42]. Specific dietary patterns, such as "local snacks-fish and seafood-high salt foods", were associated with a higher risk of mild cognitive impairment (MCI) and dementia. Conversely, an inverse relationship was observed between the "tropical fruits-oats" dietary pattern and dementia incidence, suggesting that certain dietary habits might play a role in influencing cognitive risk.

Research involving brain MRI scans, cognitive testing, and nutritional assessments demonstrated that higher MIND diet ratings were associated with enhanced cognitive function and specific cognitive domains. This suggests that the MIND diet positively impacts cognitive performance and brain capacity [14].

Robustness and limitations of studies

While the collective body of research highlights the positive impact of the MIND diet on cognitive health, it is essential to acknowledge the strengths and limitations inherent in these studies. Including longitudinal study designs in several investigations has conferred robustness to the findings. These designs enable the observation of correlations over time, providing stronger support for potential causal relationships. Additionally, the substantial sample sizes in some studies enhance the generalisability of results, making them more applicable to larger populations [38, 40].

A common limitation across these studies is self-reported dietary evaluations, which may introduce recollection bias and not fully reflect individuals' nutritional intake. However, the longitudinal nature of the observational study designs helps mitigate this limitation by allowing repeated assessments and comparisons over time. This longitudinal approach enhances the reliability of the dietary data, contributing to more accurate interpretations [43]. In contrast to the overall trend of positive associations, Cornelis et al. study introduced contrasting results [44]. Their findings suggested a slight cognitive worsening associated with higher MIND diet adherence, particularly among highly educated participants. This disparity underscores the complexity of diet–cognition relationships and the potential influence of individual factors such as education level. These contradictory results emphasise the need for further exploration and the consideration of individual variations.

A fundamental limitation of these studies is their observational nature. This limits the establishment of direct cause-and-effect relationships between the MIND diet and cognitive decline. The presence of confounding variables inherent in observational designs can impact the interpretation of findings. While these studies provide valuable insights into associations, they cannot definitively determine whether the MIND diet directly leads to cognitive improvement or protection against decline.

Interventional approaches to address limitations

To overcome the limitations inherent in observational studies and to more definitively explore the relationship between the MIND diet and cognitive health, researchers have undertaken interventional approaches, offering valuable insights into causal connections. In a randomised controlled trial, Liu et al. examined the impact of the MIND diet on cognitive performance within at-risk individuals aged 65–84 [34]. Participants were divided into two groups: one maintaining their regular diet and the other following the MIND diet with slight caloric restriction. The study assessed cognitive performance, medical evaluations, blood pressure checks, anthropometric analyses, and sample collection. Notably, a subgroup underwent MRI scans. This interventional design allowed for a controlled exploration of how the MIND diet and caloric restriction influence cognitive outcomes among individuals at risk for cognitive decline.

Elsayed et al. conducted a study targeting healthy, obese women to investigate the effects of the MIND diet on cognitive performance and brain structure [45]. Participants were assigned either a calorie-restricted control diet or the modified MIND diet group. The study's well-controlled design facilitated the examination of cognitive performance using neurocognitive tests, assessment of brain-derived neurotrophic factor (BDNF), amyloid-beta, and homocysteine levels, and MRI scans to reveal changes in brain structure. This interventional approach, focusing on a specific population, elucidated the potential cognitive and brain structural benefits of the MIND diet.

Arjmand et al. analysed the abilities and brain structure of obese women following either a slightly modified MIND diet or a standard calorie-restricted diet [13]. The interventional study, spanning 3 months, assessed working memory, verbal recognition memory, and attention. Brain scans were employed to identify changes in brain areas associated with cognitive functions. This study contributes to our understanding of the MIND diet's impact on cognitive abilities and brain structure in the context of obesity.

In their study, Morris et al. investigated the MIND diet's influence on cognitive decline [11]. The results revealed that individuals adhering to the MIND diet experienced slower cognitive decline, with improvements in specific cognitive domains like memory, attention, and problem-solving skills. The observational study highlighted the potential benefits of the MIND diet but emphasised the need for further interventional research to establish definitive causal links.

Mixed findings and future research directions

While a substantial body of evidence supports the positive effects of the MIND diet on cognitive health, a subset of studies yields contradictory outcomes, warranting deeper examination and the identification of research trajectories. In a study assessing the cognitive effects of a mild caloric restriction MIND diet compared to a control diet, Barnes et al. found no significant difference in global cognition scores between the MIND and control-diet groups over a 3-year trial period [46]. This study's results provide a note of caution, suggesting that the MIND diet's impact on cognitive health might not be as universal as initially anticipated. Krueger et al. evaluated cognitive battery properties in the MIND diet Intervention, a randomised control trial to slow cognitive decline in older adults at risk for Alzheimer's dementia [47]. Their findings align with Barnes et al., revealing no significant differences in global cognition scores between MIND and control-diet groups over the 3-year trial period. These parallel results underscore the complexity of the MIND diet's effects on cognitive function.

The emergence of mixed findings can be attributed to variability in study designs, intervention durations, and participant characteristics. Each study's unique combination of factors influences the outcomes, highlighting the need for careful consideration when interpreting results. To achieve a more comprehensive understanding of the MIND diet's impact on cognitive function, it is imperative to embrace future research endeavours that address the limitations of existing studies. Larger sample sizes will enhance statistical power, longer intervention periods will capture potential delayed effects, and rigorous methodologies will ensure valid and reliable data collection.

Challenges and considerations for future research

Evaluating the MIND diet's effectiveness in mitigating cognitive decline involves navigating a complex landscape shaped by numerous confounding factors and potential biases. Cognitive decline, a multifaceted outcome, is influenced by variables encompassing genetics, socioeconomic status, and lifestyle factors, which extend to the MIND diet itself. For instance, Huang et al. highlighted the need for a tailored Chinese version of the MIND diet due to distinctive dietary practices in China, illustrating the influence of cultural variations on the diet's applicability [48]. Additionally, studies like Van Lent et al., 2021 and Barnes et al., 2023 underscored the potential generalisability limitations to diverse racial backgrounds, as their participant samples were predominantly European ancestry [14, 46].

Several studies within our comprehensive analysis emphasise a crucial aspect. A common method to assess dietary pattern adherence is the Food Frequency Questionnaire (FFQ) [49]. However, this approach relies on participants' recollection accuracy, introducing potential recall bias [49]. Notably, relying on informants responsible for meal preparation, particularly when individuals have MCI or AD, raises concerns about data quality and completeness [50]. Informants may be influenced by their cognitive limitations and perspectives, complicating the accurate documentation of participants' dietary habits and MIND diet adherence, especially in populations with cognitive impairments. Future research should explore methodologies that minimise recall bias and address measures like food monitoring apps or wearable devices that could offer real-time assessments of nutritional intake, reducing the impact of recall bias and enhancing the reliability of findings. The studies by Wesselman et al., 2021 exemplify the significance of this issue, recognising the

potential for non-differential misclassification and the importance of systematic accounting for factors influencing observed relationships [39].

Robust study designs that meticulously control potential confounders are needed to address these challenges. Advanced statistical techniques, such as propensity score matching, can create more comparable study groups and mitigate biases. Moreover, involving diverse populations across different geographic and socioeconomic contexts will be crucial for a comprehensive understanding of the MIND diet's effects. While observational studies provide valuable insights, the need for RCTs becomes evident when grappling with causality complexities and assessing the true benefit of the MIND diet. Much research exploring the MIND diet's cognitive association relies on observational methods, which possess limited power in determining causality. Observational designs are susceptible to confounding variables that obscure causal conclusions, underscoring the necessity of rigorous RCTs. In an RCT, individuals are randomly assigned to the MIND diet or a control group, minimising confounding variables. This approach reduces biases and strengthens the causal link between diet and cognitive outcomes. Barnes et al., 2023 conducted a study with 301 participants in the MIND diet group and 303 in the control diet group. Contrary to observational trends, the study showcased minimal cognitive differences between the two groups, highlighting the potential for divergent findings [46]. Adherence to robust RCT methodologies is paramount for future studies to attain higher quality. Ensuring adequate sample sizes, appropriate blinding mechanisms, and extended follow-up periods significantly enhances result reliability. Coordinating RCTs across diverse demographics and contexts not only bolsters results from generalisability but also furnishes more compelling evidence for the reported cognitive benefits of the MIND diet.

Determining the optimal level of adherence to the MIND diet for noticeable cognitive benefits presents a substantial challenge. Hypothetically, subgroup studies assessing cognitive outcomes across varying levels of adherence could reveal thresholds beyond which cognitive advantages become more pronounced. Such investigations offer practical insights for individuals considering diet. However, such studies would necessitate innovative methods to capture diet adherence accurately. Beyond the conventional FFQ, food-tracking apps and smart devices could offer bias-free insights into adherence levels. These modern tools provide real-time feedback, potentially refining our understanding of the relationship between dietary adherence and cognitive benefits.

Clinical implications and recommendations

The transition from research findings to actionable dietary guidance is paramount in the context of cognitive health. Our comprehensive narrative evaluation yields a wealth of insights into the potential impact of the MIND diet on cognitive decline prevention. However, the realisation of tangible cognitive improvements hinges on translating these results into practical and comprehensible dietary recommendations applicable to diverse populations.

Achieving this objective necessitates collaborative efforts among researchers, healthcare professionals, and dietitians. This collaborative synergy aims to develop tailored educational resources elucidating the nuances of the MIND diet and its cognitive implications. Culturally tailoring this information makes it more accessible to various communities, dismantling barriers and fostering dietary adherence.

Incorporating behavioural modification strategies introduces a crucial layer to the translation process. Healthcare providers can guide patients in seamlessly integrating the MIND diet into their daily routines, considering individual preferences, cultural nuances, and obstacles. This personalised approach enhances adherence and amplifies the potential for enduring cognitive benefits [51]. A deliberate focus on high-risk populations emerges as a pivotal strategy within cognitive health promotion. This approach entails systematically recognising and catering to populations vulnerable to cognitive impairments. Older individuals with a family history of cognitive impairments stand out among these high-risk groups, warranting specific interventions to bolster cognitive resilience.

The amalgamation of personalised nutritional guidance and strategic emphasis on high-risk populations resonates harmoniously with the broader therapeutic implications and recommendations framework. This harmony aligns with the fundamental objective of promoting cognitive health for all, underlining the significance of tailoring approaches to meet the unique needs of at-risk individuals.

Limitations and strengths of study

While this review provides valuable insights, it is essential to acknowledge certain limitations. The diverse methodologies across the studies, along with variations in participant demographics, assessment tools, and dietary adherence measurements, could limit the comparability and generalisability of the results. In addition, only studies published in English were included in the review. However, this study exhibits strengths that contribute to its reliability. The comprehensive literature search conducted across multiple databases and sources ensures the

inclusion of a wide range of relevant studies. A narrative synthesis approach was employed, allowing for qualitative analysis and interpretation of trends in the evidence. Finally, the study goes beyond presenting findings by discussing their implications for clinical practice and suggesting potential areas for further investigation.

Conclusion

This comprehensive review provides a review of the existing literature. The amalgamation of various studies offers valuable insights into the potential benefits of the MIND diet for cognitive health. Evidence from epidemiological research consistently suggests a positive correlation between adherence to the MIND diet and improved cognitive performance. Numerous studies demonstrate a potential preventive effect against cognitive decline and highlight the significance of dietary habits in promoting cognitive well-being.

However, the review also underscores the complexities and challenges of studying dietary interventions and cognitive health. Mixed findings, variations in study methodologies, and potential biases necessitate cautious interpretation of the results. Observational studies' limitations, including recall bias and confounding factors, warrant consideration when evaluating the impact of the MIND diet on cognitive decline.

Abbreviations

MIND diet	Mediterranean-DASH Diet Intervention for Neurodegenerative Delay
AD	Alzheimer's disease
DASH	Mediterranean and Dietary Approaches to Stop Hypertension
ROS	Reactive oxygen species
BGM	Brain–gut microbiota system
MRI	Magnetic resonance imaging
MCI	Mild cognitive impairment
BDNF	Brain-derived neurotrophic factor
FFQ	Food Frequency Questionnaire

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Author contributions

NA conceptualised the study. All authors were involved in the literature review. MA and NA extracted the data from the reviews studies. All authors wrote the final and first drafts. All authors read and approved the final manuscript.

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Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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