Nutrition's impact on brain aging: A Comprehensive Review of Cognitive and Emotional Outcomes

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Abstract

Purpose: Aging is characterized by a progressive decline in physiological functions, including those of the brain. As individuals age, cognitive and emotional functionalities are subject to change, Consequently, it is essential to consider both cognitive abilities and emotional functioning when examining the effects of aging on the brain.

Objectives: The objective is to synthesize current scientific evidence on the relationship between nutrition and brain aging, with a specific focus on cognitive abilities as a measure of brain function.

Methodology: A systematic review was conducted on nine studies. The PRISMA statement standards were adhered to in this systematic review.

Findings: The findings showed how important it is for people to change their diets to prevent the onset and progression of various comorbidities and to encourage healthy aging. The findings of the study included in this Comprehensive review indicate that good aging and a higher quality of life may be achieved by abstaining from bad behaviors, particularly those related to food.

Conclusions: The current body of study indicates a relationship between nutrition and brain aging, but additional studies are necessary to expand our understanding of these complex interactions and to develop clear dietary recommendations to support cognitive health across the lifespan.

Keywords: Brain Aging, Cognitive Abilities, Nutrition, Systematic Review.

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تأثير التغذية على شيخوخة الدماغ: مراجعة شاملة للنتائج المعرفية والعاطفية

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ملخص

الغرض: تتميز الشيخوخة بالانخفاض التدريجي في الوظائف الفسيولوجية، بما في ذلك وظائف الدماغ. مع تقدم الأفراد في العمر، تخضع الوظائف المعرفية والعاطفية للتغيير، وبالتالي، من الضروري مراعاة القدرات المعرفية والأداء العاطفي عند دراسة آثار الشيخوخة على الدماغ.

الأهداف: الهدف هو تجميع الأدلة العلمية الحالية حول العلاقة بين التغذية وشيخوخة الدماغ، مع التركيز بشكل خاص على القدرات المعرفية كمقياس لوظيفة الدماغ.

المنهجية: أجريت مراجعة منهجية على تسع دراسات. تم الالتزام بمعايير بيان PRISMA في هذه المراجعة المنهجية .

النتائج: أظهرت النتائج مدى أهمية تغيير نظامهم الغذائي للأشخاص لمنع ظهور وتطور الأمراض المصاحبة المختلفة ولتشجيع الشيخوخة الصحية. تشير نتائج الدراسة المتضمنة في هذه المراجعة الشاملة إلى أن الشيخوخة الجيدة ونوعية حياة أعلى يمكن تحقيقها من خلال الامتناع عن السلوكيات السيئة، خاصة تلك المتعلقة بالطعام.

الاستنتاجات: تشير مجموعة الدراسة الحالية إلى وجود علاقة بين التغذية وشيخوخة الدماغ، ولكن من الضروري إجراء دراسات إضافية لتوسيع فهمنا لهذه التفاعلات المعقدة ووضع توصيات غذائية واضحة لدعم الصحة المعرفية طوال العمر.

الكلمات المفتاحية: شيخوخة الدماغ، القدرات المعرفية، التغذية، المراجعة المنهجية.

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Introduction:

The aging process is multifaceted, affecting the human organism on both physiological and psychological levels. As individuals age, cognitive and emotional functionalities are subject to change, often leading to a decline in memory, executive function, processing speed, and emotional regulation(Baranowski, Marko, Fenech, Yang, & MacPherson, 2020; Grosso, 2020). The intricate interplay between cognitive and emotional aspects of brain aging is crucial for understanding overall brain health and developing strategies to maintain mental well-being in older adults (Vauzour et al., 2017).

The natural biological process of aging is marked by a slow deterioration of physiological processes, including those of the brain. As the world's population ages, there is growing interest in understanding the factors that contribute to cognitive decline and neurodegenerative diseases associated with aging. Among these factors, nutrition has garnered significant attention due to its modifiable nature and potential to influence brain health(Baranowski et al., 2020; Bowtell, Aboo-Bakkar, Conway, Adlam, & Fulford, 2017; Chen et al., 2023; Grosso, 2020; Terock et al., 2022).

Aging is linked to functional and structural changes in the brain, including synaptic loss, neuronal death, and alterations in neurotransmitter systems(Melzer, Manosso, Gil-Mohapel, & Brocardo, 2021; Vauzour et al., 2017). These changes are thought to contribute to the observed deterioration in cognitive functions like executive function, memory, and attention (Baranowski et al., 2020; Currenti et al., 2021; Grosso, 2020) The quality of life and independence of an individual can be greatly impacted by cognitive deterioration, thus understanding the underlying mechanisms and identifying potential interventions is of paramount importance (Chen et al., 2023).

The role of nutrition in brain health has been a subject of research for several decades. Studies have indicated that certain nutrients and dietary patterns can influence neural plasticity, oxidative stress, inflammation, and other cellular processes that are critical for maintaining cognitive function(Bowtell et al., 2017; Currenti et al., 2021; Li et al., 2022; Solfrizzi et al., 2017). For instance, omega-3 fatty acids, vitamins, antioxidants, and minerals have been associated with a reduced risk of cognitive decline and dementia (Melzer et al., 2021). Furthermore, Vitamin D deficiency may contribute to accelerated brain aging, and vitamin D may have neuroprotective effects, potentially influencing brain volume in areas other than the hippocampus as suggested by(Terock et al., 2022).

Epidemiological studies have provided insights into the relationship between dietary habits as well as the chance of dementia and cognitive decline. Large-scale cohort studies have found associations between Mediterranean and DASH diet adherence and slower rates of cognitive decline(Chen et al., 2023; Vauzour et al., 2017). These dietary patterns are rich in fruits, whole grains, vegetables, and fish, suggesting a potential protective effect of these foods or their constituents against brain aging.

Multiple mechanisms have been proposed to explain how nutrition could impact cognitive function during aging. These include modulation of inflammation, oxidative stress, mitochondrial function, and the integrity of cell membranes(Enderami, Zarghami, & Darvishi-Khezri, 2018; Wang et al., 2020). For example, Certain foods have anti-inflammatory and antioxidant qualities that may assist in maintaining neuronal integrity and function, reducing the effects of aging on cognitive loss. (Baranowski et al., 2020; Melzer et al., 2021; Vauzour et al., 2017).

Randomized controlled trials (RCTs) have investigated the impacts of nutritional interventions on cognitive outcomes in older adults. Supplementation with specific nutrients such as B vitamins, vitamin D, and polyphenols has shown varying degrees of efficacy in improving cognitive performance or slowing its decline in older populations(Bowtell et al., 2017; Melzer et al., 2021).

Neuroscientific research has revealed that cognitive and emotional processes are interconnected, with brain regions such as the prefrontal cortex and the amygdala playing pivotal roles in both domains(Kunugi, 2023; Polokowski, Shakil, Carmichael, & Reigada, 2020). Consequently, it is essential to consider both cognitive abilities and emotional functioning when examining the effects of aging on the brain. The impact of nutrition on these aspects of brain aging has garnered significant attention, as dietary patterns and specific nutrients may have the potential to influence not only cognitive performance but also emotional well-being(Alwerdt & Small, 2017; Johnson et al., 2020; Polokowski et al., 2020).

Recent research has started to explore the relationship between dietary patterns, like emotional health outcomes, and the Mediterranean diet in the aging population. These studies have suggested that adherence to such diets, whole grains, omega-3 fatty acids, rich in fruits, and vegetables, may confer protective effects against the development of depression, anxiety, and other emotional disorders(Melzer et al., 2021; Moore et al., 2017). However, the mechanisms underlying the influence of nutrition on emotional brain aging remain an area of active investigation.

Moreover, the bidirectional relationship between cognitive and emotional functions suggests that nutrients that benefit cognitive health, such as B vitamins, antioxidants, and polyunsaturated fatty acids, may also have implications for emotional well-being(Froud, Murphy, Cribb, Ng, & Sarris, 2019). For example, it has been demonstrated that omega-3 fatty acids contribute to neuroprotection and neuroplasticity, which could potentially enhance both cognitive functions and emotional regulation(Polokowski et al., 2020).

Significant public health problems include brain aging and cognitive decline, particularly in light of the worldwide trend of aging populations. It is essential to comprehend modifiable elements, such as diet, that might impact brain health to establish treatments and preventative measures. This issue encourages interdisciplinary study and collaboration since it crosses several disciplines, including psychology, nutrition, gerontology, and neuroscience. Knowing how to avoid age-related cognitive decline and neurodegenerative disorders through diet might have a big financial impact, as these conditions are linked to growing healthcare expenditures. The review's objective is to compile the most recent data, which is important considering the intricate and even contradicting conclusions in the various research on this subject. Studies from a variety of nations are included in the study, underscoring the topic's worldwide significance and the possibility for cross-cultural understanding.

Scientific significance

The review adds to the body of knowledge by synthesizing the most recent research on the connection between diet and brain aging. It offers a comprehensive viewpoint that is sometimes ignored in evaluations of this kind by addressing both the cognitive and affective components of brain aging. The results may influence dietary guidelines for preserving cognitive function over the long term. With this information, customised dietary therapies to promote healthy aging of the brain might be developed. Sustaining cognitive function as one age is essential for independence and quality of life. This study advances our knowledge of how diet can help achieve this objective. Furthermore, by comprehending the relationship between nutrition and brain aging, individualised dietary recommendations based on personal risk factors may be developed. This review adds to the expanding body of knowledge and suggests topics for further investigation.

In summary, this review's subject is current and very significant. It tackles a crucial public health issue having broad ramifications for people's health, healthcare systems, and society at large. This information is especially relevant since it may be used to create useful dietary guidelines. The review might, however, make a stronger argument for its significance if it went into greater detail about these wider ramifications and the necessity of comprehending nutrition's involvement in brain aging in light of present demographic trends.

The objective of the Systematic Review

Given the complexity of the topic and the abundance of individual studies, a systematic review is needed to offer a thorough and critical assessment of the available data. The objective of this comprehensive review is to synthesize current scientific evidence on the relationship between nutrition and brain aging, with a specific focus on cognitive abilities as a measure of brain function. Furthermore, the study aims to measure the impact of nutrition on brain aging by examining the relationship between nutritional factors and cognitive abilities in older people. This review aims to identify consistent patterns, highlight potential mechanisms, and provide recommendations for future research directions.

The Preferred Reporting Items for PRISMA criteria were followed in this systematic review, ensuring a rigorous and transparent methodology(Moher et al., 2015). A thorough search strategy was used to find pertinent papers in databases including Web of Science, PubMed, and Scopus. Selection criteria will include peer-reviewed studies published from 2017 onwards that study the relationship between nutrition and cognitive abilities in aging adults.

In conclusion, the relationship between nutrition and brain aging is a field of significant interest with profound implications for public health. As cognitive decline poses a major challenge to an aging society, understanding the role of dietary factors in brain health could lead to the development of effective strategies to maintain cognitive function and improve the quality of life for older adults. This systematic review will critically assess the current state of research, identify gaps in knowledge, and suggest areas for future investigation.

Methodology:

The PRISMA statement standards were adhered to in this systematic review, filed under the registration number [CRD42023462257] inside the global database PROSPERO. Figure 1 shows the studies that the protocol was used to choose for review.

Study design:

Ovid) database, Scopus, and the IUGM Research Center. Only published comprehensive reviews were included in the search, and only those written in English were acceptable. By employing Boolean indicators, the search strategy integrated keywords and heading terms related to the population (humans, men, and women), the outcomes (brain aging, cognitive abilities, emotional state), the intervention (nutrition, diet), and the type of study (systematic review). The studies were limited to those released during the previous seven years.

The systematic reviews used the following search strategy:

- Ovid Med: "brain aging" AND "nutrition" AND "cognitive abilities and emotional" AND " brain food" AND "brain age." Limiters: people, English language, and publication date range (last seven years) utilizing Subject Heading.
- Scopus: "brain food" AND "brain age" AND "nutrition" AND "nutritional profile". Limiters: people, English-language-reviewed articles, and the time frame for publications (last seven years).

Google Scholar: "brain aging" AND "nutrition" AND "cognitive abilities and emotional" AND "brain age". Limiters: people, peer-reviewed articles, and the time frame for publications (last seven A comprehensive assessment of the literature was performed using the Medline (years).

Study Selection Criterion:

The selection of the research to be included was done using the available databases. Duplicate entries were not included. After determining if a study was eligible based on titles and abstracts, full-text publications underwent evaluation, and studies' titles and abstracts were examined, followed by a review of the full text to determine the eligibility.

A few categories of research and case studies were left out of the review. Excluded from consideration were studies with participants younger than 20 years of age, as were studies that did not focus primarily on brain aging. Furthermore, the analysis did not include research that excluded dietary therapies from their study's interventions. Publications of other kinds, including case reports, editorials, letters, and conference abstracts, were not included.

Inclusion criteria:

The documents included in the selection were: (1) conducted in the over-18-year-old population, including both men and women; (2) published in the years 2017–2023; (3) written in English; (4) full text available; and (5) comprehensive reviews, and randomized clinical trials. These studies investigated the effect of nutrition on brain aging.

Data Selection:

Several variable characteristics, such as author, publication year, publication type, significant results, and conclusions, were included in the data retrieved from the chosen publications. The title and abstract of each qualifying article were carefully considered in selecting them. Nine studies were chosen for this systematic review's initial iteration. These publications were listed in the database's studies' bibliography, even though they did not show up in the selected set of keywords.

Exclusion criteria:

The following categories of study were excluded from consideration: (1) those that did not include human subjects; and (2) those that had nothing to do with the subject matter of the study, such as studies on pharmaceutical interventions or others: 3) articles that are redundant or that report on the same cohort (those with a smaller sample size or shorter follow-up period were removed); 4) unrelated to brain aging or nutrition; and 5) aging outcomes evaluated in individuals under the age of sixty.

The PubMed-MEDLINE database yielded 8023 citations as part of the search strategy; the relevant articles were carefully selected based on the abstract and title. Following a screening process based on the abstract, 725 of the 936 papers that were initially based on the title were analysed. After analysing the entire texts of these 725 papers, 10 were judged appropriate for inclusion in the present review (Figure 1).

Figure 1. A flowchart illustrates the steps involved in choosing the literature for the entire study.

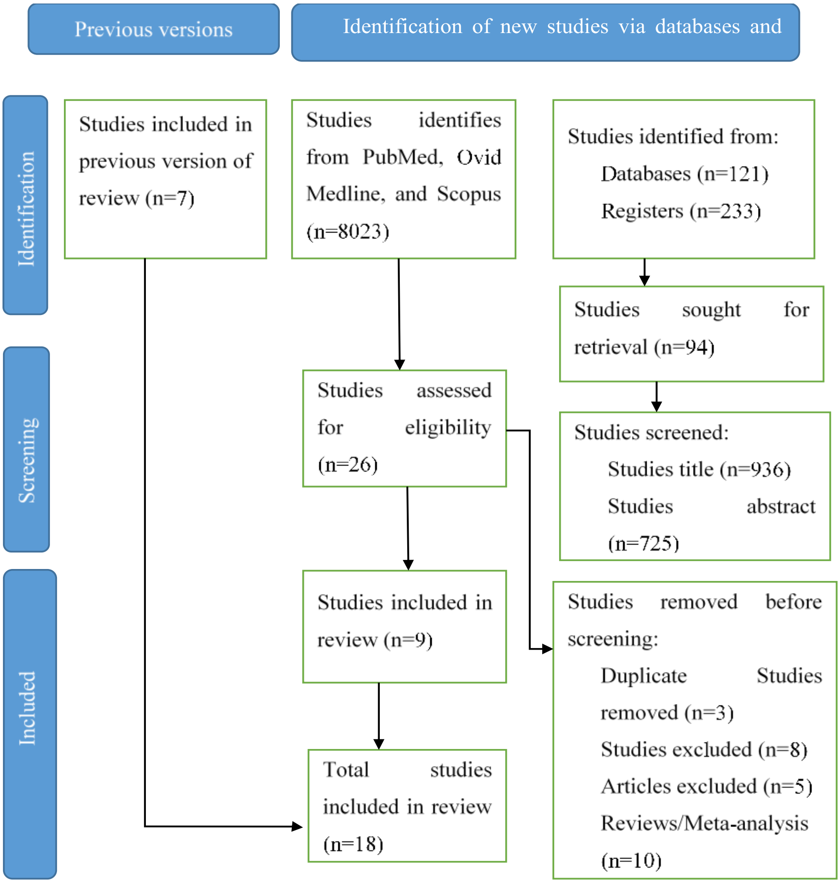

Figure 1. Flow chart of the literature search to retrieve the total number of studies for systematic reviews.

Findings:

The study features of the included papers are given in Table (1) The study design, nation, location, and sample size are all shown in this table based on information found in the included papers.

Table (1) Summary of characteristics of studies.

Authors	Setting	Country	Study Design	Sample Size	Participants Characteristics
Jan, Terock et al., 2022	Hospital	West Pomerania, Germany	a broad cohort study based on the population	1865 (adults)	age 20-82 years gender (51.2%) women
Alonso-Pedrero et al., 2020	Academical Medical Center	Spain	Prospective Cohort Study (PCS)	886 (adults)	Age 57–91 years Gender (645 men and 241 women)
Joanna, Bowtell et al, 2017	Hospital	New Haven, Conn., USA	Experimental protocol	26 (adults)	age 65-70 years gender (14 female, 12 meals)
Fortin, A. et al., 2018	University Hospital	Canada	Randomized Trial (RT)	28 (Adults)	Age 18–65 years Gender (57% men)
Walter Currenti et al, 2020	Academical Medical Center	The southern Italian city of Catania	observational study	916 (adults)	aged 50 or more years old (men and women)
Chou, Yi-Chun, et al., 2019	University Hospital	Taiwan	A prospective cohort study	436 (adults)	Age ≥ 65 years Gender (53% women)
Mujica-Parodi. et al., 2020	Academical Medical Center	USA	Cohort study	42 (adults)	Age 18–88 years Gender (52.4% women)
Amy, Froud, et al, 2017	Academical Medical Center	Victoria, Australia	Experimental design	There were 187 individuals with severe depressive illness and 55 healthy, non-depressed controls	Aged 18–75 years
Neth, Bryan et al., 2020	Academical Medical Center	USA	Cross-over study	20 (Adults)	Age 50–80 years Gender (75% women)

Based on the table provided, the study designs mentioned are General population-based cohort study, Prospective Cohort Study (PCS), Experimental protocol, Randomized Trial (RT), Observational study, Cohort study, Experimental design, and Cross-over study.

Cohort Studies: (Alonso-Pedrero et al., 2020), (Jan, Terock, et al., 2022) and Chou, (Yi-Chun, et al., 2019) both conducted prospective longitudinal cohort studies, observational studies where participants are followed over time to assess the outcomes after exposure to certain risk factors or interventions. In these studies, the researchers did not manipulate the exposure level but rather observed the natural occurrences within the population. (Mujica-Parodi et al., 2020) also conducted a cohort study, but the details provided do not specify whether it was prospective or retrospective. Cohort studies like these are valuable for identifying temporal relationships between exposures and outcomes.

Randomized Trials: (Fortin, A. et al., 2018) carried out a randomized experiment, which is an interventional study where participants are randomly assigned to different groups to compare the effects of a specific treatment or intervention. Randomized trials are considered the gold standard for determining causality because they control for confounding variables through randomization.

Cross-over Studies: (Neth, Bryan, et al., 2020) used a cross-over study design. A cross-over study involves two or more treatments given consecutively to the same group of participants. This design allows each participant to serve as their control, which can increase the efficiency of the study and reduce the effects of confounding variables.

Experimental Protocols: (Joanna, Bowtell, et al., 2017) and Amy, Froud, et al. (2017) conducted studies with experimental protocols, where participants were likely exposed to controlled conditions or interventions. The outcomes were then measured to determine the effects of the intervention.

Observational Studies: (Walter Currenti et al., 2020) conducted an observational study, this is a kind of research in which participants are observed and relevant variables are measured without the participants receiving any treatments. Observational studies are useful for generating hypotheses that can be tested in more rigorous experimental settings.

From Table No. 1, cohort studies (including both general population-based and prospective) appear to be the most frequently used design, with a total of four studies following this approach. Cohort studies are a popular choice in epidemiological and public health research because they can provide valuable information about the associations between exposures and outcomes over time. Each of the other study designs (experimental protocol, randomized trial, observational study, experimental design, and cross-over study) is represented by one study each in this sample. This variety of study designs reflects the diverse approaches researchers take to answer different research questions in the field of nutrition and its impact on health, particularly brain health and aging.

The studies listed were conducted in various countries across North America, Europe, Asia, and Australia, and demonstrate global interest in the relationship between aging, cognitive health, and diet. None of the listed studies were conducted in Middle Eastern countries. This absence is noteworthy as the inclusion of diverse geographical locations, including the Middle East, can provide more comprehensive data that accounts for regional dietary patterns, genetic backgrounds, and lifestyle factors that may influence health outcomes. The lack of representation from the Middle East highlights a gap in the research that could be addressed in future studies to ensure findings are culturally relevant and applicable to populations in that region. It is essential to have a diverse range of study locations to generalize the research findings and to understand the potential variations in how diet and lifestyle factors affect brain aging and cognitive health across different cultures and environments.

Regarding sample size, the average sample size across all studies is approximately 495 participants. Regarding the inclusion of female and male participants in the studies, not all studies provided a clear breakdown of the number of males versus females. However, the studies tend to include both genders, with some studies having a higher representation of one gender over the other. The average percentages of women in the studies where the gender distribution is provided indicate a relatively balanced inclusion of both genders, with a slight leaning towards a higher representation of women in some cases.

The settings of the listed studies are primarily hospital environments, academic medical centers, and university hospitals. These settings are typical for clinical and observational studies in the health sciences. Hospitals provide access to a wide range of medical equipment and expertise, making it easier to conduct comprehensive health assessments and interventions. It also has a diverse patient population, which can enhance the generalizability of the findings. However, the hospital environment can be less controlled than in a dedicated research facility.

Academic medical centers are often affiliated with universities, which can facilitate access to a multidisciplinary team of researchers and a variety of resources for conducting high-quality studies. It may also be more focused on research outcomes and have populations that are more representative of the general public than hospital patients. Despite the potential for a diverse participant pool, the individuals who choose to participate in studies at academic centers may still be a self-selecting group, potentially introducing selection bias. The settings may also be more urban, which might not reflect rural or other specific populations. Likewise, university hospitals have the advantage of being hubs for research and education, often with state-of-the-art facilities. It can provide a suitable environment for controlled clinical trials and other rigorous study designs. University hospitals may still encounter the issue of not accurately representing the wider population, particularly if they serve a specific geographic area or demographic. There is also the possibility that participants may have a higher health literacy level, which could skew results.

One limitation across all these settings is the potential for selection bias, as participants who attend hospitals or academic medical centers for studies may academic not be representative of the general population in terms of health status, socioeconomic status, and other factors. Moreover, these studies often take place in urban or academic environments, which may not capture the diverse experiences and health behaviors of individuals in more rural or less accessible regions. The outcomes are described in Table 2.

Table (2) Summary of results of relevant studies.

Authors	Data Collection Procedure	Study Outcomes
Jan Terock et al., 2022	From the local population registration data, adults were randomly chosen to create a two-stage stratified cluster sample. All images were obtained using the same 1.5 T Siemens MRI scanner (Magnetom Avanto, Siemens Healthineers, Erlangen, Germany) using a T1-weighted magnetisation prepared rapid acquisition gradient echo (MPRAGE) sequence. In addition to brain age, we also considered the volumes of the left and right hippocampus, the overall volume of the brain, and the amount of grey matter. In every model, the intracranial volume was controlled. Brain age was calculated using gender-stratified ordinary least squares regression, where the dependent variable was chronological age and the independent variables were the volumes of the 169 brain regions.	It was demonstrated that neuroimaging patterns of advanced brain aging were associated with vitamin D deficiency using data from a large general population sample. Furthermore, the results demonstrated a favorable relationship between vitamin D levels and the hippocampal, grey matter, and total brain sizes. Only older individuals show effects of blood vitamin D levels on brain measurements, according to an age-stratified study.
Alonso-Pedrero et al., 2020	Telomere length (TL) was measured from saliva samples, and data on the intake of ultra-processed foods (UPF) was collected using a validated 136-item food frequency questionnaire (FFQ). The association between the probability of having short telomeres and the intake of energy-adjusted UPF was examined using logistic regression models.	Higher odds of short TL were associated with higher UPF consumption (>3 servings/d) in an elderly Spanish population included in the SUN cohort. Those who ingested the highest amounts of UPF had approximately double the chance of developing short telomeres compared to those who consumed the lowest amounts. Those in the fourth quartile (>3 servings/d) of UPF consumption were shown to be more likely to have a family history of diabetes, dyslipidemia, and CVD, as well as to snack more often between meals than those in the first quartile (<2 servings/d). There was a decline in adherence to the Mediterranean diet that coincided with the increase in UPF consumption.

Authors	Data Collection Procedure	Study Outcomes
Joanna L Bowtell et al, 2017	Five distinct cognitive domains are measured by the ACE-III: language, verbal fluency, attention, memory, and visuospatial abilities. To ensure that the questionnaires were suitable for the study, safety screening questions for magnetic resonance imaging (MRI) were used. Cognitive impairment, age under 65, MRI contraindications, and consuming more than five servings of fruit each day were the exclusion criteria. ACE-III scores alone did not result in any competitors being eliminated. Participants were partnered and randomly allocated to a group based on their ACE-III score. Measurements were taken both before and after a 12-week course of either Blueberry Active (CherryActive Ltd., Sunbury, UK) or an isoenergetic placebo supplement. The present study's battery of CogState Ltd. tests, which assessed a range of cognitive domains, took roughly thirty-five minutes to complete.	Long-term use of blueberry concentrate supplements, which provide 387 mg of anthocyanins daily, has been shown to improve cognitive and cerebrovascular function in healthy older adults. In all cases, there was a considerable drop in serum glutathione levels, with the blueberry condition generally showing a smaller decline. The percentage change in performance of the 2-back tests showed a little improvement in the blueberry compared to the placebo groups. The blueberry supplement and placebo groups did not significantly vary in their performance on the other cognitive function measures.
Fortin, A. et al., 2018	After being randomly assigned to one of two intervention groups, participants followed the MedDiet or the low-fat diet for six months. Anthropometric (waist circumference, WC), metabolic, and nutritional studies were performed at inclusion, three months, and six months.	This study suggests that a non-restrictive 6-month dietary intervention may assist persons with T1D and MS regulate their weight without significant changes in anthropometric and metabolic indicators. Overall dietary fat consumption was shown to be lower in the low-fat diet group (P-interaction = 0.09). Body mass index decreased significantly in both groups (−1.1 kg/m2 MED-diet; P-interaction = 0.56) and −0.7 kg/m2 low-fat. There were no significant differences seen in any metabolic marker between the groups.
Walter Currenti et al, 2020	Electronic data was collected using tablet computers and in-person conversations with participants. Data on the patient's condition was also obtained, including anthropometric measurements made by standard procedures, history of existing cardiometabolic diseases, and cancer. To gauge dietary intake, two versions of the Food Frequency Questionnaire (FFQ—a long and a short version—were employed. The cognitive state was evaluated using the Short Portable Mental State Questionnaire (SPMSQ), which was designed to evaluate cognitive impairment in both the general and hospital populations.	Of the eighty-two individuals with cognitive impairment, four indicated significant impairment, whereas the remainder reported mild impairment. Shows that individuals with TRF were less likely to experience cognitive impairment than those without eating time restrictions [odds ratio (OR) = 0.28; 95% confidence intervals (CI): 0.07–0.90]; individuals who ate breakfast but not dinner (OR = 0.37, 95% CI: 0.16–0.89) showed a similar relationship. Individuals who ate evening ingested more calories, carbohydrates, fiber, polyunsaturated fats (PUFA), vitamin C, vitamin E, salt, fish, and vitamin D, whereas those who ate breakfast consumed less total meat, nuts, dairy products, and legumes.

Authors	Data Collection Procedure	Study Outcomes
Chou, Yi-Chun, et al., 2019	Diet quality was assessed using the modified Alternative Healthy Eating Index (mAHEI), which was calculated using a 44-item FFQ at baseline. Vegetable variety was estimated using the diet diversity score (DDS). The Montreal Cognitive Assessment—Taiwanese version (MoCA-T) was used to test global cognition, while the Wechsler Memory Scale—Third Edition (WMS-III) was used to measure domain-specific cognition, or the logical memory and attention domains.	The findings show that good diet quality was associated with a decreased probability of overall cognitive decline (adjusted odds ratio (AOR) = 0.54, confidence interval (CI) = 0.31–0.95) and loss in the attention domain (AOR = 0.56, CI = 0.32–0.99) as compared to poor diet quality. In older persons with high vegetable diversity, a high-quality diet was associated with a lower risk of global cognitive impairment (AOR = 0.49, CI = 0.26–0.95). Indicated that a high-quality diet and a diverse vegetable intake were associated with a lower prevalence of cognitive decline in older adults.
Mujica-Parodi. et al., 2020	Magnetic resonance imaging (MRI) data collection and processing; motor activity and spatial navigation; metabolic neuroimaging datasets; and functional magnetic resonance imaging (fMRI).	The findings show that brain network destabilisation may represent early signs of hypometabolism, which is associated with dementia. Dietary supplements that produce ketones increase energy availability, possibly protecting the aging brain. Lower ($p < 0.001$) destabilisation of the brain network (DBN), greater ($p < 0.001$) amplitude of low-frequency fluctuations (ALFF), age-related decline in cognitive acuity ($p < 0.001$), an inverse association between ALFF and network switching ($p < 0.001$).
Amy Froud et al, 2017	Research staff with training in clinical assessment conducted all measures. The MADRS score was the primary result for the depression assessment. The HAM-A was used to measure anxiety levels. (MINI 6.0) was utilised to evaluate individuals for further mental disorders. The Short Form Survey-12 was used to evaluate the participants' general well-being and quality of life in connection to their health (SF-12). Dietary intake was measured with the DQES v2. Participants were referred to Australian Clinical Laboratories (ACL) for a blood test after their initial screening visit, which necessitated an eight- to fifteen-hour fast. Peripheral blood was extracted into a serum separator tube and sent to the ACL Melbourne laboratory on the day of collection. Following that, the serum was divided into tubes and labeled with the ID of the individual. After that, it was maintained at -20 degrees Celsius until the serum BDNF was ready to be analysed.	The sociodemographic features of the depressed cohort and the healthy control group did not alter significantly. There were notable variations in the mean MADRS ($P < 0.001$) and HAM-A ($P < 0.001$) scores between the two groups. The moderately depressed participants were indicated by a mean MADRS score of 24.67. The only significant difference in general health was seen in the perceived health score of the SF-12 survey; the depressed cohort scored higher (M = 2.04, SD =.97) than the control group (M = 0.98, SD =.69). A t-test revealed that the mean ADQS of the depressed cohort (n = 141) was 13.25 (±2.28), significantly lower than the mean score of 14.15 ± 2.40 for the control group. Was found to be a highly consistent predictor of blood BDNF levels. Furthermore, a significant link was demonstrated between a lower ADQS and a larger level of depression severity (total MADRS score) using an ANOVA that took age, gender, and body mass index into consideration. Additionally, there was no significant link seen in the medication-free group's ANOVA between blood BDNF levels and genotype.

Authors	Data Collection Procedure	Study Outcomes
Neth, Bryan J. et al., 2020	For six weeks, the participants were randomly assigned to either the modified Mediterranean-ketogenic diet (MMKD) or the American Heart Association Diet (AHAD). Before and after each diet randomisation, baseline cognitive state, lumbar puncture (LP), MRI, and metabolic profiles were recorded.	MMKD was associated with higher Aβ42 and decreased tau in the cerebrospinal fluid. The results suggest that a ketogenic strategy may help prevent cognitive decline in those who are at risk of Alzheimer's disease. MMKD may help prevent cognitive decline in individuals at risk of Alzheimer's disease (AD) by improving cerebral spinal fluid (CSF) AD biomarker profile, peripheral lipid and glucose metabolism, cerebral perfusion, and cerebral ketone body absorption.MMKD: decreased triglycerides and very low-density lipoprotein cholesterol (VLDL-C) levels; increased CSF Aβ42 and decreased tau levels in the mild cognitive impairment (MCI) group; AHAD: decreased tau levels in the MCI group; increased cerebral perfusion and cerebral ketone body uptake (11C-acetoacetate), primarily in the subjective memory complaints (SMC) group.

As stated in our primary objective, the evaluation of the nutritional state was the focus of every study. Some studies examined telomere length in addition to nutritional status, whereas others assessed the role of nutritional condition in cognitive impairment. In Table 2, the principal molecular findings are explained.

To sum up, according to table no. 2, data collection methods and tools used in the studies mentioned, focusing on brain aging and related criteria were: first, the MRI (Magnetic Resonance Imaging) for evaluating the brain volumes and structure with consideration of gender-stratified ordinary least square (Jan Terock et al., 2022), MRI safety screening question (Joanna L Bowtell et al., 2017), and functional MRI to assess brain networks stability. The second was Cognitive Assessments including Addenbrooke's Cognitive Examination III (ACE-III) evaluated various cognitive domains, along with a battery of cognitive tests from CogState Ltd. (Jonna et al., 2017). The Short Portable Mental State Questionnaire (SPMSQ) was utilized to detect cognitive impairment (Walter et al., 2020). The Montreal Cognitive Assessment—Taiwanese version (MoCA-T) and the Wechsler Memory Scale—Third Edition (WMS-III) were used to assess global and domain-specific cognitive functions (Chou, 2019). Moreover, some studies used the Telomere length index as an indicator for aging (Alonso-Pedro, 2020) and clinical evaluations (Amy, 2017). In summary, MRI and cognitive assessments were the primary tools used for data collection related to brain aging. The criteria for judging brain aging included both structural and functional brain changes, as well as performance on cognitive tests and biological aging markers. For dietary intake measuring the main tool was the questionnaire to measure the consumption of processed food, modified index, and food frequency.

According to studies outcomes, the studies collectively provide empirical evidence suggesting that nutrition does have an impact on brain aging and cognitive health. Several key findings emerge, considering diet quality: Higher diet quality, characterized by increased intake of fruits, and vegetables, and following specific dietary regimens, such as the Mediterranean diet, is linked to improved cognitive function and a decreased risk of cognitive decline, and a higher intake of ultra-processed foods is linked to markers of accelerated aging, such as shorter telomeres. Considering specific nutrients: Vitamin D levels and anthocyanins (found in blueberries) may play roles in maintaining brain health and function. Considering eating patterns: Interventions such as Time-Restricted Feeding may have beneficial effects on cognitive health.

The results showed that Emotional functionality, which encompasses mood regulation, stress response, and the experience of positive and negative emotions, can be as important as cognitive function in determining the standard of living for the elderly. Like cognitive decline, emotional disturbances in the elderly, such as increased susceptibility to stress or a higher prevalence of mood disorders, have been linked to various dietary factors. The consumption of certain foods and nutrients has been associated with changes in brain structure, neurochemistry, and overall mental health, suggesting that diet may play a significant role in emotional resilience and the risk of psychiatric conditions in later life.

These findings align with research findings suggesting that maintaining dietary patterns, as opposed to consuming sufficient amounts of individual food components, might be the most efficient strategy for safeguarding against cognitive decline. Determining the nutritional needs for healthy cognitive aging and converting them into practical dietary recommendations will be a key focus of future studies.

Despite findings, there are challenges in establishing clear cause-and-effect relationships between nutrition and brain aging. These challenges include heterogeneity in study designs, population characteristics, assessment tools, and the multifactorial nature of cognitive decline. Furthermore, the long latency period for the development of cognitive impairment complicates the identification of critical periods for nutritional intervention.

In conclusion, the current body of research indicates a relationship between nutrition and brain aging, but additional studies are necessary to expand our understanding of these complex interactions and to develop clear dietary recommendations to support cognitive health across the lifespan.

Despite these findings, some gaps and limitations should be addressed in future research, such as, but not limited to, the causality: Most of the studies are observational, so they cannot conclusively establish causality between diet and brain aging. Long-Term Effects: To gain a deeper understanding of the long-term effects of nutrition on brain aging, longitudinal studies are necessary. Standardization: There is a lack of standardization in the measures used to assess diet quality and cognitive health, complicating comparisons across studies. Diverse Populations: The studies largely focus on older adults, and more research is needed across different age groups and in diverse populations, including underrepresented regions like the Middle East. Biological Mechanisms: While associations are noted, the underlying biological mechanisms by which diet affects brain aging are not fully understood and warrant further investigation.

This extensive study's conclusion demonstrated how crucial it is for individuals to alter their diets to promote good aging and stop the development of a variety of comorbidities. Antioxidants, vitamins, and potassium can be found in diets that are low in carbohydrates and abundant in fruits, nuts, vegetables, grains, fiber, fish, and unsaturated fats. Furthermore, increasing vegetable intake and ingesting green tea catechins may improve working memory, reduce instability in the brain network, and shield the attention domain from cognitive decline.

Conclusion:

The initial goal of this systematic study was to show how diet and brain aging are related, with an emphasis on cognitive ability as a proxy for brain function. According to the research included in this comprehensive review, giving up unhealthy habits, especially those involving food, can help one age well and have a higher-quality life.

Numerous commonalities were observed across the diets examined in this comprehensive evaluation. Even with the insights this systematic review offers, there is still a lot of material that needs more investigation.

Ultimately, these findings have a major impact on the creation of new nutritional therapies targeting biomarkers associated with aging. This systematic review does, however, have several shortcomings. One of the drawbacks is that, because various diets and biomarkers have varying impacts, it can be challenging to arrange and organize them.

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