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Dietary diversity and cognitive performance in older adults: a systematic review

Sorayya Kheirouri[1,3*] and Hamed Alizadeh[2]

Abstract

Background and objective Promoting dietary diversity (DD), which refers to the variety or the number of different food groups that people eat over the time given, is important for brain health maintenance and may be beneficial for inhibiting neurodegenerative diseases. This research aimed to review the literature and summarize research evidence for achieving an inclusive estimate concerning the relationship between DD and cognitive function in adults.

Methods We systematically queried the databases of PubMed, Web of Science, and Google Scholar, without imposing any date restrictions, up to June 2024 to identify original literature that sheds light on the intricate relationship between DD and cognitive function. Employing rigorous criteria, we meticulously screened studies, eliminating duplicates or those unrelated to our focus. Subsequently, we critically evaluated the findings from the selected studies, descriptively summarizing them. Additionally, we engaged in an in-depth exploration of potential mechanistic pathways linking DD to cognitive performance.

Results Of the 388 citations obtained, 23 articles were included in the final review. All the studies reported a positive association between DD score and cognitive functioning and indicated that higher DD was accompanied by good memory ($n=3$) and lower risk of cognitive decline ($n=19$), dementia ($n=3$), and Alzheimer's disease ($n=1$).

Conclusion The results indicate that sustaining a diverse diet among older people may help maintain cognitive functioning. Dietary diversity represents a promising clinical avenue for mitigating cognitive decline associated with diverse brain disorders, potentially preventing or attenuating deterioration.

Keywords Dietary diversity, Cognitive performance, Memory, Learning, Dementia, Alzheimer's disease

Introduction

Population aging is one of the main challenges of the contemporary world. Based on the World Health Organization estimation, the percentage of the world's older population aged > 60 will increase from 12% in 2015 to 22% in 2050 [1]. Between 2020 and 2050, it is anticipated the number of individuals ≥ 80 years to triple [1]. As age increases, the structure and function of the brain also alter, influencing cognitive performance, learning abilities, and memory. According to scientific research, age-associated alterations in synapses and neuronal networks are associated with age-related cognitive decline [2]. Multiple factors, such as brain ischemia and trauma

*Correspondence:
Sorayya Kheirouri
Kheirouris@tbzmed.ac.ir
[1]Department of Nutrition, Tabriz University of Medical Sciences, Tabriz, Iran
[2]Student Research Committee, Khoy University of Medical Sciences, Khoy, Iran
[3]Department of Nutrition, Faculty of Nutrition and Food Sciences, Tabriz University of Medical Sciences, Attar Nishabouri St., POBOX: 14711, Tabriz 5166614711, Iran

[3, 4]; the incidence of degenerative dementia, including Alzheimer's disease (AD); and high exposure to stress hormones [5] and toxins [6] can independently destroy the brain with age and contribute to cognitive dysfunction. In opposition, choosing an appropriate lifestyle, such as having a healthy and balanced diet [7, 8], regular physical activity [9], and low alcohol intake [10], might increase neuroplasticity and delay neurodegeneration and cognitive decline possibly by diminishing inflammation and oxidative stress [11, 12].

According to Food and Agriculture Organization (FAO) definition, "dietary diversity (DD) is a qualitative measure of food consumption that reflects household access to a variety of foods, and is also a proxy for nutrient adequacy of the diet of individuals" [13]. Dietary diversity addresses the count of various foods or food groups consumed in a defined period. For household DD, the potential score range is 0–12 and for Women's DD is 0–9, a higher score reflects a more diverse diet [13]. Adherence to higher DD is associated with numerous favorable health outcomes. According to cross-sectional studies, having a high DD reduces the risk of cardiovascular diseases, hypertension, and diabetes mellitus among community-dwelling older people [14] and depression [15] and increases mental health [16].

Scientific evidence suggests that diverse diets can be beneficial for brain health and may preserve cognitive performance. A direct link has been documented between high DD and healthy aging in aged individuals [17]. A monotonous diet and insufficient nutrient intake may be related to cognitive dysfunction [18, 19]. Several studies have evaluated the association between DD and cognitive performance [20, 21]. Given that systematic reviews on specific nutrients or dietary patterns and cognitive function exist, to our knowledge, there is no comprehensive report focusing on measuring dietary diversity and cognitive performance. The research question was: Is DD associated with cognitive function in older adults? Therefore, this research aimed to systematically review the literature and summarize research evidence for achieving an inclusive estimate concerning the relationship between DD and cognitive function in older adults.

Table 1 Description of the PECO strategy

Population	Older adults
Exposure	Low dietary diversity
Comparator	People with high dietary diversity or healthy subjects (few studies used dietary diversity data as continuous scale and had no comparator)
Outcome	Risk of cognitive impairment, Alzheimer's disease, dementia, or memory loss

Methods

We used the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines to deliver a transparent and systematic report [22]. The Deputy for Research and Technology, Tabriz University of Medical Sciences, Tabriz, Iran, registered and approved the protocol of this study, prospectively (IR.TBZMED.VCR.REC.1403.058) (file:///C:/Users/Admin/Downloads/ba1sa8sdh3y4c1bh.pdf).

Search strategy

An advanced search was performed in PubMed, Web of Science, and Google Scholar databases until June 2024 to identify original published studies investigating the relationship of DD with cognitive performance or AD or dementia or memory loss. A systematic evidence search was performed using the following keywords: "cognitive" OR "cognition" OR "dementia" OR "memory" OR "learning" OR "Alzheimer's disease" OR "mental" and "dietary diversity" OR "food variety" OR "diet variety" OR "dietary variety" in title-abstract-keywords. The search had no date constraint. A hand search was conducted in the Google Scholar database up to the twentieth page, besides an advanced search. Supplementary Table 1 presents a comprehensive search strategy. Table 1 provides a PECO approach for this review.

Eligibility criteria

Original investigations on older adults appraising the relationship between DD and cognitive functioning were suitable for inclusion. Only investigations with the English language were addressed in this review. Protocols, chapters, books, reviews, abstracts, and the thesis were exclusion criteria. Articles that studied the association of dietary patterns, quality, habits, and behaviors with cognitive performance were not qualified for inclusion in the current study. Studies on children or adolescents were also excluded. In addition, studies on other neurological diseases, such as Parkinson's and Huntington's diseases, and those on mental health, such as depression, anxiety, and distress, were excluded, because different neurological conditions can have distinct pathologies, progression patterns, and responses to dietary factors, which could confound the results and reduce the specificity of our findings. We also excluded animal studies to ensure that our findings are directly applicable to human populations.

Selection of the studies

We transferred the acquired investigations from the search to an Endnote file and organized them to obliterate replicated evidence. Two investigators rated the studies independently to achieve appropriate articles for this systematic review based on reviewing the title and abstract in the first step, and then full text of the publications (results, tables, or other sections) were reviewed. Although disagreements between two investigators were minimal, however, in the case of different opinions regarding the eligibility of a study, a consensus was gained via discussion or by arbitration of a third independent investigator.

Data extraction

Our analysis encompassed several key variables: the first author's name and publication year, geographical region, study design, subject count, health status of participants, gender distribution, age demographics, follow-up duration in prospective studies, DD assessment method and definitions for "low" vs. "high" DD, food intake evaluation approach, cognitive functioning assessment method and clinical diagnosis (dementia and AD), data analysis techniques, consideration of confounding factors, and the resulting findings regarding global cognitive function, memory loss, risk of AD/dementia.

Evaluation of article quality and bias risk

Two independent reviewers assessed the quality and bias risk of the chosen studies using the Newcastle-Ottawa quality assessment tool [23]. They evaluated cross-sectional and cohort studies on three criteria: the selection of groups with and without exposure, the comparability of these groups, and the outcomes. The studies were classified using a star system into three categories: high, moderate, or low quality. Studies scoring 7 or higher in total were deemed high quality [23].

Results

Selection of studies

In our investigation, we retrieved 388 research studies initially (as depicted in Fig. 1). After eliminating duplicates, 323 studies remained. We identified 51 publications relevant to the study's topic and scope when reviewing titles and abstracts. Subsequent critical appraisal led to the exclusion of 28 studies: 19 were deemed irrelevant, one was a commentary article, and six were duplicates of other included studies, one was in chines, and one assessed the combination effect of DD and traffic-related air pollution on cognitive function. Ultimately, our review included 23 relevant studies (Fig. 1).

Characteristics of the included studies

Most included studies ($n = 18$) were published from 2020 onwards, indicating the topic's novelty (Table 2). All the investigations exclusively focused on adults with a mean age of 50 years or older. Studies were mostly from East Asia ($n = 19$; China ($n = 12$), Taiwan ($n = 3$), and Japan $n = 4$). All studies considered both sexes. Most studies ($n = 15$) used the MMSE tool to assess cognitive functioning, and 19 investigations regarded the role of main confounding factors in their statistical analysis.

Quality assessment of studies

The quality scores for cohort studies ranged between eight and nine, except one, indicating minimal bias (Supplementary Table 2). A significant concern was the ambiguity regarding whether the outcome of interest was present at the beginning of the study.

For the eight cross-sectional studies, quality scores varied from 5 to 8 (Supplementary Table 3). A primary issue identified was the non-response rate among the groups. Notably, none of the studies provided information on the dropout rate. Another issue was not considering confounders such as age, gender, and other covariates in the analysis.

Association between DD score and cognitive performance

As shown in Tables 2 and 19 studies [17, 21, 24–40] investigated the link between DD score and cognitive performance and all found a positive association between DD score and cognitive functioning and indicated that higher DD was accompanied with lower risk of cognitive decline (odds ratios ranged from 0.54 to 0.92).

Chen et al. [24], in a cross-sectional study of 14,318 older people, demonstrated that cognitive impairment, assessed by the MMSE tool, was higher among people with low DD (a score of ≤ 2 from seven food groups derived from FFQ) compared with people with a high DD. Psychological balance mediated the association between DDS and cognitive decline. Chen et al. [25], in a prospective cohort study of 81,847 older individuals, showed that higher DD (a score of 4–7 from seven food groups derived from FFQ) was correlated to reduced probability of cognitive decline, measured by MMSE tool, among older people. The authors found that smoking behavior may adversely affect the association among women. Chen et al. [26], in a prospective cohort study of 1,839 elderly, explored that low DD (a score of ≤ 3 from six food groups derived from 24-hour dietary recall) was associated with cognitive impairment, measured by a short portable mental status questionnaire. Clausen et al. [27], in a household survey of 1085 older subjects, demonstrated a positive association between food variety score (ranged 0–5 food groups derived from 21 food-item FFQ and 24-hour recall) and improved cognitive function measured by the MMSE tool. Hsiao et al. [28], in a cohort study of 3213 community-dwelling adults (aged ≥ 50), showed an inverse dose-response association between the dietary variety score and the risks of cognitive decline. Huang et al. [21], in a cross-sectional study of 1115 older adults, found higher cognitive decline (measured by MMSE tool) in people with low DD (a score of ≤ 4 derived by 24-hour dietary recall and

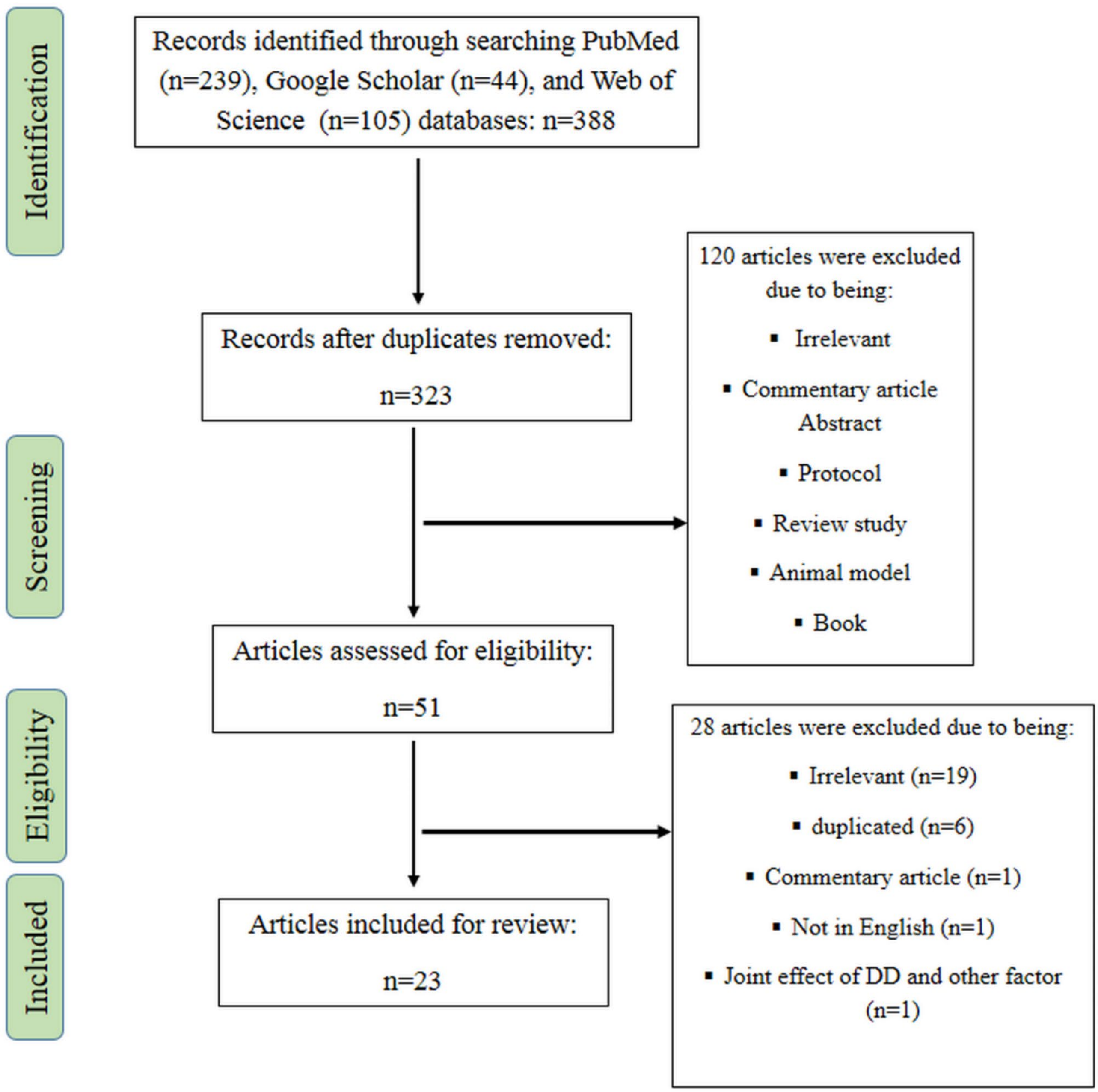

Fig. 1 Flow diagram of the study

79-food item FFQ). Huang et al. [29], in a cohort study of 15,777 older individuals, found a reduced risk of cognitive frailty (assessed by the MMSE tool) in people with high DD, derived by simplified FFQ. Kiuchi et al. [30], in a cross-sectional study of 8987 older adults, revealed a direct association between DD (considering 10 food groups) and reduced mild and global cognitive impairment, assessed by MMSE and national center for geriatrics and gerontology-functional assessment tool. Liu et al. [31], in a prospective cohort study of 9726 older adults, demonstrated a low cognitive impairment incidence rate in people with consistent high DD. Milte et al. [32], in a prospective cohort study of 617 adults (aged 55–65), found improved cognitive function (evaluated by the telephone interview of cognitive status) among people with higher DD, obtained from 111-item FFQ. Otsuka et al. [33], in a cohort study of 298 men and 272 women, showed that each SD increase in DD was accompanied by 21% reduced cognitive decline and participants in the highest quartile of DD were 44% less likely to have cognitive impairment. Song et al. [34], in a prospective study of 6237 older adults, observed an increased risk of cognitive impairment and a faster decline in the MMSE score in participants with low-low and high-low DD score

Table 2 Summary and characteristics of the 25 selectedstudies assessing the relationship between the dietary diversity and cognitive performance

Reference	Country/ Type of study	Population and sex	Age (year)	Follow-up time	Method of DD assessment	Method of food intake assessment	Method of cognitive functioning assessment	Method of correlational analysis	Covariates	Findings
Chen et al. 2024 [24]	China/ Cross-sectional	14,318 older adults (7883 female)	> 65	-	DDS (7 food groups) DDS range: 0–7 Low DDS: ≤ 2 High DDS: 7	FFQ	MMSE Score range: 0–30 Impaired cognition: <24	Chi-square test and binary logistic regression	Psychological balance	Cognitive impairment was higher among people with low DDS ($p < 0.001$). In adjusted model, individuals with a high DDS had lower odds of cognitive decline (OR (95% CI): 0.54 (0.45, 0.65) than those with low DDS. Psychological balance mediated the association between DDS and cognitive decline with a mediating effect of 27.24%.
Chen et al. 2022 [25]	China/ Prospective cohort	81,847 older adults (female: >53%)	Mean: >85	16 years	DDS (7 food groups) Score range: 0–7 Low DDS: 0–3 High DDS: 4–7	FFQ	MMSE Score range: 0–30 Impaired cognition: ≤16 for without schooling ≤ 19 for those with 1–6 years of education ≤ 23 for those with > 6 years of education	Generalized estimation equation	Age, education, income, residence status, region, marital status, self-rated health status, number of family members, exercise	Higher DDS was associated with lower probability of cognitive impairment among older adults [OR (95%CI): 0.92 (0.90, 0.98)]. Smoking behavior may adversely affect the association among women.
Chen et al. 2011 [26]	Taiwan/ Prospective cohort	1,839 elderly (925 male)	≥ 65	10 years	DDS (6 food groups) Score range: 1–6 Low DDS: ≤ 3	24-hour dietary recall	Short Portable Mental Status Questionnaire Score range: 0–10 Intact cognition: 10 Mild impairment: 8–9 Moderate to severe impairment: 0–7	Chi-square test	Not stated	Severe cognitive impairment was associated with low DDS ($p < 0.001$)*. DDS was a predictor of survival in relation to cognitive impairment [HR (95% CI): 0.62 (0.42, 0.90), $p < 0.05$].
Clausen et al. 2005 [27]	Botswana/ Household survey	1085 subjects (both sexes)	≥ 60 (72.2 ± 9.3)	-	Food variety score Score range: 0-112	21 food-item FFQ and 24-hour recall	MMSE Maximum score: 26 Cognitive impairment: 0–15	Chi-square test	Not stated	People with cognitive impairment had low food variety score compared to those with normal cognitive function ($p = 0.026$).

Table 2 (continued)

Reference	Country/ Type of study	Population and sex	Age (year)	Follow-up time	Method of DD assessment	Method of food intake assessment	Method of cognitive functioning assessment	Method of correlational analysis	Covariates	Findings
Dutta et al. 2021 [20]	India/ Cross-sectional	60 dementia patients and 60 controls (both sexes)	≥ 60	-	DDS (seven food groups) Maximum score: 7	24-hour dietary recall	International Classification of Diseases (ICD)-10 criteria. Severity of dementia assessed by MMSE tool.	Comparative	Not stated	The mean values of food variety score, DDS, and dietary serving score were significantly lower in people with dementia as compared with the healthy group.
Hsiao et al. 2022 [28]	Taiwan/ Cohort	3213 community-dwelling adults Males: 52.0%	≥ 50	4 years	Dietary variety score (10 main food) Maximum score: 10 Q1: 1–3 Q5: 8–10	FFQ	Short Portable Mental Status Questionnaire, the Rey Auditory Verbal Learning Test, and the Wechsler Adult Intelligence Scale Score range: 0–22 Low cognitive function < 10	Logistic regression	Demographics factors, health behaviors (e.g., physical activity), and comorbidities	Inverse dose-response association was observed between the dietary variety score and the risks of cognitive decline. The risk reduced with the higher dietary variety score quintile group (Q5) as compared to the lowest dietary variety score quintile group (Q1) [OR (95% CI): 0.76 (0.57, 1.03).
Huang et al. 2021 [21]	Taiwan/ Cross-sectional	1115 adults Both sexes	≥ 65	-	DDS (six food groups) Score rang: from 0 to 6 High DDS: >4 Low DDS: ≤ 4	24 h dietary recall and 79-food item FFQ	MMSE Score range: 0–30 Impaired cognition: ≤ 26	Logistic regression	Age, sex, sampling stratum, education, body mass index, smoking, and general health	Cognitive impairment risk was higher in people with prefrailty or frailty and lower DDS (OR: 2.15, 95% CI: 1.21–3.83).
Huang et al. 2023 [29]	China/ Cohort	15,777 older individuals Females: 53.5%	65–79	6 years	DDS (eight food groups) Score rang: from 0 to 16 Low DDS: ≤6 High DDS: ≥12	Simplified FFQ	MMSE Cognitive impairment: ≤17 for those with an education less than a year, 18–20 for 1–6 years of education, and 21–24 for a period more than 6 years	Cox regression	Age, sex, residence, education level, marital status, living pattern, pension, smoking habits, alcohol consumption, physical activity, BMI, hypertension, diabetes, stroke, and heart disease	Compared to a DDS of "≤6", both a DDS of "9–10" [HR (95% CI): 0.84 (0.75, 0.93)], "11–12" [HR (95% CI): 0.84 (0.75, 0.95)], and "≥12" [HR (95% CI): 0.85 (0.74, 0.98)] were found to associate with a reduced risk of cognitive frailty (P for the trend < 0.05). A 1-point increase in DDS corresponded with a 2% [HR (95% CI): 0.98 (0.96, 0.99)] lower risk of cognitive frailty.

Table 2 (continued)

Reference	Country/ Type of study	Population and sex	Age (year)	Follow-up time	Method of DD assessment	Method of food intake assessment	Method of cognitive functioning assessment	Method of correlational analysis	Covariates	Findings
Kiuchi et al. 2024 [30]	Japan/ Cross-sectional	8987 older adults (44.3% male)	73.9 ± 5.5	-	DDS (10 food groups) Score range: 0–10 High DDS: ≥ 3	1-week consumption frequency of 10 food groups	MMSE and National Center for Geriatrics and Gerontology-Functional Assessment Tool Cognitive impairment: MMSE score < 24	Logistic regression	Not stated	High DDS was associated with reduced MCI [OR (95% CI): 0.83 (0.73–0.94)] and global cognitive impairment [OR (95% CI): 0.77 (0.65–0.92)] after adjusting for covariates.
Kheirouri et al. 2024 [40]	Iran/ Cross-sectional	60 Alzheimer's patients and 29 healthy individuals (51 female)	> 60	-	DDS range: 0 to 17	Three-day food record	MMSE	Linear and binary regression	Age, gender, BMI, and disease duration	The DDS was significantly lower in the AD group than in the healthy group ($p < 0.001$). There was a significant association between DDS with total MMSE score ($\beta = 0.33$, $p = 0.02$), memory ($\beta = 0.35$, $p = 0.02$), and language ($\beta = 0.32$, $p = 0.03$). A high dietary diversity reduced the odds of AD by 79% [OR (95% CI): 0.21 (0.10, 0.42), $p < 0.001$] in a multivariate model.
Liu et al. 2022 [31]	China/ Prospective cohort	9726 older adults Males: 47.8%	≥ 65 (80.0 ± 10.1)	52,325 person-years (12 years)	DDS (nine food groups) Score rang: from 0 to 18 High DDS:13–18 Medium DDS: 7–12 Low DDS: 0–6	FFQ	MMSE Maximum score: 30 Cognitive impairment: 20 points for illiterate, 23 points for participants with 1–6 years of education, 27 points for those with more than 6 years of education	Cox regression	Age, sex, residence, education level, occupation, source of income, current marital status, living pattern, smoking status, alcohol drinking, BMI, physical activity, use of artificial dentures, comorbidities	High-to-high group had the lowest incidence rate of cognitive impairment. Compared to high-to-high overall DDS change patterns, the multivariable adjusted HRs (95%CI) for high-to-medium, medium-to-medium, medium-to-low, low-to-medium and low-to-low DDS change patterns were 1.33 (1.12–1.57), 1.11 (0.94–1.32), 1.61 (1.39–1.86), 2.00 (1.66–2.40), 2.30 (1.90–2.78) and 2.80 (2.23–3.53), respectively. Compared with participants with stable DDS change pattern, those who in large improvement of DDS had a 13% lower risk of cognitive impairment [HR (95%CI): 0.87 (0.78–0.98)].

Table 2 (continued)

Reference	Country/ Type of study	Population and sex	Age (year)	Follow-up time	Method of DD assessment	Method of food intake assessment	Method of cognitive functioning assessment	Method of correlational analysis	Covariates	Findings
Milte et al. 2019 [32]	Australia/ Prospective cohort	617 adults (315 female)	55–65	5 years	Dietary guideline index-13 Low or high dietary variety: Not stated	111-item FFQ	The Telephone Interview of Cognitive Status Score range: 0–50 Mild cognitive impairment: 28–31 and 28 and Dementia: ≤ 27	Linear regression	Age, sex, education, urban/rural status and physical activity	In total population, participants who had higher DDS in past displayed better cognitive function [β (95% CI): 0.28 (0.03, 0.52)]. The significant association was not observed for recent DD.
Otsuka et al. 2017 [33]	Japan/ Cohort	570 participants 298 men 272 women	60–81	12 years	DDS (17 food groups)	3-day dietary record	MMSE Score range: 0–30 Cognitive impairment: ≤ 23	Generalized estimating equation analyses	Age, sex, follow-up time, baseline MMSE score, education, BMI, annual household income, smoking status, energy intake, and disease history	1 SD increase in DDS was accompanied by 21% reduced cognitive decline, in fully adjusted model [OR (95% CI): 0.79 (0.70–0.89), $p < 0.001$]. Participants in the highest quartile of DDS were 44% less likely to have cognitive decline [OR (95% CI): 0.56 (0.38–0.83), $p = 0.003$].
Otsuka et al. 2023 [41]	Japan/ Cohort	38,797 participants (17,708 men and 21,089 women)	Mean: >54	11 years	DDS The total number of listed 133 food items consumed at least once per day (range from 2.8 to 71.9).	133 food-item FFQ	Disabling dementia, consistent with the Long-Term Care Insurance System standards	Cox regression	Age, sex, BMI, history of diabetes, alcohol consumption, total energy intake, smoking status, total physical activity, occupational types, living status	Among women, but not among men, the DDS was inversely associated with disabling dementia [highest quintile vs. lowest quintile: HR (95% CI): 0.67; 0.56–0.78; p for trend < 0.001].
Song et al. 2022 [34]	China/ prospective cohort	6237 old adults (both sexes)	> 80	Mean: 5.26 years	DDS (9 food groups) DDS range: 0–18 Low: 0–9 High: 10–18	FFQ	MMSE Score range: 0–30 Cognitive impairment: < 18	Cox regression	Age, sex, BMI, number of teeth, use of artificial dentures, occupation, marital status, residence type, education level, living pattern, exercise, smoking, drinking status, chronic diseases	Relative to the high–high DDS change pattern, participants in the low–low and high–low patterns were associated with an increased risk of cognitive impairment with a HR (95% CI) of 1.43 (1.25, 1.63) and 1.44 (1.24, 1.67), and a faster decline in the MMSE score over the follow-up year.

Table 2 (continued)

Reference	Country/ Type of study	Population and sex	Age (year)	Follow-up time	Method of DD assessment	Method of food intake assessment	Method of cognitive functioning assessment	Method of correlational analysis	Covariates	Findings
Xiao et al. 2023 [35]	China/ Cross-sectional	1,982 middle-aged and older adults (89.71% female)	63.37 ± 5.00	-	DDS (9 food groups) Score range: 0 to 9 Low: 0–6 High: 8–9	64 food- items FFQ	Petersen's criteria and neuropsychological test battery	Linear and logistic regression	Age, sex, marital status, educational level, household income, smoking status, drinking status, physical activity, energy intake, BMI, hypertension, and diabetes	Compared to the lowest quartile of DDS (0, 6], the multivariable-adjusted OR (95% CI) of MCI was 0.55 (0.37, 0.84) ($p = 0.005$) for the highest DDS quartile (8, 9]. Higher DDS was positively associated with better performance of cognitive domains, including global cognitive function (β = 0.20, 95% CI: 0.12, 0.30), episodic memory (β = 0.21, 95% CI: 0.07, 0.35), attention (β = 0.15, 95% CI: 0.03, 0.26), language fluency (β = 0.24, 95% CI: 0.10, 0.38), and executive function (β = −0.24, 95% CI: −0.38, −0.10).
Yang et al. 2024 [36]	China/ Longitudinal study	1201 old adults (52.1% female)	82.39 ± 12.08	4 years	DDS (9 food groups) Score range: 0–9	The frequency of food intake	Chinese MMSE Score range: 0–30	Linear regression	Age, sex, education, marital status, economic status, health status, activities of daily living, Instrumental activities of daily living, abdominal obesity, superoxide dismutase, total cholesterol, triglyceride, and anemia status	Increased levels of dietary diversity delayed cognitive impairment [β (95% CI): 0.077 (0.045, 0.409), $p < 0.05$)].
Yin et al. 2017 [37]	China/ Cross-sectional	8,571 elderly participants (53.7% female)	≥ 65	-	DDS (9 food groups) Score range: 0 to 9 Best DD: ≥7 Poor DD: <3	Frequency of nine food groups (not FFQ)	MMSE Cognitive impairment: 19/20 for those without formal education, 22/23 for those with primary school, and 26/27 for those with more than 6 years of education	Linear and logistic regression	Age, sex, education, marital status, smoking, alcohol drinking, physical activities, leisure activities, social activities, waist circumference, blood pressure, hearing decline, activities of daily life disability, diabetes, and stroke	Poor DDS was associated with increased cognitive impairment [OR (95% CI): 1.29 (1.14, 1.47).

Table 2 (continued)

Reference	Country/ Type of study	Population and sex	Age (year)	Follow-up time	Method of DD assessment	Method of food intake assessment	Method of cognitive functioning assessment	Method of correlational analysis	Covariates	Findings
Yokoyama et al. 2023 [43]	Japan/ Prospective cohort	4972 community-dwelling adults (both sexes)	≥ 65	6·8 years	DDS (ten food groups) Low DD: 0–2 Middle: 3–4 High: 5–10	FFQ	According to the national long-term care insurance system	Cox regression	Age, sex, education, living situation, smoking status, subjective poverty level, drinking habits, exercise habits, BMI, medical history, chewing ability, depressive symptoms, and cognitive function	In the highest DD category group incident disabling dementia was 18% lower compared with those in the lowest group [HR (95% CI): 0·82 (0·69, 0·97), p-trend = 0·019].
Zhang et al. 2020 [42]	China/ Prospective cohort	4356 participants (both sexes)	61.9 ± 7.9	5 years	DDS (eight food groups) Total score: 8 Low: 0–2 High: 6–8	Three consecutive days 24-hour dietary recall and family food weight inventory	Self-report memory status Memory score was calculated based on a subset of items collected by telephone interview (immediate and delayed free-recall test (ten words) and the Serial 7s test.). OK memory: very good or good	Linear and logistic regression	Age, gender, living region, education level, alcohol intake, smoking status, income, and medical history	In participants with OK memory, a higher DDS was associated with self-reported good memory [OR (95%CI): 1.15 (1.07, 1.24)] and inversely associated with bad memory [(OR (95%CI): 0.82 (0.75, 0.89)]. Higher DDS was associated with higher memory score (β (95%CI): 0.74 (0.56, 0.91). In participants aged ≥ 65 years, the association between DDS and self-reported good memory was insignificant.
Zhang et al. 2021 [17]	China/ Prospective cohort	3085 (both sexes)	60 to 80	5 years	DDS (eight food groups) Score range: 1–8 Low: 1.7–3.3 High: 4.4-8	Three consecutive days 24-hour dietary recall and family food weight inventory	Immediate and delayed free-recall test (10 words), the Serial 7s test, and counting backward from 20. Score range: 0 to 27	Logistic regression	Age, gender, region of residence, residency, education, household income, marriage status, smoking, alcohol use, and BMI	Higher DDS (tertiles: 3 vs. 1) was associated with better cognitive function [OR (95% CI):1.77(1.46, 2.15), $p < 0.001$].

Table 2 (continued)

Reference	Country/ Type of study	Population and sex	Age (year)	Follow-up time	Method of DD assessment	Method of food intake assessment	Method of cognitive functioning assessment	Method of correlational analysis	Covariates	Findings
Zheng et al. 2021 [38]	China/ Prospective cohort	11,970 participants (both sexes)	≥ 80	3.94 ± 2.4 years (46,738 person-years)	DDS (eight food groups) High: ≥ 5	FFQ	MMSE Score range: 0–30 Cognitive impairment: <18	Cox regression	Age, sex, residence, occupation, education, income, current marital status, living pattern, smoking status, alcohol drinking, physical exercise status, number of teeth, use of artificial denture, hypertension, heart disease, cerebrovascular disease, respiratory disease, digestive system diseases, baseline MMSE, and disability in ADL.	Each one unit increase in DDS was associated with a 4% lower risk of cognitive impairment [HR (95% CI): 0.96 (0.94, 0.98), $p < 0.001$].
Zhong et al. 2023 [39]	China/ Prospective cohort	14,382 older adults (53.7% female)	Mean: 82.3	9-year	DDS (nine food groups) DDS range: 0 to 18	FFQ	Chines MMSE	Cox regression	Age, sex, living areas, marital status, occupation, education, income, BMI, exercise, smoking status, drinking status, and health status	Group with the low-to-low DDS had increased cognitive frailty risk compared with the high-to-high DDS group, with adjusted hazard ratios [HR (95% CI): 1.96 (1.53, 2.52)]. A declining or persistently low DDS and a moderately or extremely declining DDS were associated with a significantly higher incidence of cognitive frailty risk.

AD: Alzheimer's Disease; CI: Confidence Interval; DDS: Dietary Diversity Score; MMSE: Mini-Mental State Examination; FFQ: Food Frequency Questionnaire; BMI: Body Mass Index; MCI: Mild Cognitive Impairment; HR: Hazard Ratio; OR: Odds Ratio change patterns compared to the high–high pattern. Xiao et al. [35], in a cross-sectional study of 1,982 middle-aged and older adults, showed that the risk of mild cognitive impairment was 45% lower in participants with the highest DD compared to those with the lowest DD. Higher DD was positively associated with better performance in cognitive domains, including global cognitive function, episodic memory, attention, language fluency, and executive function. Yang et al. [36], in a longitudinal study of 1201 old adults, found that increased levels of DD delayed cognitive impairment. Yin et al. [37], in a cross-sectional study of 8,571 elderly participants, showed that poor DD was associated with increased cognitive impairment. Zhang et al. [17], in a prospective cohort study of 3085 older adults, reported that higher DD was associated with better cognitive function. Zheng et al. [38], in a prospective cohort study of 11,970 older participants, indicated that each one-unit increase in DD score was associated with a 4% lower risk of cognitive impairment. Zhong et al. [39], in a prospective cohort study of 14,382 older adults, observed an increased cognitive frailty risk in people with low-to-low DD compared to those with high-to-high DD. A persistent low DD and a moderate or extreme declining DD were associated with a significantly higher incidence of cognitive frailty risk. Kheirouri et al. [40], in a cross-sectional study of 60 Alzheimer's patients, found a positive association between DD score and total MMSE score.

Association between DD and memory

Three studies [35, 40, 41] investigated the correlation between DD score and memory and all found a positive association between DD score and good memory (β ranged from 0.21 to 0.74). Kheirouri et al. [40], in a cross-sectional study of 60 Alzheimer's patients, found a positive association between DD and memory. Xiao et al. [35], in a cross-sectional study of 1,982 middle-aged and older adults, showed that a higher DD was positively associated with episodic memory. Zhang et al. [41], in a prospective cohort study of 4356 participants, showed that a higher DD was associated with self-reported good memory and inversely with bad memory. In participants aged ≥ 65 years, the association between DD and self-reported good memory was insignificant.

Association between DD and dementia and AD

Four studies [20, 40, 42, 43] investigated the connection between DD score and dementia or AD and all reported a positive association between DD score and dementia ($n = 3$, hazard ratios ranged from 0.67 to 0.82) and AD ($n = 1$, OR = 0.21).

Dutta et al. [20], in a cross-sectional study of 60 dementia patients and 60 controls (aged ≥ 60), found that people with dementia had lower DD (considering seven food groups obtained from 24-hour dietary recall) than healthy people. Otsuka et al. [42], in a study of 38,797 participants, reported that the DD score was inversely associated with disabling dementia among women, but not among men. Yokoyama et al. [43], in a prospective cohort study of 4972 community-dwelling adults, found that disabling dementia incident was 18% lower in people with the highest DD score compared with those in the lowest group. Kheirouri et al. [40], in a cross-sectional study of 60 Alzheimer's patients and 29 healthy individuals, showed lower DD in patients with Alzheimer's than in healthy people and found a positive association between DD and total MMSE score. The authors indicated that a high DD reduced the chance of AD by 79%.

Discussion

There are new modifying therapies for AD, but these are not widely available and their cognitive effects in the long-term are not yet known, preventive strategies assume paramount importance in mitigating the anticipated rise in cognitive decline. Promoted DD, which ensures the adequacy of diverse vitamins, minerals, nutrients, phytochemicals, and flavonoids, is important for brain health maintenance and might be beneficial to inhibit nutrient deficiencies and neurodegenerative and chronic diseases [14, 44]. Extensive research has explored the potential impact of diverse nutrients and dietary components on preventing cognitive dysfunction, AD, and other forms of dementia [45, 46]. The results from the present systematic review of observational studies provided an evidence that sustaining a diverse diet among older people may help maintain cognitive functioning.

Considering that studies utilizing various methodologies for assessing DD and cognitive performance yielded consistent results regarding their association, it appears that the differing methods did not significantly influence the overall outcomes.

The prefrontal cortex and hippocampus are important brain structures involved in cognitive functioning and memory processing and are recognized to be atrophies in dementia [47, 48]. Studies concerning the association of DD and hippocampal performance are limited. However, scientific evidence suggests that higher adherence to healthy, high quality, and diverse diet may help protect hippocampal structure (Fig. 2). Akbaraly et al. [49], in a study of 459 participants, reported that long-term exposure to a high-quality diet (11 years) was related to larger hippocampal volume measured by multimodal magnetic resonance imaging examination. Otsuka et al. [50], in a study of 1683 community dwellers, demonstrated that higher DD was associated with less reduction in total grey matter and hippocampal volumes over a two-year follow-up. Gaudio et al. [51], in a study of 9925 participants, showed a positive connection between vegetable

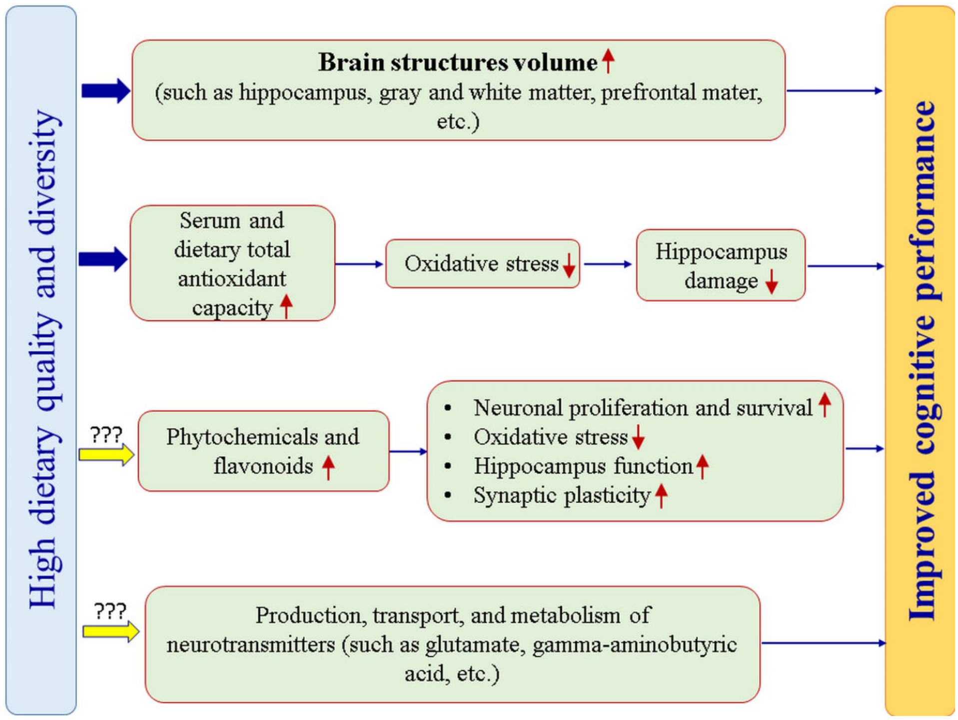

Fig. 2 Conceivable mechanistic pathways for the association between dietary diversity and cognitive performance

consumption and total white matter volume and between fresh fruit intake and grey matter volume in several brain structures that strongly contributed to the pathophysiology of dementia, including the hippocampus. Mou et al. [52], in a prospective population-based study of children, found lower cerebral white matter volume in children with a higher intake of snacks, sugar, and processed foods at the age of one year. The authors observed larger total brains in children with higher intake of whole grains, dairy, and soft fats at age eight and larger cerebral gray matter volumes at age ten. Greater brain gyrification and surface area were observed in those with higher diet quality and intake of whole grains, dairy, and soft fats at age eight. Croll et al. [53], in a population-based study of 4447 participants according to brain magnetic resonance imaging data, reported that higher diet quality was associated with larger brain volume, hippocampal volume, and gray and white matter volumes. Jensen et al. [54], in a systematic review study, found that poor dietary quality was associated with decreased volume and connectivity of different brain structures, such as the hippocampus. Raji et al. [55], in a study of 260 cognitively normal people based on brain magnetic resonance imaging data, demonstrated that dietary fish intake was associated with higher gray matter volumes. Kokubun and Yamakawa [56], in a study of 171 healthy individuals based on brain magnetic resonance imaging data, showed that gray matter volume was high in the individuals with high consumption of milk and yogurt. Participants with high intake of alcohol and animal foods had low gray matter volume. Brain atrophy may not accrue in those with a balanced intake of vegetables and animal foods.

The brain is greatly susceptible to oxidative destruction, and older people commonly have high serum oxidative stress and low antioxidant status [57, 58]. According to experimental studies, the hippocampus is more vulnerable to oxidative stress damage [59]. As shown in Fig. 2, retaining a high DD promotes serum and dietary total antioxidant capacity [58, 60, 61]. Kong et al., in a cross-sectional study of 335 older adults, concluded that adherence to high DD influences oxidative stress levels and is related to high total antioxidant capacity [62]. Therefore, eating diverse foods may help mitigate the risk of oxidative damage on brain and cognitive impairment by reducing oxidative stress.

Another explanation for the mechanism of action of high dietary variety in improving cognitive performance may be attributed to the possible high content of phytochemicals and flavonoids in varied foods. Earlier evidence shows that a high intake of phytochemicals and flavonoids is associated with improved brain function and cognitive performance, learning, and memory. This is, possibly because they support neuronal proliferation and survival, lower oxidative stress, promote hippocampus function, and enhance synaptic plasticity [63, 64]. Scientific researchers believe that a varied diet is rich in phytochemicals and flavonoids. However, until now, there is no scientific evidence to directly assess the relationship between DD and dietary phytochemicals or flavonoids, and this subject deserves more research attention.

Recent evidence suggests the involvement of various neurotransmitters such as glutamate, gamma-aminobutyric acid (GABA), serotonin, and dopamine in cognition, memory, learning, and their changes [65, 66]. Diet might affect the production, transport, and metabolism of the neurotransmitters. Sandoval-Salazar et al. showed that high-fat diet consumption increased frontal cortex glutamate and glutamine but decreased GABA levels in rats. But Berrycactus fruit intake reduced glutamate concentration [67]. Shah et al., in an animal study, reported that vitamin C treatment reduced brain glutamate concentrations and inverted the hippocampus alterations induced by increased glutamate [68]. High diverse diet may involve indirectly in the production, transport, and metabolism of neurotransmitters by enhancing the intake of certain food components such as fats or vitamin C. Molani-Gol et al., in a systematic review study, demonstrated that consuming more diverse foods predicts dietary vitamins adequacy, particularly vitamin C [69]. Ruel, in a review study, indicated that greater DD was linked to an increase in energy, fat, protein, carbohydrates, and several vitamins, especially vitamin C, and minerals [70]. However, the effect of DD on neurotransmitter synthesis, transport, and function remains unclear (Fig. 2).

Strengths of the study

The freshness of the publication year of most included studies refers to the newness of the topic. The presence of prospective cohort studies with substantial sample sizes promotes the statistical power of the findings. Considering gender balance in the studies enhances the societal relevance of the investigation. Most included studies deemed the role of potential confounders in the DD-cognitive functioning evaluation, which refers to the independent role of DD in the relationship.

Limitations of the study

Using different cut-off points for high and low DD and considering different numbers of food groups to calculate DD across the included studies may affect the results of the studies. Using a subjective and questionnaire-based method (e.g., MMSE) or self-reported tools to evaluate cognitive performance may lead to miscategorization of cognitive function and act as a potential source of bias, especially across different populations. Although many studies controlled for known confounders (e.g., age, sex, BMI, socioeconomic status), there may still be unmeasured variables, such as genetic factors or subtle differences in lifestyle, that could affect some observed associations. The observational nature of the studies is not able to explore the causal effect of DD on cognitive performance. Due to high heterogeneity among the studies, regarding statistical analysis and measured endpoint outcome, we could not assess publication bias, which may skew the apparent consensus about the result of this review.

Conclusion

The results indicate that sustaining a diverse diet among older people may help maintain cognitive functioning. Dietary diversity represents a promising clinical avenue for mitigating cognitive decline associated with diverse brain disorders, potentially preventing or attenuating deterioration.

Suggestions for future research

The effect of DD on phytochemicals and neurotransmitters that contribute to cognition remains an unresolved question, necessitating further investigation. Furthermore, randomized trials to explore causality, and mechanistic animal studies or particular population subgroups (e.g., those at risk for dementia) are suggested for future investigations.

Implication of the findings

The results of this study hold considerable applications for public health, particularly in preserving cognitive performance during aging. Moreover, these findings offer valuable insights for formulating dietary recommendations to prevent cognitive disturbances. However, we reiterate that evidence is mostly associative and that public health guidelines would benefit from stronger causal data or intervention trials.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12883-025-04096-6.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

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None.

Author contributions

Sorayya Kheirouri and Hamed Alizadeh were involved in the search and selection of the articles and participated in data extraction and manuscript writing. The authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval
The Deputy for Research and Technology, Tabriz University of Medical Sciences, Tabriz, Iran, registered and approved the protocol of this study (IR.TBZMED.VCR.REC.1403.058) (file:///C:/Users/Admin/Downloads/ba1sa8sdh3y4c1bh.pdf).

Consent for publication
Not applicable.

Consent to participate
Not applicable.

Competing interests
The authors declare no competing interests.

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