



Revisión

The effect of fruit and vegetable consumption on the decreased risk of mild cognitive impairment in patients referring to health examination centers — A systematic review and meta-analysis

Efecto del consumo de frutas y verduras en la disminución del riesgo de deterioro cognitivo leve en pacientes remitidos a centros de reconocimiento médico: revisión sistemática y metaanálisis

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Abstract

Introduction: nutritional factors play an essential role in the occurrence of cognitive impairment. The present study aimed to investigate the effect of fruit and vegetable consumption on the decreased risk of mild cognitive impairment in patients referring to health examination centers.

Methods: a comprehensive search was conducted across five electronic bibliographic databases. Two groups of keywords were selected for search in the databases. Two independent researchers screened and selected the studies by examining the titles and abstracts. Two evaluators gathered essential details from the chosen studies. To assess the quality of the studies, appraisal instruments from the Joanna Briggs Institute (JBI) were utilized. Moreover, a meta-analysis was performed focusing on the values of the odds ratio.

Results: 38 studies were entered into the study; 36 studies (94.7 percent) revealed that fruit and vegetable consumption can affect the occurrence of mild cognitive impairment. The values of the odds ratio related to the effect of vegetable consumption and fruit intake on the decreased risk of mild cognitive impairment were between 0.20 to 0.82 and 0.14 to 0.92, respectively. The results showed that vegetable consumption [odds ratio: 0.60 (95 % CI: 0.40 to 0.79)] and fruit intake [odds ratio: (95 % CI: 0.46 to 0.86)] can decrease the risk of MCI.

Conclusions: the results revealed that fruit and vegetable consumption can significantly decrease the risk of mild cognitive impairment. Therefore, it is suggested that preventive plans for fruit and vegetable consumption should be implemented, especially in low- and middle-income countries.

Keywords:

Fruit. Vegetable. Mild cognitive impairment. Systematic review. Meta-analysis.

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Resumen

Introducción: los factores nutricionales desempeñan un papel esencial en la aparición del deterioro cognitivo. El presente estudio tuvo como objetivo investigar el efecto del consumo de frutas y verduras en la disminución del riesgo de deterioro cognitivo leve en pacientes remitidos a centros de reconocimiento médico.

Métodos: se realizó una búsqueda exhaustiva en cinco bases de datos bibliográficas electrónicas. Se seleccionaron dos grupos de palabras clave para la búsqueda en las bases de datos. Dos investigadores independientes examinaron los títulos y resúmenes de los estudios seleccionados. Dos evaluadores recopilaron detalles esenciales de los estudios seleccionados. Para evaluar la calidad de los estudios, se utilizaron instrumentos de evaluación del Instituto Joanna Briggs (JBI). Además, se realizó un metaanálisis centrado en los valores del odds ratio.

Resultados: se incluyeron 38 estudios en el estudio; 36 estudios (94,7 por ciento) revelaron que el consumo de frutas y verduras puede afectar a la aparición del deterioro cognitivo leve. Los valores de la razón de probabilidades relacionados con el efecto del consumo de verduras y la ingesta de frutas sobre la disminución del riesgo de deterioro cognitivo leve fueron de entre 0,20 a 0,82 y 0,14 a 0,92, respectivamente. Los resultados mostraron que el consumo de verduras [odds ratio: 0,60 (IC del 95 %: 0,40 a 0,79)] y la ingesta de frutas [odds ratio: (IC del 95 %: 0,46 a 0,86)] pueden disminuir el riesgo de deterioro cognitivo leve.

Conclusiones: los resultados revelaron que el consumo de frutas y verduras puede disminuir significativamente el riesgo de deterioro cognitivo leve. Por lo tanto, se sugiere que se implementen planes preventivos para el consumo de frutas y verduras, especialmente en países de ingresos bajos y medios.

Palabras clave:

Fruta. Verdura. Deterioro cognitivo leve. Revisión sistemática. Metaanálisis.

INTRODUCTION

Mild cognitive impairment (MCI) is a medical condition characterized by memory or cognitive difficulties in individuals compared to ones of the same age (1). The symptoms of MCI are less severe compared to those associated with Alzheimer's disease or other forms of dementia (2). Individuals with MCI generally maintain the ability to manage their self-care and perform everyday tasks (2). Notably, MCI doesn't cause serious problems in the cognitive performance of people to impair their daily lives (3). MCI is often seen as a critical period for the prevention of Alzheimer's disease, providing a "window of opportunity" to potentially reverse or stabilize cognitive decline (4). During this time, some individuals may experience a return to normal cognitive functioning (4). As a transitional stage between normal aging and the onset of dementia, MCI is considered a key focus for interventions aimed at slowing the progression of dementia (5). Based on the results of a systematic review and meta-analysis performed by Bai et al., it has been found that the global prevalence of MCI in community-dwelling adults aged 50 and older was 15.56 percent (6). Further, findings from another meta-analysis revealed that about 39.2 % of those diagnosed with MCI progress to dementia over time (7). These statistics underscore the partial progression rate of the condition towards more severe neurodegenerative diseases, highlighting the importance of early detection and intervention efforts. These results indicate that despite the relative prevalence of this disease, the disease in only some cases progresses to dementia and Alzheimer's disease. So that and that intervention measures can be helpful.

Mild Cognitive Impairment (MCI) is a reversible condition, and early detection and intervention can prevent the progression to dementia and Alzheimer's disease. Research suggests that approximately one-third of dementia cases could potentially be avoided by managing modifiable risk factors (8). Various elements affect cognitive performance, including age, gender, obesity in mid-life, hypertension in mid-life, sleep disturbances, and insufficient physical activity (9). Dietary habits also significantly impact the likelihood of developing MCI. Healthy eating patterns are a crucial strategy for preventing or postponing MCI in older adults (10). Increasing evidence indicates that diets with plants

are particularly beneficial for preventing cognitive decline. This is largely due to the protective effects of antioxidants found in vegetables and fruits, which are essential for maintaining cognitive health (11). Several preclinical research has demonstrated that the polyphenolic antioxidants of fruits and vegetables can significantly reduce or even prevent neuronal death, thereby potentially lowering the incidence of dementia, particularly in cellular and animal studies (12). Earlier research has indicated that sufficient or high consumption of fruits and/or vegetables is associated with a decreased risk of cognitive impairments (13). In a systematic review, early evidence suggests that there are correlations between food insecurity at various life stages and overall cognitive abilities, executive function, and memory (14,15). The results of another meta-analysis show that increased intake of fruits and vegetables among the elderly has a relationship with a reduced incidence of cognitive disorders in this population group (16).

As mentioned, nutritional factors play an essential role in the occurrence of cognitive impairment and some systematic review and meta-analysis studies have summarized this relationship. However, no systematic review and meta-analysis were performed on the relationship between fruit and vegetable consumption with mild cognitive impairment. Additionally, the impact of fruit intake, vegetable consumption, and the combined intake of both fruits and vegetables may be different (17,18). For these reasons, it is required that a systematic review and meta-analysis study is performed to summarize these findings. Therefore, the present study aimed to investigate the effect of fruit and vegetable consumption on the decreased risk of mild cognitive impairment in patients referring to health examination centers.

METHODS

This systematic review and meta-analysis were officially registered with PROSPERO and adhered to the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (19). All methods were performed in accordance with relevant guidelines and regulations. However, this study is a systematic review and meta-analysis and does not require ethical approval by the institution.

SEARCH STRATEGY

A comprehensive search was conducted across five electronic bibliographic databases: Scopus, PubMed, Medline, Web of Science, and Embase, with the search completed by November 05, 2024. Two groups of keywords were selected for search in the databases. The keywords of the first group were “veget*” OR “fruit*” OR “juice” and the keywords in the second group were “Mild Cognitive Impairment*” OR “mild cognitive defect*” OR “mild neurocognitive disorder*” OR “mild cognitive disorder*” OR “MCI”.

ELIGIBILITY CRITERIA

A range of study types with the English language were incorporated into the systematic review. Moreover, all studies on the persons referring to health examination centers were entered into the study. However, this study excluded review and meta-analysis articles, editorial letters, case reports, and papers presented at conferences.

STUDY SELECTION

All articles retrieved from the databases were transferred into Endnote for evaluation, where any duplicates were identified and eliminated. Two independent researchers (W.H. and G.Z.) then screened the studies by examining the titles and abstracts to determine their relevance. Articles with unrelated titles and abstracts were discarded. The full texts of the remaining articles were thoroughly examined by the researchers to verify the criteria. Relevant studies were subsequently included in the review. In instances of disagreement between the two primary researchers, a third researcher (S.Y.) was consulted to resolve the issue.

QUALITY ASSESSMENT

To assess the quality of the studies, appraisal instruments from the Joanna Briggs Institute (JBI) designated for case-control, cross-sectional, and cohort research were utilized. The JBI checklist serves as an effective instrument to examine the quality across different studies (20). Upon filling out these checklists, the positive responses were summed to calculate an overall score. Subsequently, based on this score, the studies were classified into three distinct groups: low quality, moderate quality, and high quality.

DATA EXTRACTION

In this phase, two evaluators gathered essential details from the chosen studies. These details encompassed the author's identity, publication year, design of the study, nation, sample size, gender distribution, age range, consumption type, tools, outcome, and findings.

DATA ANALYSIS

The concordance among evaluators was assessed using Cohen's kappa coefficient (21). The resulting kappa values for the various stages were recorded at 0.91 and 0.93, respectively. Beyond the descriptive results, a meta-analysis was performed focusing on the values of odds ratio. For subgroup analyses, countries were categorized into low and middle-income (LMIC) and high-income (HIC) groups, following the World Bank's classifications (22). In the study also. The research was grouped into four geographic areas: Europe, East/Southeast Asia, the Middle East, and the Americas. The studies were temporally divided based on whether they occurred before or after the year 2015. All data processing was carried out using STATA version 14.2.

RESULTS

SEARCH RESULTS AND STUDY SELECTION

In this study, we collected 1,353 articles from multiple databases. From this source, 313 duplicated papers were removed. Following this, two researchers scrutinized the titles and abstracts of the 1040 remaining articles. After this preliminary assessment, 1,000 articles were eliminated either because they failed to meet the inclusion criteria or because they met the criteria for exclusion. Consequently, the full texts of 40 articles were thoroughly evaluated, and 38 of these were ultimately chosen to be entered into the study. The process is depicted in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram (Fig. 1).

SPECIFICATION OF THE ARTICLES

Tables I and II outline the details of the articles incorporated into this systematic review. Among the 38 qualified studies, 11 studies were conducted using a cohort design, 9 studies using a cross-sectional design, and 18 studies using a case-control design. 4 studies have been carried out in Singapore, 11 studies in China, 6 studies in the United States, 2 studies in Taiwan, 4 studies in Malaysia, 4 studies in South Korea, and 1 study in each of the countries of India, France, Micronesia, Mexico, Greece, Netherland, Egypt, and the Central African Republic. Also, 1 study was conducted jointly in countries of China, Ghana, India, Mexico, Russia, and South Africa.

Among these studies, all 38 papers were performed on males and females. The age range of the subjects studied in the reviewed papers was between 40 and 90 years old. Also, the frequency of participants in 16 studies (42.1 percent) was lower than 500 people, in 9 studies (23.7 percent) was between 500 and 1000 persons, and in 13 studies (34.2 percent) was higher than 1,000 persons. 20 studies were simultaneously conducted on fruits and vegetables, 5 studies on fruits, 7 studies on vegetables, and 6 studies on juice.

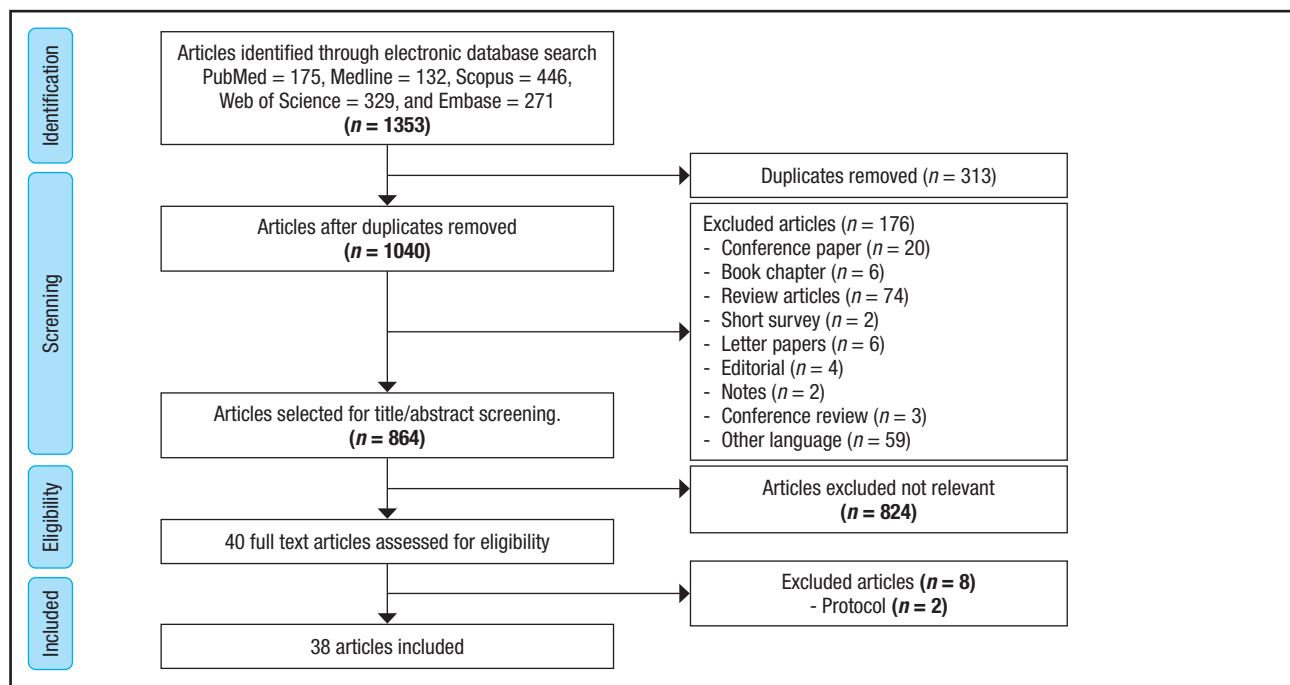


Figure 1. The flow diagram of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).

Table I. The total details of the articles encompassed in this systematic review

Author (year)	Country	Study type	Sample size	Age	Gender	Consumption type (vegetable/ fruit/juice)
Y. Lu (2021)	Singapore	cohort	2640	66.1	male-female	fruits/vegetables
H. Fangfang (2022)	China	cross-sectional	1461	73.4	male-female	fruits/vegetables
Preeti Gazbare (2024)	India	cross-sectional	605	40-60	male-female	vegetables
Feng Sha (2022)	China	cohort	7422	90	male-female	fruits/vegetables
Rosebud O. Roberts (2010)	USA	cohort	1,233	81.5	male-female	fruits/vegetables
Kai-Yong Huang (2020)	Singapore	cross-sectional	748	68.1	male-female	fruits/vegetables
K Ritchie (2010)	France	cohort	1433	72.5	male-female	fruits/vegetables
Shao-Yuan Chuang (2019)	Taiwan	cohort	2681	73.5	male-female	fruits/vegetables
A.R. Borenstein (2007)	Micronesia	case-control	1631 (cases = 50, controls = 1,581)	77.4	male-female	fruit bats
Robert Krikorian (2010)	USA	case-control	12 (cases = 5, controls = 7)	78.2	male-female	Concord grape juice
Li Dong (2016)	China	cross-sectional	248	62.9	male-female	fruits/vegetables
Iffa Hafizah (2015)	Malaysia	case-control	114 (cases = 25, controls = 89)	case = 65.5-control = 67.5	male-female	fruits/vegetables
Guei-Chiuan Chen (2019)	Taiwan	cross-sectional	985	70.8	male-female	vegetables
Nurul Fatin Malek Rivan (2022)	Malaysia	cohort	280	67.3	male-female	fruits/vegetables

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Table I (Cont.). The total details of the articles encompassed in this systematic review

Author (year)	Country	Study type	Sample size	Age	Gender	Consumption type (vegetable/ fruit/juice)
Angel Gabriel Garrido-Dzib (2024)	Mexico	case-control	73 (cases = 34, controls = 39)	case = 73.4-control = 67.2	male-female	fruits/vegetables
Xinting Jiang (2024)	China	case-control	599 (cases = 350, controls = 249)	case = 67.8-control = 64.5	male-female	fruits: berries, grapes, fruit juice
Jingzhu Fu (2021)	China	cohort	4,457	60-≥ 75	male-female	vegetables
Lee Smith (2023)	China, Ghana, India, Mexico, Russia, and South Africa	cohort	32,715	62.1	male-female	fruits/vegetables
CP Chong (2019)	Malaysia	cross-sectional	1,209	68.08	male-female	fruits
Wei Li (2019)	China	case-control	507 (cases = 101, controls = 406)	cases = 72.7, controls = 65.7	male-female	vegetables
Divya Vanoh (2017)	Malaysia	cohort	1,993	68.5	male-female	fruits and fresh fruit juices
S. Pilleron (2015)	Central African Republic, Congo	case-control	788 (cases = 62, controls = 726)	cases = 72.7, controls = 65.7	male-female	fruits/vegetables
Kai-Yong Huang (2024)	China	case-control	789 (cases = 131-controls = 658)	cases = 69.6, controls = 69.9	male-female	fruits
Kyoung Yun Kim (2021)	South Korea	cross-sectional	275	50-≥ 75	male-female	vegetables
Dayeon Shin (2018)	South Korea	case-control	239 (cases = 20, controls = 219)	cases = 80.5, controls = 73.4	male-female	fruits/vegetables
Ashley F. Curtis (2024)	USA	case-control	37 (cases = 24, controls = 13)	cases = 76.3, controls = 76.2	male-female	elderberry Juice
Thanos Chatzikostopoulos (2024)	Greece	case-control	80 (cases = 40, controls = 40)	cases = 69.8, controls = 69.3	male-female	pomegranate seed oil (PSO)
Robert Krikorian (2012)	USA	case-control	21	case = 78, controls = 75	male-female	Concord grape juice
Lei Feng (2019)	Singapore	case-control	663 (cases = 90, controls = 573)	case = 69.2, control = 67.4	male-female	mushroom
Robert Krikorian (2010)	USA	case-control	16 (cases = 9, controls = 7)	cases = 76.2, controls = 80.2	male-female	blueberry juice
Erin L Boespflug (2018)	USA	case-control	16 (cases = 8, controls = 8)	cases = 80.4, controls = 75.5	male-female	blueberry juice
Kyoung Yun Kim (2018)	South Korea	case-control	276 (cases = 79-controls = 197)	50-80	male-female	fruits/vegetables
Jay L. P. Fieldhouse (2020)	Netherlands	case-control	223 (cases = 90-controls = 133)	cases = 66, controls = 61	male-female	fruits/vegetables
Qiumin Huang (2021)	China	cohort	4,309	68.4	male-female	fruits/vegetables
Afei Qin (2023)	China	cohort	2,454	75.4	male-female	fruits/vegetables

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Table I (Cont.). The total details of the articles encompassed in this systematic review

Author (year)	Country	Study type	Sample size	Age	Gender	Consumption type (vegetable/fruit/juice)
Shih-Wei Nien (2023)	China	case-control	40 (cases = 21, controls = 19)	cases = 70.5, controls = 72.4	male-female	fruits/vegetables
Yingjiao Deng (2024)	China	cross-sectional	728	60-≥ 80	male-female	fruits/vegetables
Iman I. Salama (2019)	Egypt	cross-sectional	186	51.3	male-female	vegetables

Table II. The details of the articles encompassed in this systematic review

Author (year)	Tools	Outcome (MCI)	Findings	Quality
Y. Lu (2021)	Mini Nutritional Assessment (MNA) scales and Mini-Mental State Examination (MMSE)	Odds ratio: Few fruits/vegetables daily: [1.77 (95 % CI: 1.14-2.74)]	Individuals with a high nutritional risk score (3 or higher) were more likely to develop mild cognitive impairment (MCI)	Q1
H. Fangfang (2022)	Mini-Mental State Examination (MMSE) and interview	Odds ratio: Non-daily vegetable: [1.27 (95 % CI: 1.006-1.601)] Fruit (< 1 day/week): [1.487 (95 % CI: 1.231-1.797)]	Vegetable consumption on a non-daily basis was linked to an increased probability of mild cognitive impairment (MCI)	Q1
Preeti Gazbare (2024)	Addenbrookes Cognitive examination-III test, International physical activity questionnaire and Simple lifestyle indicator questionnaire, interview	Odds ratio: Consumption of vegetarians: [0.84 (95 % CI: 0.54-1.32)]	The dietary patterns did not show a significant association with mild cognitive impairment (MCI)	Q2
Feng Sha (2022)	Chinese version of Mini-Mental State Examination (CMMSE), food frequency questionnaire (FFQ)	Hazard ratio: Daily consumption of fresh fruits: [1.28 (95 % CI: 1.15-1.42)] Consumption of fresh vegetables: [0.90 (95 % CI: 0.75-1.08)]	Regular intake of fresh fruits was associated with an increased likelihood of reversing mild cognitive impairment (MCI)	Q1
Rosebud O. Roberts (2010)	Food Frequency Questionnaire (FFQ), Chinese Dietary Balance Index, and Mini-Mental State Examination	Odds ratio: vegetables > 191.0 g/day intake: [0.66 (95 % CI: 0.44-0.99)] Fruits > 276.8 g/day intake: [0.92 (95 % CI: 0.61-1.38)]	The likelihood of developing mild cognitive impairment (MCI) was lower in individuals with a high Mediterranean diet (MeDi) score	Q1
Kai-Yong Huang (2020)	Mini-Mental State Examination (MMSE), Montreal Cognitive Assessment (MoCA), a battery of neuropsychological tests (Block Design, Digit Span, Rey Auditory Verbal Learning Test, Semantic Fluency, and Color Trails Test), structured questionnaires	Odds ratio: Consume fruits (≥ 4 times per week): [0.51 (95 % CI: 0.33-0.80)]	The findings indicated that regular fruit intake (four or more days per week) was inversely related to the incidence of mild cognitive impairment (MCI)	Q3
K. Ritchie (2010)	Modified Peterson's criteria for mild cognitive impairment, standardized interview, Center for Epidemiological Studies depression scale	Hazard ratio: Fruit/vegetables < twice/day: [1.38 (95 % CI: 1.11-1.70)]	Fruit and vegetable intake has a significant effect on lowering the occurrence of mild cognitive impairment (MCI)	Q1

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Table II (Cont.). The details of the articles encompassed in this systematic review

Author (year)	Tools	Outcome (MCI)	Findings	Quality
Shao-Yuan Chuang (2019)	Food-frequency questionnaire, Mini-Mental State Examination score (MMSE)	Odds ratio: Fresh vegetables ≥ 21 times/week: [0.60 (95 % CI: 0.39-0.93)] Fresh fruits ≥ 7 times/week: [0.36 (95 % CI: 0.23-0.58)]	The dietary pattern score has an inverse association with the presence of mild cognitive impairment	Q1
A. R. Borenstein (2007)	Cognitive Abilities Screening Instrument (CASI) score	Odds ratio: Eat fruit bat as a child: [0.91 (95 % CI: 0.67-1.23)] Eat fruit bat as a young adult: [1.35 (95 % CI: 0.93-1.97)] Eat fruit bat as an adult: [0.55 (95 % CI: 0.25-1.24)]	Dietary habits may play a role in the development of mild cognitive impairment	Q1
Robert Krikorian (2010)	Academic and Medical History Questionnaire, California Verbal Learning Test, Spatial Paired Associate Learning Test, Geriatric Depression Scale	-	The results indicate that Concord grape juice consumption could potentially improve cognitive abilities in patients	Q1
Li Dong (2016)	Montreal Cognitive Assessment (MoCA) test, semi-quantified food-frequency questionnaire (FFQ)	-	A diet with abundant vegetables and fruits may reduce the likelihood of cognitive decline	Q1
Iffa Hafizah (2015)	Mini-Mental State Examination score (MMSE), Geriatric Depression Scale, neurocognitive testing scales (Rey auditory verbal learning test (RAVLT), clock drawing test (CDT), digit span)	-	Individuals without mild cognitive impairment (MCI) consumed notably more fruits and vegetables (281.6 ± 77.2 g/day) in contrast to those diagnosed with MCI (250.4 ± 51.3 g/day)	Q3
Guei-Chiuan Chen (2019)	Test of memory, orientation, judgment, and function	-	A vegetarian diet could potentially lead to a reduced occurrence of mild cognitive impairment	Q1
Nurul Fatin Malek Rivan (2022)	Petersen criteria, Rey Auditory Verbal Learning Test (RAVLT), Geriatric Depression Scale-15 (GDS-15), Malay version Mini-Mental State Examination (M-MMSE), dietary history questionnaire (DHQ)	-	Dietary habits may offer protection against the onset of mild cognitive impairment	Q1
Angel Gabriel Garrido-Dzib (2024)	Food-frequency questionnaire (FFQ), Partial Least-Squares Discriminant Analysis (PLS-DA)	-	Consumption of sufficient amounts of fruits and vegetables may enhance the quality of life among individuals with mild cognitive impairment (MCI)	Q1
Xinting Jiang (2024)	Dietary habit questionnaire, medical history inquiry, physical examination, neuropsychological test, laboratory examination (genetic detection such as APOE), imaging examination (brain MRI, Amyloid β -PET)	Odds ratio: Berries: [0.685 (95 % CI: 0.502-0.935)] Grapes: [0.702 (95 % CI: 0.509-0.969)]	The research indicated that the intake of berries and grapes may safeguard cognitive abilities	Q1

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Table II (Cont.). The details of the articles encompassed in this systematic review

Author (year)	Tools	Outcome (MCI)	Findings	Quality
Jingzhu Fu (2021)	Food frequency questionnaire, Petersen criteria, Mini-Mental State Examination (MMSE)	Odds ratio: Vegetarian pattern: [0.72 (95 % CI: 0.53-0.98)]	The findings indicate a notable relationship between a vegetarian diet and the incidence of mild cognitive impairment (MCI)	Q1
Lee Smith (2023)	Aging-Alzheimer's Association criteria, questionnaire	Odds ratio: Fruit consumption: [0.53 (95 % CI: 0.43-0.66)] Vegetable consumption: [0.82 (95 % CI: 0.59-1.15)]	Increased intake of fruits and vegetables was linked to reduced likelihood of mild cognitive impairment	Q1
C. P. Chong (2019)	Dietary history questionnaire (DHQ), digit span, Rey Auditory Verbal Learning Test (RAVLT), Mini-Mental State Examination (MMSE), Montreal Cognitive Assessment (MoCA), digit symbol, VR	-	Fruit intake was notably correlated with improved scores on the mini-mental state examination (MMSE)	Q1
Wei Li (2019)	Food frequency questionnaire (FFQ), Mini-Mental State Examination (MMSE), Montreal Cognitive Assessment (MoCA)	Odds ratio: Green vegetables everyday consumption: [0.218 (95 % CI: 0.116-0.411)]	Individuals who consumed green vegetables daily exhibited a notably reduced risk of mild cognitive impairment compared to those who did not use green vegetables in their daily diet	Q1
Divya Vanoh (2017)	Dietary History Questionnaire (DHQ), digit span, Rey Auditory Verbal Learning Test (RAVLT), Mini-Mental State Examination (MMSE)	-	The findings suggested that consumption of fruits and fresh fruit juices was associated with lower cognitive functioning	Q1
S. Pilleron (2015)	Petersen criteria, Free and Cued Selective Reminding Test, Zazzo's cancellation task, Isaac's Set Test of verbal fluency, food frequency questionnaire	Odds ratio: Consumption of fruits: [1.82 (95 % CI: 0.88-3.77)] Consumption of vegetables: [2.52 (95 % CI: 1.21-5.23)]	The research shows the relationship between dietary patterns and cognitive impairments	Q1
Kai-Yong Huang (2024)	Mini-Mental State Examination (MMSE)	Odds ratio: Constipation and infrequent fruit consumption: [1.51 (95 % CI: 1.277-1.797)]	The occurrence of mild cognitive impairment (MCI) has been associated with factors such as constipation and low intake of fruits	Q2
Kyoung Yun Kim (2021)	Mini-Mental State Examination (MMSE), food frequency questionnaire	-	The consumption pattern of legumes and vegetables did not show a significant relationship with the incidence of mild cognitive impairment (MCI)	Q2
Dayeon Shin (2018)	Korean-Mini Mental State Examination (K-MMSE), food frequency questionnaire	Odds ratio: Seafood and vegetable patterns: [0.45 (95 % CI: 0.04-5.63)]	Older adults who followed a dietary pattern rich in seafood, vegetables, fruits, bread, snacks, soy products, beans, chicken, pork, ham, eggs, and milk exhibited a lower risk of mild cognitive impairment compared to their counterparts who did not adhere to this diet	Q1

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Table II (Cont.). The details of the articles encompassed in this systematic review

Author (year)	Tools	Outcome (MCI)	Findings	Quality
Ashley F. Curtis (2024)	Clinical Dementia Rating (CDR) scale, Mini-Mental State Exam (MMSE), Hopkins Verbal Learning Test (HVL), Boston Naming Test (BNT), Rey-Osterrieth Complex Figure Test (Rey CFT), Anagram problem-solving tasks, Visuospatial Problem Solving (VPS)	-	Regular intake of elderberry juice could potentially enhance visuospatial cognitive flexibility in individuals with mild cognitive impairment (MCI)	Q1
Thanos Chatzikostopoulos (2024)	Alzheimer's Disease Assessment Scale-Cognitive Subscale (ADAS-cog), Mini-Mental State Examination (MMSE), Montreal Cognitive Assessment (MoCA), Rivermead Behavioral Verbal Learning Test, Rey Auditory Verbal Learning Test (RAVLT), Rey-Osterrieth Complex Figure Test, Trail Making Test Part B (TMT B), Functional Cognitive Assessment Scale (FUCAS).	-	The findings indicated that individuals who consumed pomegranate seed oil demonstrated a statistically significant improvement in overall cognitive abilities, verbal episodic memory, and both processing and executive functions compared to those who did not consume the oil	Q1
Robert Krikorian (2012)	Structured interview, Clinical Dementia Rating (CDR), Montreal Cognitive Assessment (MOCA), Rey Auditory Verbal Learning Test (RAVLT), Geriatric Depression Scale (GDS)	-	Individuals with grape juice consumption exhibited a decreasing semantic interference during memory assessments. Functional magnetic resonance imaging revealed comparatively higher activation in the anterior and posterior areas of the right hemisphere in these subjects	Q1
Lei Feng (2019)	Singapore modified Mini-Mental State Examination (SM-MMSE), Clinical Dementia Rating (CDR), Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV), 6-item mushroom consumption questionnaire	Odds ratio: Mushroom consumption (> 2 portions per week): [0.43 (95 % CI: 0.23-0.78)]	People who consumed more than two portions per week compared to ones who ate mushrooms less than once per week exhibited a lower likelihood of developing mild cognitive impairment (MCI)	Q1
Robert Krikorian (2010)	Verbal Paired Associate Learning Test (V-PAL), California Verbal Learning Test (CVLT), Geriatric Depression Scale (GDS)	-	Enhanced performance was noted in paired associate learning and the recall of word lists	Q1
Erin L. Boespflug (2018)	Functional magnetic resonance imaging, Academic and Medical History Questionnaire, modified Clinical Dementia Rating (mCDR), Montreal Cognitive Assessment (MoCA), California Verbal Learning Task (CVLT), Geriatric Depression Scale (GDS)	-	Participants with blueberry consumption demonstrated increasing activation in the left pre-central gyrus, left middle frontal gyrus, and left inferior parietal lobe, as measured by blood oxygen level-dependent (BOLD) signaling, under conditions of working memory load	Q1
Kyoung Yun Kim (2018)	Semi-quantitative food frequency questionnaire (SQ-FFQ), mini-mental state examination (MMSE)	Odds ratio: Vegetables: [0.678 (95 % CI: 0.274-1.681)] Fruits: [0.144 (95 % CI: 0.044-0.468)]	Consumption of fruits was observed to substantially reduce the odds ratio related to the risk of mild cognitive impairment (MCI)	Q1

(Continues on next page)

Table II (Cont.). The details of the articles encompassed in this systematic review

Author (year)	Tools	Outcome (MCI)	Findings	Quality
Jay L. P. Fieldhouse (2020)	Visual Association Test (VAT), Rey Auditory Verbal Learning Task, visual object and space perception battery, trail making test (TMT), frontal assessment battery, the backward condition of digit span, the color-word subtest of the Stroop test, letter fluency, Dutch Healthy Diet-Food Frequency Questionnaire (DHD-FFQ)	-	The studies indicated that reduced consumption of vegetables is linked with diminished overall cognitive abilities, including aspects of visuospatial skills, attention, and executive functions	Q1
Qiumin Huang (2021)	Semi-quantitative food frequency questionnaire, Montreal Cognitive Assessment (MoCA)	Odds ratio: Consumption of fresh vegetables: [1.03 (95 % CI: 0.86-1.23)] Fresh fruit: [0.93 (95 % CI 0.77-1.11)]	Individuals who consumed more fresh vegetables and fruits generally exhibited better overall cognitive function and specific cognitive domains and were less likely to have mild cognitive impairment (MCI)	Q1
Afei Qin (2023)	Mini-mental State Examination (MMSE), PhenX (consensus measurements for phenotypes and exposures) Toolkit, Psychological Well-Being (PWB) scale, interview	Odds ratio: Vegetable intake: [1.075 (95 % CI: 1.038-1.114)] Fruit intake: [0.995 (95 % CI: 0.869-1.14)]	Elderly individuals with regular consumption of fruits and vegetables in their diet showed a lower risk of mild cognitive impairment (MCI)	Q1
Shih-Wei Nien (2023)	Clinical dementia rating (CDR), mini-mental state examination (MMSE), dietary records	Odds ratio: MIND diet (plant-based foods): [0.20 (95 % CI: 0.04-0.99)]	Consumption of fruit has a positive relationship with the Mini-Mental State Examination (MMSE) scores	Q1
Yingjiao Deng (2024)	Montreal Cognitive Assessment-Basic (MoCA-B) scale, Simple Food Frequency Counting Survey Scale	-	Consumption of fruits and root vegetables was associated with a reduced risk of mild cognitive impairment (MCI)	Q1
Iman I. Salama (2019)	Montreal Cognitive Assessment test (MoCA), Addenbrooke's Cognitive Examination III (ACE III), The Quick Mild Cognitive Impairment (Quick MCI)	Odds ratio: Vegetables: [1.2 (95 % CI: 1.04-1.43)]	A low monthly consumption of vegetables was identified as a predictive factor for mild cognitive impairment (MCI)	Q3

The quality evaluation of the studies incorporated in the review was conducted using the JBI critical appraisal checklist. From the overall selection, 32 papers were identified as high quality, three as moderate quality, and three as low quality.

MAIN FINDINGS

Among the 38 studies, only 2 studies with moderate quality levels did not show a significant relationship between vegetable consumption and the change in the risk of mild cognitive impairment. 36 studies (94.7 percent) revealed that fruit and vegetable consumption can affect the occurrence of mild cognitive impairment.

The values of the odds ratio related to the effect of vegetable consumption and fruit intake on the decreased risk of mild cognitive impairment were between 0.20 to 0.82 and 0.14 to 0.92,

respectively. Also, the values of the odds ratio related to insufficient fruit and vegetable consumption on the increased risk of this disease were between 1.03 to 2.52 and 1.49 to 1.82. The lowest odds ratio was observed in the relationship between the MIND diet (plant-based foods) and the decreased risk of this impairment (OR: 0.20) and the highest odds ratio was related to the association between total vegetable consumption and the increased risk of MCI (OR: 2.52). The lowest odds ratio was seen in the relationship between total fruit consumption and the decreased risk of this impairment (OR: 0.14) and the highest odds ratio was also related to the association between total fruit consumption and the increased risk of MCI (OR: 1.82). Only two studies investigated the combination effect of fruit and vegetable consumption on the risk of MCI. The results of these studies showed that a few daily consumptions of fruits/vegetables can increase the odds ratio related to the risk of MCI by 1.77 and the hazard ratio of this risk by 1.38.

RESULTS OF THE META-ANALYSIS

Regarding the high heterogeneity of the results, the meta-analysis of the odds ratio values was performed using a random effect model. Figure 2 shows the meta-analysis results related to the odds ratio of the relationship between vegetable and fruit consumption and decreased risk of mild cognitive impairment, respectively. The results showed that vegetable consumption [odds ratio: 0.60 (95 % CI: 0.40 to 0.79)] and fruit intake [odds ratio: (95 % CI: 0.46 to 0.86)] can decrease the risk of MCI.

Table III describes the findings of subgroup analysis for the odds ratio values of these relationships. On consumption of vegetables and fruits, the results showed that the decrease in risk of MCI was higher in high-income countries, east/southwest Asia/Oceania, and after 2015.

DISCUSSION

Given the prevalence of cognitive impairment in different countries, it is very important to identify factors affecting the incidence of these impairments. One of these factors is the consumption of fruits and vegetables. Mild cognitive impairments

are a warning stage that can be controlled to prevent more serious consequences. However, the results of studies on fruit and vegetable consumption and the occurrence of this disorder have not been summarized in previous studies. Therefore, the present study aimed to investigate the effect of fruit and vegetable consumption on the decreased risk of mild cognitive impairment in patients referring to health examination centers.

Thirty-six studies (94.7 percent) revealed that fruit and vegetable consumption can affect the occurrence of mild cognitive impairment. Therefore, it can be concluded that fruit and vegetable consumption has a significant effect on the increased risk of MCI. However, it should be noted that to increase the effectiveness of fruit and vegetable consumption on MCI, the consumption of other foods should be controlled (23). The consumption of some unhealthy foods, such as fast foods, can reduce the effect of fruits and vegetables (24,25), and the consumption of healthy foods, such as dairy products and fish, can increase the effect of these foods on mild cognitive impairment (26,27). Nicklaus and Remy also concluded that practices related to complementary feeding, such as timing and food diversity, are likely linked to the development of healthy dietary patterns, including the consumption of fruits and vegetables (28).

Research has also indicated a relationship where increased consumption of plants is associated with better cognitive preservation, particularly when fruits and vegetables are consumed together (29–31). Recent research emphasizes the necessity of both fruit and vegetable intake to support cognitive health in the elderly. It can be because of several mechanisms, which will be explained below.

Fruits and vegetable consumption may lower the risk of mild cognitive impairment (MCI) due to their numerous health advantages, including their roles in reducing inflammation and oxidative stress, boosting metabolic processes, improving vascular health, and enhancing the conduction of nerve signals (32). The benefits of fruits and vegetables are due to the contribution of nutrients and phytochemicals such as antioxidants, flavonoids, folate, vitamin C, and vitamin D. Firstly, fruits and vegetables are rich sources of dietary antioxidants such as those found in berries, which may influence the onset of MCI. The brain is particularly vulnerable to oxidative harm, and either oxidative stress or insufficient antioxidant defenses are likely contributors to the development and progression of both dementia and possibly MCI (33). Secondly, these foods are also rich in flavonoids, which are believed to support cognitive function through their neuroprotective effects, improving neuronal activity and promoting the growth of new neurons (34). Thirdly, a significant amount of folate found in fruits and vegetables plays a role in DNA methylation, a process critical for aging and the development of dementia, by acting as a methyl donor (35). Additionally, folate influences the expression of both β -secretase and γ -secretase, enzymes involved in the production of A β and the formation of amyloid plaques (35). Folate also plays a role in reducing tau protein phosphorylation and the subsequent development of neurofibrillary tangles by indirectly modulating the activity of protein phosphatase cyclin-dependent kinase and glycogen synthase kinase (35). Furthermore,

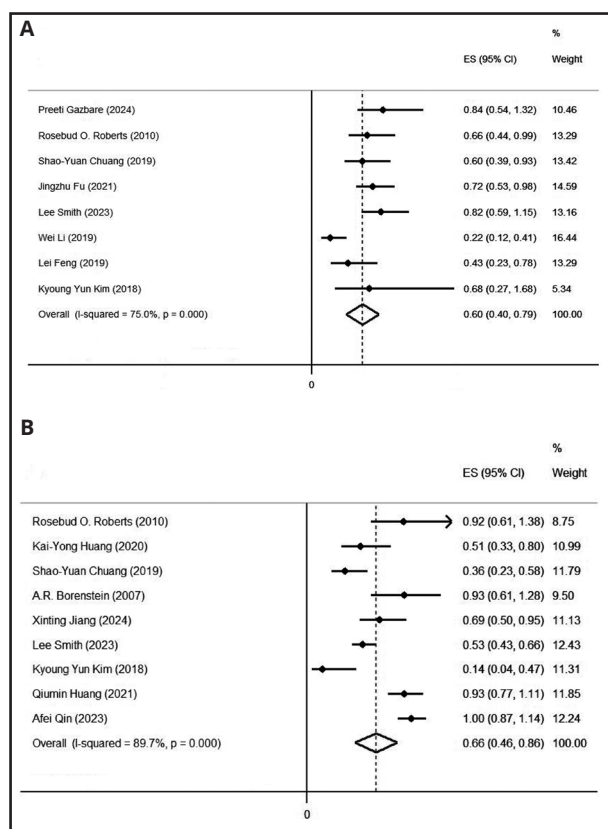


Figure 2. The results of the meta-analysis related to the odds ratio values of the relationship between vegetable intake (A) and fruit consumption (B), and the decreased mild cognitive impairment.

Table III. Results of subgroup analysis for the vegetable consumption and MCI risk

Type	Subgroup analysis					
Vegetable consumption	Subgroup	Category (number of studies)	OR [95 % CI]	I ² (%)	Q statistic (df)	p of heterogeneity
	Income level	High income (3) LMICs (5)	0.55 [0.36, 0.74] 0.62 [0.34, 0.90]	0.0 84.7	2 4	0.479 < 0.001
	Region	Europe (-)	-	-	-	-
		East /southeast Asia/Oceania (6)	0.54 [0.32, 0.77]	75.6	5	0.001
		Middle East (-)	-	-	-	-
Americas (1)		0.66 [0.38, 0.93]	-	0	-	
	Africa (-)	-	-	-	-	
	Study date	In or before 2015 (1) After 2015 (7)	0.66 [0.38, 0.93] 0.59 [0.37, 0.81]	- 77.4	0 6	- < 0.001
Fruit consumption	Income level	High income (3) LMICs (6)	0.49 [0.09, 0.89] 0.73 [0.51, 0.95]	85.1 90.0	2 5	0.001 < 0.001
	Region	Europe (-)	-	-	-	-
		East /southeast Asia/Oceania (7)	0.65 [0.39, 0.90]	91.5	6	< 0.001
		Middle East (-)	-	-	-	-
		Americas (1)	0.92 [0.53, 1.30]	-	0	-
	Africa (-)	-	-	-	-	
	Study date	In or before 2015 (2) After 2015 (7)	0.92 [0.67, 1.17] 0.59 [0.37, 0.82]	0.0 91.8	1 6	0.969 < 0.001

a deficiency in vitamin B within the diet can lead to elevated levels of homocysteine, which is directly neurotoxic and can impair neurotransmitter synthesis through the 1-carbon pathway (36). Several randomized controlled trials have indicated that high-dose vitamin B supplementation may decelerate brain shrinkage in individuals with mild cognitive impairment (37,38). Additionally, research has suggested a relationship between plasma vitamin C levels and cognitive function (39,40). It has been observed that individuals with mild cognitive impairment have lower plasma vitamin C levels compared to healthy individuals, and a vitamin C-rich diet could lower the risk of cognitive decline (41). The protective effects on cognitive health may particularly be attributed to high fruit consumption, which is a major source of vitamin C (33). Ultimately, the cognitive advantages derived from fruit and vegetable intake are likely due to the presence of various bioactive compounds rather than any single nutrient. Indeed, dietary supplements have not consistently shown effectiveness in preventing dementia among older adults (42-44).

However, there are probable differences between the effect of fruit and vegetable consumption on the risk of mild cognitive impairments, which can be because of different compounds in these products. In addition to the direct effect, vegetables, and fruits can indirectly affect the risk of MCI through different ways. Sufficient fruit consumption, particularly the fiber found in fruits, could support cognitive health by aiding in long-term weight control and decreasing the likelihood of developing type 2 diabetes

and metabolic syndrome (45), while the inorganic nitrates present in green leafy vegetables are believed to enhance cognitive functions by safeguarding cardiovascular health (46,47). The results of the meta-analysis in the present study showed that vegetable consumption [0.60 (95 % CI: 0.40 to 0.79)] and fruit intake [0.66 (95 % CI: 0.46 to 0.86)] can decrease the risk of MCI. Which group of vegetables or fruits is more beneficial depends on the type of fruit or vegetable and their consumption pattern. Moreover, this may be the reason for the differences between the results of different studies. So the range of odds ratio values related to the effect of fruit and vegetable consumption on the decreased risk of MCI in the present study was between 0.20 and 0.92.

The observed potential U-shaped correlation between the intake of vegetables and mild cognitive impairment (MCI) is intriguing. This may be attributed to the specific types of vegetables consumed by individuals who eat large quantities of them. For instance, certain vegetables such as leafy greens with high amounts of vitamin K and folate might show greater protective benefits against cognitive decline compared to other types (44). Additionally, it is important to consider that increased fruit consumption might lead to hyperglycemia in older adults with diabetes *mellitus*. Based on the Clinical Practice Guideline, it is advised that diabetic patients consume two servings of fruits daily that are rich in dietary fiber and have a low glycemic index to maintain effective glycemic control (48). To supply the required nutrients,

Lalji et al. state that daily consumption of four to five portions of fruits and vegetables is generally recommended (49). However, fruit and vegetable consumption must be balanced. Jung et al. found that the excessive intake of these foods can be associated with adverse effects particularly for people with diabetes and hypertension because fruits have a high level of natural sugars and canned vegetables have a high sodium level (50).

In terms of vegetable type, tomatoes, and onions were identified as the most consumed vegetables. Tomatoes are rich in lycopene, a significant bioactive compound (51). Lycopene acts as a natural neuroprotective agent and is thought to support cognitive health and address various neurological conditions such as cerebral ischemia, Parkinson's disease (PD), Alzheimer's disease (AD), and depression (52). Onions contain quercetin, another potent flavonoid (53). The study also highlighted that tropical fruits are abundant in natural antioxidants like phenolic and polyphenolic compounds, flavonoids, and ascorbic acid, more so than fruits from temperate climates (54). Tropical fruits including bananas, guavas, jackfruits, papayas, dragon fruits, and mangoes are noted because of their high dietary fiber content and generally low to moderate glycaemic indices. These properties may enhance glycemic management in older adults with diabetes (55). Therefore, the intake of tropical fruits can protect diabetic older adults from cognitive decline (48).

Among various products, the results showed that the lowest odds ratio was observed in the relationship between the MIND diet (plant-based foods) and the decreased risk of this impairment (OR: 0.20). Therefore, it seems that fruits and vegetable intake associations with consumption of other useful product can make highest effect on the decreased risk of MCI. The observed decrease in risk may be linked to various neuroprotective components found in the MIND diet. For example, fish rich in omega-3 fatty acids possess antioxidant and anti-inflammatory properties (56), while mushrooms play a role in preventing the formation of beta-amyloid (57). Algae are known for their neuroprotective attributes (58), and soy enhances cognitive abilities through its antioxidant content (59). The compound allicin in garlic helps in slowing the breakdown of acetylcholine (60). Similarly, epigallocatechin gallate in tea decreases oxidative stress (61). Corn is another source of antioxidants that contribute to neuroprotection (62). Edible plant oils, which are high in essential fatty acids, have neuroprotective benefits and have a higher unsaturated fatty acid content than animal oils (63). Additionally, the abundant vitamins in fruits and vegetables slow cognitive deterioration (64), and nutrients like polyunsaturated fatty acids and polyphenols are known to improve cognitive performance (65).

On consumption of vegetables and fruits, the results subgroup analysis showed that the decrease in risk of MCI was higher in high-income countries, east/ southwest Asia/ Oceania, and after 2015. It may be because of differences in the nutritional habits between Asian people, particularly the population of East Asia and European and American people. For example, staples in Asian diets often include rice, noodles, and cereals, while Western diets prefer wheat-based products such as bread and pasta. Additionally, East Asians commonly consume fish, beans, and soy

products for protein, while the Western population favors meat-based proteins. Differences in food preparation methods also contribute to the distinctiveness between these dietary cultures (66). Also, the results show that high-income countries compared to low- and medium-income countries may place greater emphasis on healthy diets and include preventive measures to reduce cognitive impairment in their intervention plans. Also, access to healthy foods can be associated with higher costs, which limits their use in low- and middle-income countries (67).

As a limitation, the studies didn't consider the difference between people with different demographic characteristics in the relationship between fruit and vegetable consumption and the decreased risk of MCI. Moreover, in the reviewed studies, the effects of fruit and vegetable consumption were reported separately but not together. Therefore, it is suggested that the combined impacts of their consumption on mild cognitive impairment be examined in the next studies. Furthermore, it is required that the effect of fruit and vegetable intake along with the consumption of other foods in different cultures is investigated to eliminate the role of confounders.

CONCLUSIONS

In total, the results showed that fruit and vegetable consumption can significantly decrease the risk of mild cognitive impairment. So, the range of odds ratio values related to this relationship was between 0.20 and 0.92. The results also indicated that the decrease in risk of MCI was higher in high-income countries and east/southwest Asia/Oceania. Therefore, it is suggested that preventive plans for fruit and vegetable consumption should be implemented, especially in low- and middle-income countries. Also, it is recommended that the effectiveness of these interventional plans is investigated in the next cohort studies.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All methods were performed in accordance with relevant guidelines and regulations. However, this study is a systematic review and meta-analysis and does not require ethical approval by the institution.

DATA AVAILABILITY

The data used to derive the findings in this study are available from the corresponding author upon reasonable request.

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