Review

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Dietary Fat Intake and Cognitive Function among Older Populations: A Systematic Review and Meta-Analysis

G.-Y. Cao[1], M. Li[1], L. Han[2], F. Tayie[3], S.-S. Yao[1], Z. Huang[1], P. Ai[1], Y.-Z. Liu[4], Y.-H. Hu[1,5], B. Xu[5]

1. Department of Epidemiology and Biostatistics, School of Public Health, Peking University, Beijing, China; 2. Department of Medicine, Yale School of Medicine, New Haven, Connecticut, US; 3. Department of Food, Nutrition and Dietetics; Human Environmental Studies; Southeast Missouri State University; Cape Girardeau, MO, US; 4. Department of Toxicology, School of Public Health, Tianjin Medical University, Tianjin, China; 5. Peking University Medical Informatics Center, Beijing, China

Corresponding Author: Beibei Xu, Peking University Medical Informatics Center, Beijing, China. Phone: 010-82805904. E-mail: xubeibei@bjmu.edu.cn

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Abstract

OBJECTIVE: The associations between dietary fat intake and cognitive function are inconsistent and inconclusive. This study aimed to provide a quantitative synthesis of prospective cohort studies on the relationship between dietary fat intake and cognitive function among older adults.

METHODS: PubMed, EMBASE, PsycINFO and Web of Science databases were searched for prospective cohort studies published in English before March 2018 reporting cognitive outcomes in relation to dietary fat intake. Four binary incident outcomes included were mild cognitive impairment (MCI), dementia, Alzheimer disease (AD) and cognitive impairment. The categories of dietary fat intake were based on fat consumption or the percentage of energy from fat consumption, including dichotomies, tertiles, quartiles and quintiles. The relative risk (RR) with the corresponding 95% confidence intervals (CIs) was pooled using a random effects model.

RESULTS: Nine studies covering a total of 23,402 participants were included. Compared with the lowest category of consumption, the highest category of saturated fat intake was associated with an increased risk of cognitive impairment (RR = 1.40; 95% CI: 1.02-1.91) and AD (RR: 1.87, 95% CI: 1.09-3.20). The total and unsaturated fat intake was not statistically associated with cognitive outcomes with significant between-study heterogeneity.

CONCLUSION: This study reported a detrimental association between saturated fat intake and cognitive impairment and mixed results between unsaturated fat intake and selected cognitive outcomes. Given the substantial heterogeneity in the sample size and methodology used across studies, the evidence presented here should be interpreted with caution.

Key words: High-fat diet, cognitive function, mild cognitive impairment, dementia, Alzheimer's disease.

Introduction

Cognitive decline has been estimated to appear among approximately 25% to 50% of the community-dwelling older population (1). The burden of cognitive impairment as well as the associated financial costs could be unbearable for individuals, families, and public health services (2, 3). Previous studies have reported that dietary fat intake served as a risk factor for cognitive decline among older populations (4-6). Dietary habits of older adults have undergone significant changes during a period of nutrition transition, such as an increasing trend in percentage of energy from total fat, from about 25% in 1991 to 32% in 2009 (7). Recently, the Prospective Urban Rural Epidemiology (PURE) study, which was conducted in 18 countries located on 5 continents, showed that higher total fat and saturated fat (SFA) intake were associated with reduced total mortality (8). Inconsistent findings were reported regarding the associations between different types of dietary fat intake and a variety of health outcomes, including cognitive decline, diabetes, cancer, stroke, myocardial infarction and mortality (9-13). A review by nutrition scientists reported that replacement of SFA with naturally occurring unsaturated fats (UFA) provided health benefits for the general population (14).

In the past decade, an increasing number of population-based studies have been conducted on the associations between dietary fat intake and cognitive impairment (15-20). However, results from these studies were inconsistent and inconclusive. Owing to different study designs and methods for assessments of cognitive outcomes or dietary fat, it is difficult to draw conclusions on the consistency of the associations. In addition, previous reviews and meta-analyses have mostly focused on the associations between polyunsaturated fatty acids (PUFAs) and cognitive function (21-23). They reported that higher docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) intakes were associated with better cognitive performance. To our knowledge, no previously published meta-analysis has examined cognitive outcomes in relation to the intake of different types of dietary fat among older adults. Therefore, this study aimed to examine the associations between different types of dietary fat intake and cognitive outcomes among older populations.

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Methods

Search strategy

Two reviewers (C.G.Y. and L.M.) searched for articles published before March 2018 using electronic databases, including PubMed, EMBASE, PsycINFO, and Web of Science. Studies were identified using the search terms "(fat intake OR high-fat diet OR dietary fat) AND (cognition OR cognitive function OR cognitive decline OR cognitive impairment OR dementia OR Alzheimer's)". The language was restricted to English. The complete search strategy is presented in Supplementary Table 1.

Eligibility criteria

Original studies were included in this meta-analysis if they met all of the following criteria: (1) investigated the association between dietary total fat, SFA, MUFA, or PUFA intake and cognitive outcomes in population-based samples; (2) used a prospective cohort design; (3) included a population aged ≥ 55 years; (4) incorporated the cognitive outcomes of mild cognitive impairment (MCI), dementia, and Alzheimer's disease (AD) as defined by validated cognitive tests; and (5) reported the relative risks (RRs), odds ratios (ORs), or hazard ratios (HRs) with corresponding 95% confidence intervals (CIs) of cognitive outcomes in relation to dietary fat intake.

Outcome measures

Four binary incident outcomes, including MCI, dementia, AD and cognitive impairment, were based on standard tests or diagnosis. In this study, cognitive impairment was the overall composite estimate of cognitive function, including any cognitive outcome, either MCI or dementia or AD (24, 25). Table 1 shows cognitive outcomes and their assessment tools.

Definition of dietary fat intake

The dietary fat intake, including total, SFA, MUFA and PUFA, were assessed by using the semiquantitative Food Frequency Questionnaire (FFQ) in each study included. The categories of dietary fat intake were based on fat consumption or the percentage of energy from fat consumption, including dichotomies, tertiles, quartiles and quintiles. Table 1 shows the types and categories of dietary fat.

Data extraction

Two reviewers (L.M. and C.G.Y.) reviewed the articles and identified all relevant studies independently. Differences in study selection were resolved by consensus discussion and consultation with a third reviewer (Y.S.S.). Data from the selected articles were extracted for this study. If multiple articles were published using the same cohort and the same cognitive outcomes, we included only the article with the mostly complete details. If multiple articles from the same cohort reported different cognitive outcomes, we included each of these articles separately in the analysis. The extracted data included the first author's last name, publication year, length of follow-up, country where the study was conducted, sample size, participants' ages at baseline, dietary assessment, cognitive outcomes and their assessment tools, categories of fat intake, covariates in the final model, and crude or adjusted RRs, ORs, or HRs with 95% CIs (Table 1). The cutoff value for each category of fat intake and the RR of cognitive impairment in relation to the individual type of fat intake are shown in Supplementary Table 2.

Risk of bias/study quality

Publication bias was estimated with Egger's regression asymmetry test (if the number of studies was ≥ 3) or Begg's adjusted rank correlation test (if the number of studies was < 3) (26, 27) which was conducted by two investigators (C.G.Y. and L.M.) independently. The quality of the included studies was evaluated independently by two investigators (L.M. and C.G.Y.) using the Newcastle-Ottawa Scale (NOS) (score range 1-9) (28). Our study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (29) and the Meta-analysis of Observational Studies in Epidemiology (MOOSE) checklist (30).

Statistical analysis

If the incidence of an outcome of interest in the study population was low, the ORs and HRs were considered as RRs (31). We calculated the summarized risk estimates of the highest vs. lowest fat intake categories to analyze the relationship between dietary fat intake and cognitive outcomes, including cognitive impairment, MCI, dementia, and AD. Statistical heterogeneity among the studies was estimated using the I2 statistic, and very low, low, moderate, and high degrees of heterogeneity were defined as ≤ 25%, 25% to ≤ 50%, 50% to ≤ 75%, and ≥ 75%, respectively (32). All effect estimates were then pooled using a weighted random-effects model. A two-sided P value < 0.05 was considered statistically significant (27). All analyses were performed using Stata software (version 14.0; Stata SE Corporation LP, College Station, TX, USA).

Table 1. Summary of studies on the associations between fat intake and cognitive outcomes

Author/Year	Follow-up (y)	Country	Sample size (% man)	Age (y)	Dietary assessment	Cognitive outcomes (Assessment tools)	Types of fat	Fat intake	Relative risk (95% CI) (Highest vs. lowest)	Covariates	NOS score
Eskelinen et al. (2008)	21	Finland	1,499 (37.7)	65-80	semiquantitative FFQ	MCI (MMSE)	Total fat SFA MUFA PUFA	Intake (grams) categorized into dichotomies	1.69 (1.00–2.87) 2.36 (1.17–4.74) 1.81 (0.87–3.80) 0.94 (0.45–1.96)	Midlife age, sex, education, follow-up time and other subtypes of fats, ApoE ε4 allele and midlife vascular risk factors including smoking, SBP, cholesterol, and BMI	9
Kalmijn et al. 1997	2.1	The Netherlands	5,386 (40.9)	Mean 67.7	170-item semi-quantitative FFQ	Dementia (DSM-III-R, NINDS-AIREN) AD (NINCDS-ADRDA)	Total fat SFA Total fat SFA	Intake (grams) categorized into tertiles	2.4 (1.1-5.2)* 1.9 (0.9-4.0) 1.6 (0.6-3.9) 1.3 (0.5-3.3)	Age, gender, education, and total energy intake	9
Luchsinger et al. 2002	4	United States	980 (33)	Mean 73.5	61-item semiquantitative FFQ	AD (NINCDS-ADRDA)	Total fat	Intake (grams) categorized into quartiles	1.41 (0.93-2.13)	Age, gender, presence of ApoE ε4 allele, years of education, and ethnic group	9
Laitinen et al. 2006	21	Finland	1,449 (37.9)	Mean 71.3	135-item semi-quantitative FFQ	Dementia (DSM-IV) AD (NINCDS-ADRDA)	SFA PUFA Total fat SFA MUFA PUFA	Intake (grams) categorized into quartiles	2.74 (0.65-11.56) 1.01 (0.29-3.55) 0.79 (0.29-2.12) 2.34 (0.51-10.74) 1.02 (0.26-4.01) 0.69 (0.22-2.19)	Age, gender, education, follow-up time, other subtypes of fat from spreads and milk, ApoE ε4 allele, midlife SBP, BMI, cholesterol, smoking, and a history of myocardial infarction, stroke and diabetes	9
Morris et al. 2003	3.9	United States	815 (39)	≥65	154-item semi-quantitative FFQ	AD (NINCDS-ADRDA)	Total fat SFA MUFA	Intake (grams) categorized into quartiles	0.9 (0.4-1.8) 2.2 (1.1-4.7)* 0.8 (0.4-1.8)	Age, time period of observation, indicator variables of quintiles of nutrition intake, gender, race, education, ApoE ε4 allele, interaction between race and ApoE ε4 allele	9
Okereke et al. 2012	4	United States	6,183 (0)	≥ 65	131 - item semi-quantitative FFQ	MCI (TICS, EBMT)	SFA MUFA PUFA	% Energy intake categorized into quintiles	1.64 (1.04-2.58) 0.52 (0.31-0.88) 1.37 (0.97-1.94)	Age, education, aspirin and vitamin E randomization assignment, race, household income, BMI, current smoking, postmenopausal hormone use, hypertension, elevated cholesterol, depression, diabetes, daily alcohol consumption, and moderate or above frequency of exercise	9
Roberts et al. 2012	3.7	United States	973 (51.0)	Median 79.5	128-item semi-quantitative FFQ	MCI (CDR)	Total fat SFA MUFA PUFA	% Energy intake categorized into quartiles	0.56 (0.34-0.91)* 0.64 (0.39-1.05) 0.78 (0.47-1.28) 0.66 (0.42-1.05)	Gender, education, total daily energy, nonparticipation at baseline, a single macronutrient, ApoE ε4 allele, type 2 diabetes mellitus, depressive symptoms, body mass index, stroke, marital status, smoking status, alcohol, occupation, and exercise frequency	9
Solfrizzi et al. 2006 (a)	2.6	Italy	278 (55.4)	Mean 73.01	77 - item semi-quantitative FFQ	MCI (MMSE)	SFA MUFA PUFA	Intake (grams) categorized into quartiles	0.86 (0.21-3.49) 0.43 (0.11-1.75) 0.25 (0.0.3-1.86)	None Age, education, and total energy intake	7
Vercambre et al. 2009	13	France	5,839 (0)	Mean 65.5	208-item semi-quantitative FFQ	Dementia (DECO)	Total fat SFA MUFA PUFA	Intake (grams) categorized into tertiles	1.03 (0.83-1.28) 1.02 (0.82-1.26) 1.16 (0.93-1.44) 1.04 (0.84-1.30)	Age, education, BMI, physical activity, total energy intake, smoking, vitamin and/or calcium, postmenopausal hormones, depression, cancer, coronary heart disease, stroke, diabetes mellitus, hypertension, and hypercholesterolemia	9

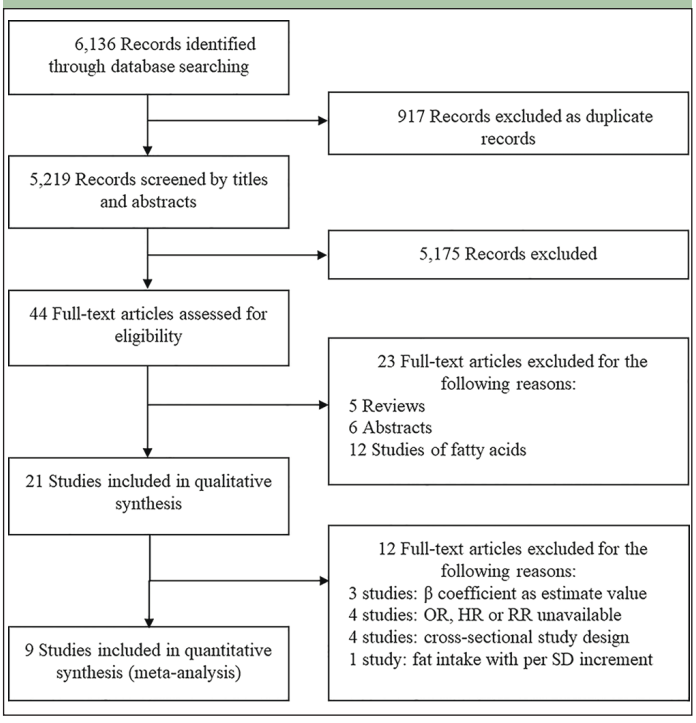
*Statistically significant difference ($P < 0.05$); SFA = saturated fat; MUFA = monounsaturated fat; PUFA = polyunsaturated fat; FFQ= Food Frequency Questionnaire.CDR = Clinical Dementia Rating, MMSE = Mini Mental State Examination, TICS = Telephone Interview for Cognitive Status, EBMT = East Boston Memory Test, IADL = Instrumental Activities of Daily Living, DECO = Observed Cognitive Deterioration ("DEtérioration Cognitive Observée"); DSM-IV = Statistical Manual of Mental Disorders, 4th edition; CSI-D = Community Screening Instrument for Dementia; DSM-III-R = Diagnostic and Statistical Manual of Mental Disorders, third edition; NINDS-AIREN = National Institute of Neurological Disorders and Stroke and Association Internationale pour la Recherche et l'Enseignement en Neurosciences; NINCDS-ADRDA = National Institute of Neurological and Communicative Disorders and Stroke-Alzheimer's Disease and Related Disorders Association.

Results

Literature research and characteristic of studies

A total of 6,080 articles were identified based on the initial search (Figure 1). After applying the inclusion criteria, nine studies covering 23,402 participants from five countries, including the United States (5, 17, 33, 34), the Netherlands (35), France (18), Finland (36, 37) and Italy (38), met the inclusion criteria and were included in the meta-analysis. Table 1 summarizes the characteristics and NOS scores of the nine included studies. The sample size of the included studies ranged from 278 to 6,183 participants, and the follow-up period ranged from 2.1 to 21 years. Seven studies included both men and women and two studies included only women (5, 18). The study quality was assessed using the NOS scale, with a score ≥ 7 considered high quality (overall mean NOS score = 8.8, SD = 0.6, range = 7-9). The included studies varied in terms of the covariates that were adjusted; however, the majority of the studies were adjusted for age, gender and education.

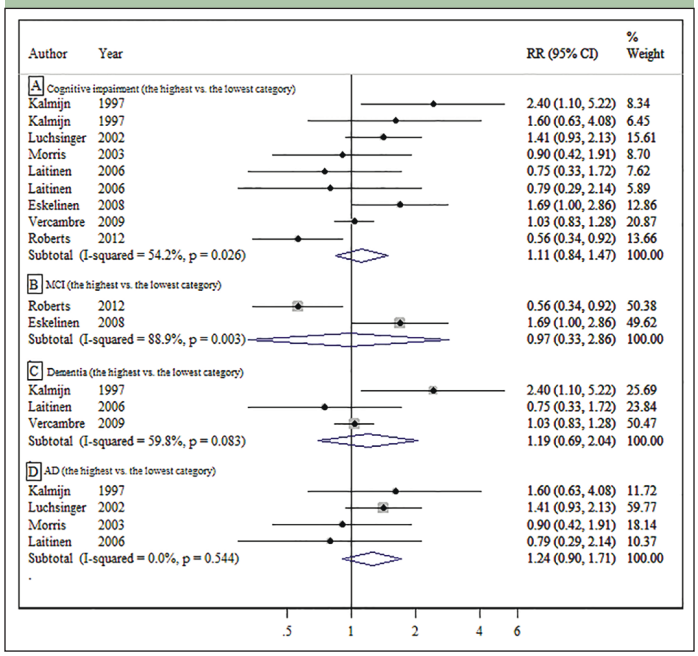
Figure 1. Flow diagram of the systematic review process



Total fat and cognitive outcomes

This meta-analysis of seven studies suggested that compared with the lowest category of total fat intake, the highest category was not significantly associated with the risk of cognitive impairment (RR = 1.11; 95% CI: 0.84-1.47), with no evidence of publication bias (P = 0.76) but significant between-study heterogeneity (I2 = 54.2%, P = 0.03) (Figure 2A).

Figure 2. Forest plots of associations between total fat intake and cognitive outcomes, including cognitive impairment (A), (B) MCI (B), dementia (C) and AD (D)



The meta-analysis of two studies found that compared with the lowest category of total fat intake, the highest category of total fat intake was not associated with the risk of MCI (RR = 0.97; 95% CI: 0.33-2.86), with no evidence of publication bias (P = 0.32) but significant between-study heterogeneity (I2 = 88.9%, P < 0.01) (Figure 2B).

This meta-analysis of three studies did not find a significant association between the highest category of total fat intake and the risk of dementia (RR = 1.19; 95% CI: 0.69-2.04) when compared with the lowest category, with no evidence of publication bias (P = 0.74) but moderate heterogeneity among the studies (I2 = 59.8%, P = 0.08) (Figure 2C).

Regarding AD, the summarized results of four studies showed that compared with the lowest category of total fat intake, the highest category was not associated with the risk of AD (RR = 1.24; 95% CI: 0.90-1.71) (Figure 2D). No evidence of publication bias (P = 0.43) or heterogeneity (I2 = 0%, P = 0.54) was observed

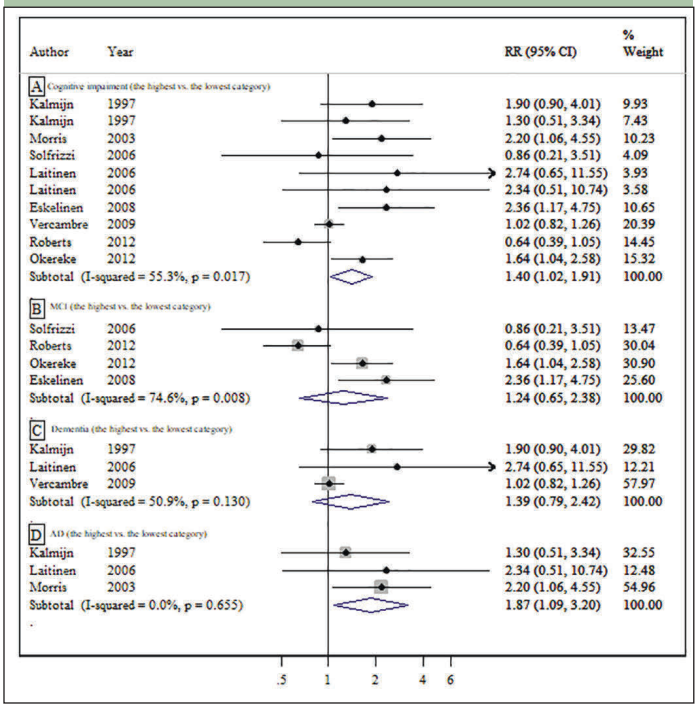
SFAs and cognitive outcomes

The meta-analysis of eight studies suggested that compared with the lowest category, the highest SFA category was associated with an increased risk of cognitive impairment (RR = 1.40; 95% CI: 1.02-1.91), with no evidence of publication bias (P = 0.12) but significant between-study heterogeneity (I2 = 55.3%, P = 0.02) (Figure 3A).

The meta-analysis of four studies found that compared with the lowest category, the highest SFA category was

not associated with the risk of MCI (RR = 1.24; 95% CI: 0.65-2.38), with no evidence of publication bias (P = 0.95) but significant between-study heterogeneity (I2 = 74.6%, P < 0.01) (Figure 3B).

Figure 3. Forest plots of associations between SFA intake and cognitive outcomes, including cognitive impairment (A), MCI (B), dementia (C) and AD (D)



The summarized estimate of three studies indicated that the highest SFA category was not associated with an increased risk of dementia (RR = 1.39; 95% CI: 0.79-2.42), with no evidence of publication bias (P = 0.12) but significant between-study heterogeneity (I2 = 50.9%, P = 0.13) compared with the lowest SFA category (Figure 3C).

The summarized results of three studies indicated an increased risk of AD (RR = 1.87; 95% CI: 1.09-3.20) for the highest versus the lowest SFA intake categories. No evidence of publication bias (P = 0.97) or heterogeneity (I2 = 0%, P = 0.66) was observed (Figure 3D).

MUFAs and cognitive outcomes

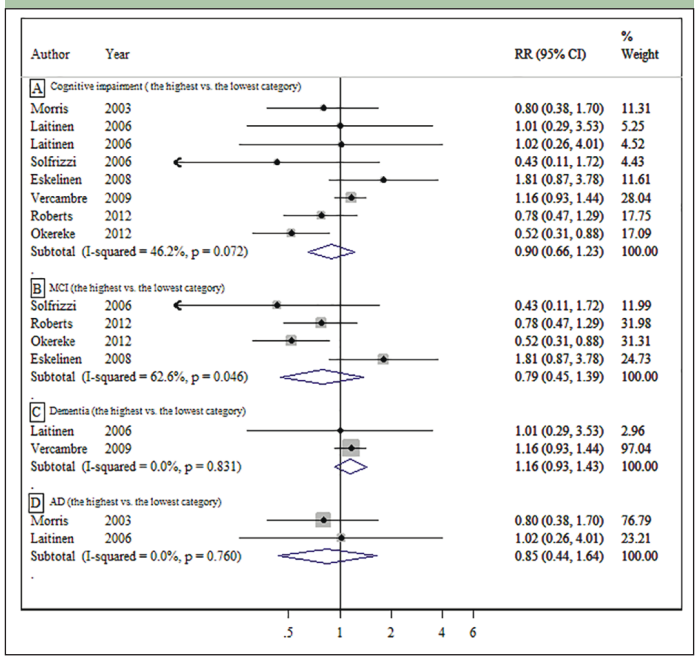
The meta-analysis of seven studies suggested that compared with the lowest category, the highest MUFA intake category was not significantly associated with the risk of cognitive impairment (RR = 0.90; 95% CI: 0.66-1.23), with no evidence of publication bias (P = 0.35) and low heterogeneity (I2 = 46.2%, P = 0.07) (Figure 4A).

The summarized estimate of three studies indicated no significant association between the highest MUFA intake category and a decreased risk of MCI (RR = 0.79; 95% CI: 0.45-1.39), with no evidence of publication bias (P = 0.91) but significant between-study heterogeneity (I2 = 62.6%, P = 0.05) (Figure 4B).

Regarding dementia, the summarized estimate of two studies indicated that compared to the lowest MUFAs category, the highest MUFA category was not associated with the risk of dementia (RR = 1.16; 95% CI: 0.93-1.43) (Figure 4C). No evidence of publication bias (P = 0.32) or heterogeneity (I2 = 0%, P = 0.83) was observed.

For AD, the summarized results of two studies indicated no statistically significant association between MUFAs and AD (RR = 0.85; 95% CI: 0.44-1.64) (Figure 4D). No evidence of publication bias (P = 0.32) or heterogeneity (I2 = 0%, P = 0.76) was observed.

Figure 4. Forest plots of associations between MUFA intake and cognitive outcomes, including cognitive impairment (A), MCI (B), dementia (C) and AD (D)



PUFAs and cognitive outcomes

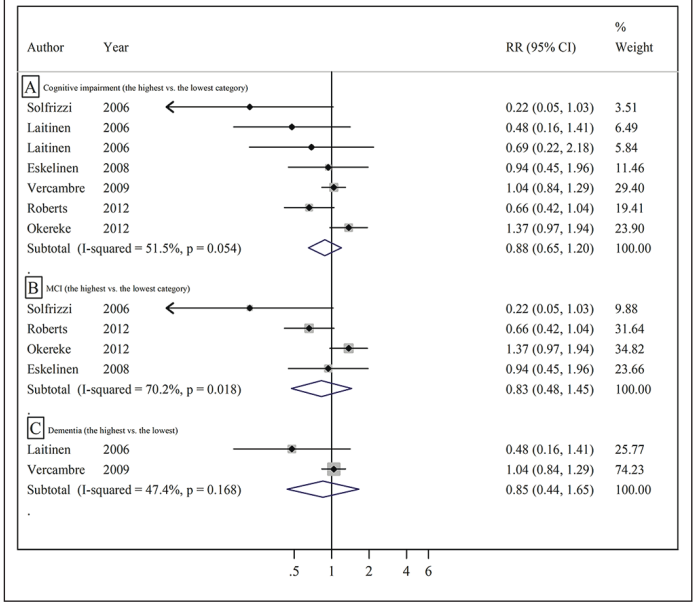
Five studies reported associations between the PUFA intake and cognitive function (Figure 5A). The summarized estimate suggested that compared with the lowest category, the highest PUFA intake category was not associated with the risk of cognitive impairment (RR = 0.88; 95% CI: 0.65-1.20), with no evidence of publication bias (P = 0.91) but significant between-study heterogeneity (I2 = 51.5%, P = 0.05).

Four studies reported an association between PUFAs and MCI. The summarized results suggested that compared with the lowest category, the highest PUFA intake category was not associated with the risk of MCI (RR = 0.83; 95% CI: 0.48-1.45), with no evidence of publication bias (P = 0.41); however, significant between-study heterogeneity (I2 = 70.2%, P = 0.02) was observed (Figure 5B).

The summarized estimate of two studies indicated no association between the highest PUFA intake category and the risk of dementia (RR = 0.85; 95% CI: 0.44-1.65),

when compared with the lowest category, with low heterogeneity (I2 = 47.4%, P = 0.17) (Figure 5C). No evidence of publication bias (P = 0.32) was observed.

Figure 5. Forest plots of associations between PUFA and cognitive outcomes, including cognitive impairment (A), MCI (B), dementia (C) and AD (D)



Discussion

Total Fat and cognitive outcomes

It should be noted that the relationship between total fat intake and cognitive function depending upon not only the quantity but also the quality of fat intake. One previous review of human epidemiological and animal studies reported both adverse and protective effects of the dietary total fat intake depending upon the quantity and quality of fat consumed (39). Moreover, one previous study has also suggested that the inconsistent associations between total fat intake and cognitive function reported in different studies may largely depend on the dietary fat composition (40).

SFAs and cognitive outcomes

Similar to our findings, a previous systematic review of three studies reported that old adults consuming a diet high in SFAs had an increased risk of dementia (41). Similarly, one cohort studies not included in this meta-analysis showed that compared with the lowest category of SFA intake, the highest category of SFA intake was associated with adverse changes in cognitive scores over different follow-up periods (6). However, one cohort study with relatively younger participants with an average age of 55.3 years reported compared with the lowest category of SFA intake, the highest category of SFA intake was not statistically significantly associated with cognitive decline assessed by four different tests (the 15 Words Verbal Learning Test, the Stroop Color Word Test, the Word Fluency test, and the Letter Digit Substitution Test) (19). Similarly, two cohort studies reported that compared with the lowest category of SFA intake, the highest category of SFA intake was not statistically significantly associated with cognitive decline among relatively healthy older women after a 3-year follow-up (16) or older women with high vascular risk after a 5-year follow-up (4).

A previous review of animal studies showed that chronic ingestion of SFAs at mid to high levels could adversely affect cognitive performance (42). A higher SFA intake was associated with an increased risk of CVD and cerebrovascular disease (43-45), which were subsequently related to cognitive impairment (46) and dementia, especially vascular dementia (47, 48). Dietary SFAs exert an effect on CVD through plasma lipoproteins that elevate low-density lipoprotein (LDL) cholesterol concentrations, which is considered the most important CVD risk factor (49, 50). Previous reviews (39, 51, 52) of human or rodent studies have suggested that a high-fat diet (HFD) rich in SFAs may result in neuronal cell dysfunction by inducing insulin resistance and impaired glucose regulation and finally lead to cognitive dysfunction. Other reviews also suggested that oxidative stress generated by fat metabolism and inflammation might explain the association between a HFD, especially high SFA intake, and aging-associated cognitive disorders (53, 54). Several animal studies have shown that mice fed a HFD rich in SFAs had inflammation induced by an increase in the Firmicutes-to-Bacteroidetes ratio (55-57).

UFAs and cognitive outcomes

Several cohort studies not included in this meta-analysis reported that compared with the lowest category of MUFA or PUFA intake, the highest category of MUFA or PUFA intake was not associated with the cognitive decline assessed by scores among older women with type 2 diabetes mellitus (58), as well as an old biracial community population aged ≥ 65 years (6) or a middle and old population aged between 43 to 70 years (19). However, one cohort study not included in this meta-analysis showed that compared with the lowest category of MUFA intake, the highest category of MUFA intake was significantly associated with better cognitive function during 3-year (16). Similar results were observed in another one cohort study reported that compared with the lowest category of MUFA or PUFA intake, the highest category of MUFA or PUFA intake was inversely related to risk of cognitive decline among the oldest women with high cardiovascular risk (4).

PUFAs and MUFAs can both exert potentially beneficial effects on cognition via antioxidant effects (59, 60), anti-inflammatory effects (61, 62), and vascular

protection through reducing macrophage uptake of plasma oxidized LDL (63, 64) and reducing triglycerides and apolipoprotein B (65-67). Other studies have shown that UFAs, especially PUFAs, might maintain cognitive function by reducing the risk of CVD and stroke with improved insulin sensitivity and glucose metabolism (68-72). The beneficial effect of PUFA on cognitive function may also be related to neuroprotection by maintaining the structural integrity of neuronal membranes (73) and enhancing synaptosomal membrane fluidity, thereby regulating neuronal transmission (74).

Limitations

Several factors limited the interpretation of our results. First, the limited number of studies as well as the considerable between-study heterogeneity may have reduced the precision of our pooled effect size estimates. Second, assessments of dietary fat intake were conducted using different items on FFQs across different settings, making a comparison of the results difficult in this meta-analysis study. Third, the definition and assessment of cognitive outcomes as well as the categories of dietary fat intake vary across studies which may result in misclassification bias. Participants were classified to each outcome using different formal diagnostic criteria, and different methods might group the same participant into different outcome categories. Furthermore, to avoid undue complexity, we simplified our meta-analysis by comparing only the highest versus the lowest fat intake categories due to varied cutoff points used to define the intermediate levels across studies. Finally, unmeasured or residual confounding in the source studies could not be addressed in this meta-analysis using only published data. Because there is insufficient number of studies reporting the dose-response relationship, the information provided was inadequate for further dose-response analyses.

Conclusion

In summary, this systematic review and meta-analysis found a detrimental association between SFA intake and the risk of cognitive function decline, whereas mixed results regarding the associations between UFA intake and the risk of selected cognitive function outcomes. However, given the substantial heterogeneity in the sample size and methodology used across studies, the evidence presented here should be interpreted with caution. Since a randomized clinical trial investigating dietary fat intake and cognitive function may not be feasible, due to practical considerations, future well-designed, prospective, cohort studies involving different populations are needed to confirm the associations between fat intake and cognitive outcomes and determine the age-, gender- and population-specific cutoff values for fat intake to provide evidence for more personalized dietary fat recommendations.

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Conflict of interest: The authors declare that they have no competing interests.

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