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Featured Article

Prudent diet may attenuate the adverse effects of Western diet on cognitive decline

Behnaz Shakersain[a,*], Giola Santoni[a], Susanna C. Larsson[b], Gerd Faxén-Irving[c], Johan Fastbom[a], Laura Fratiglioni[a,d], Weili Xu[a,e,**]

[a]Aging Research Center, Center for Alzheimer Research, Department of Neurobiology, Care Sciences and Society, Karolinska Institutet and Stockholm University, Stockholm, Sweden
[b]Unit of Nutritional Epidemiology, Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden
[c]Division of Clinical Geriatrics, Department of Neurobiology, Care Sciences and Society, Karolinska Institutet, Huddinge, Sweden
[d]Stockholm Gerontology Research Center, Stockholm, Sweden
[e]Department of Epidemiology and Biostatistics, School of Public Health, Tianjin Medical University, Tianjin, China

Abstract

Introduction: The influence of mixed dietary patterns on cognitive changes is unknown.
Methods: A total of 2223 dementia-free participants aged ≥60 were followed up for 6 years to examine the impact of dietary patterns on cognitive decline. Mini-mental state examination (MMSE) was administered. Diet was assessed by a food frequency questionnaire. By factor analysis, Western and prudent dietary patterns emerged. Mixed-effect models for longitudinal data with repeated measurements were used.
Results: Compared with the lowest adherence to each pattern, the highest adherence to prudent pattern was related to less MMSE decline ($\beta = 0.106$, $P = .011$), whereas the highest adherence to Western pattern was associated with more MMSE decline ($\beta = -0.156$, $P < .001$). The decline associated with Western diet was attenuated when accompanied by high adherence to prudent pattern.
Discussion: High adherence to prudent diet may diminish the adverse effects of high adherence to Western diet on cognitive decline.

Keywords: Dietary patterns; Cognitive decline; Population-based; Longitudinal study

1. Introduction

Cognitive decline is defined as an age-related deterioration in cognitive functioning characterized by increasing difficulties with memory, language, and other cognitive functions [1]. Cognitive decline may eventually lead to mild cognitive impairment (MCI) and dementia [2]. Because of the limited efficacy of pharmacologic therapies for MCI or dementia, a growing body of research focuses on modifiable risk factors (including diet) for progressive cognitive decline [3].

A number of studies have investigated the association between individual food items or nutrients and cognitive function and dementia [4]. Research suggests that the cumulative effect of various nutrients in a whole diet on cognitive function might differ from the effect of a single nutrient or food item [5,6]. As humans eat meals with complex combinations of nutrients that are likely to be correlated and interact with each other, the cumulative effects of different diet components have received special attention and different dietary patterns have been examined in relation to various chronic disorders [5,7]. In recent years, different dietary patterns (such as diets rich in saturated fat, sugar, red/processed meat and refined grains, and diets rich in vegetables, fruit, whole grains, and fish) have

The authors declare no conflicts of interest.
*Corresponding author. Tel.: +46-8-690-6853; Fax: +46-8-690-6889.
**Corresponding author. Tel.: +46-8-690-5848; Fax: +46-8-690-6889.
E-mail address: behnaz.shakersain@ki.se (B.S.), weili.xu@ki.se (W.X.)

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been empirically derived and studied in relation to cardiovascular disease, cancer, and mortality [8].

Currently, few population-based prospective studies have examined the association between overall food patterns and cognition or dementia [4]. Most of these studies have shown the protective effect of "Mediterranean-like diets" on dementia or cognitive decline [9,10], although findings are inconsistent [11]. In contrast, a dietary pattern low in vegetables and high in saturated/trans-fat and sugar has been associated with cognitive deficits and Alzheimer's disease (AD) [12,13]. The "Western-type" dietary pattern, which includes red meat, refined grains, high-fat dairy products, and sugar [14], has been found to play a role in the development of AD in animal models [15,16], but the influence of major dietary patterns on cognitive decline remains unclear. Most people eat a combination of healthy and less healthy foods; but the impact of mixed dietary patterns on the risk of chronic conditions remains unknown.

This study aimed to (1) identify dietary patterns in a 60+ year old population; (2) investigate the individual impact of different dietary patterns on changes in cognitive functioning; and (3) explore the combined effect of mixed dietary pattern on changes in cognitive functioning using 6-year follow-up data from a population-based cohort study of the Swedish older adults.

2. Methods

2.1. Study population

Study participants were derived from the Swedish National study on Aging and Care-Kungsholmen (SNAC-K), an ongoing longitudinal project focusing on the aging process and the Swedish care system [17]. SNAC-K participants are a random sample of individuals aged 60+ years who live either at home or in institutions in the Kungsholmen district, a central area in Stockholm, Sweden. Because of more rapid changes in health and a higher attrition rate among older age groups, the sampling is stratified by age cohort. Assessments take place at 6-year intervals for younger cohorts (60, 66, 72, and 78 years) and at 3-year intervals for older cohorts (81, 84, 87, 90, 93, 96, and 99+ years). Among the 5111 persons initially invited to participate, 4590 were alive and eligible at baseline. Of them, 3363 participated in the baseline survey and 1227 were refusers. Of the participants, 2223 persons were left for the present study after exclusion of demented people (n = 321), those with more than 20% missing values on the semi-quantitative food frequency questionnaire (SFFQ; n = 508), mini-mental state examination (MMSE) score <27 (n = 306, nondemented) [18], and missing MMSE score (n = 5) at baseline.

The first follow-up of the older cohorts was conducted from 2004 through 2007. The second follow-up of the older cohorts and the first follow-up of the younger cohorts were carried out from 2007 through 2010 (Supplementary Fig. 1).

SNAC-K was approved by the Regional Ethical Review Board in Stockholm, Sweden. Written informed consent was obtained from each participant, or if the participant had cognitive impairment, from a proxy (e.g., a close family member).

2.2. Data collection

Data on demographics, lifestyle factors, anthropometrics, medical history, and current use of medications were collected through face-to-face interviews by nurses and physicians. These interviews followed a structured protocol (http://www.snac.org). Educational level was assessed as the maximum years of formal schooling and divided into elementary school, high school, and university. Smoking status was dichotomized as never-smokers and ever-smokers. Physical activity was categorized as (1) inadequate: never, ≤2–3 times/month; (2) health-enhancing: light exercise several times/week or every day; and (3) fitness-enhancing: moderate-to-intense exercise several times/week or every day [19]. Social network was defined based on information about civil status, living arrangement, and having contact with children or friends and categorized as rich, moderate, and poor (See details in the Supplementary Material) [20]. Weights and heights were measured by nurses with a standard scale when participants were in light clothing with no shoes. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared. Arterial blood pressure was measured twice at a 5-min interval in a sitting position on the right arm with a sphygmomanometer, and the mean of the two readings was used in the analyses.

Data on chronic diseases, including vascular disorders (hypertension, stroke, heart diseases including coronary heart disease, arrhythmia, and heart failure), diabetes, and cancer, were ascertained on the basis of clinical examinations by physicians, self-reported medical histories, medication use, and the inpatient registry that cover hospitalizations in Sweden since 1969. The ninth and tenth revisions of the International Classification of Diseases (ICD-9 and ICD-10) were used in the registry. Medicinal drugs were classified in accordance with the Anatomical Therapeutic Chemical (ATC) classification system. Blood samples were taken, and genotyping was performed for apolipoprotein E (*APOE*) (rs429358) [21]. The Swedish Cause of Death Register at the National Board of Health and Welfare was used to assess death dates.

2.3. Dietary assessment

Data on dietary intake at baseline were collected using a validated SFFQ with 98 food and beverage items [22]. Participants were asked about how often on average over the past 12 months they consumed each food item on a 9-level scale ranging from never to ≥4 times per day. Portion sizes were estimated using color photos showing four plates with different portions of staple foods (potatoes, rice, and pasta), meat, and vegetables in the SFFQ. For the other food items, a standard portion size was used. For example, the size of an

apple was considered as one portion of fruit [22]. All reported frequencies of food consumption were converted to daily frequencies of food intake. Total energy intake for each participant was calculated by multiplying the daily frequencies of intake and the energy content of the specified portion sizes from the food composition database at the National Food Administration [23] using MATs software (Rudans Lättdata, Sweden). The daily frequencies of intake for each food group were adjusted for total energy intake using the residual approach [24]. None of the participants had an implausible value of total energy intake, which was defined as ±3 standard deviations of the sex-specific mean of the log-transformed energy intake.

2.4. Assessment of global cognitive function

The MMSE, a 30-point test that is used to measure global cognitive functioning, was administered at baseline and at first and second follow-ups. This test includes questions about different functions such as orientation to time and place, attention, calculation, memory, language, and visual construction [25].

2.5. Prevalent dementia diagnosis at baseline

All participants underwent clinical examinations by physicians, and cognitive testing by psychologists. The Diagnostic and Statistical Manual of Mental Disorders (fourth edition) criteria [26] was used for the diagnosis of dementia, following a validated three-step procedure: a first preliminary diagnosis of dementia made by the examining physician, then a second preliminary diagnosis was made independently by the reviewing physician; and finally, a third opinion from a senior physician was sought in case of disagreement between the two preliminary diagnoses [27].

2.6. Statistical analyses

2.6.1. Identification of dietary patterns

Exploratory factor analysis (principal component) was applied to obtain dietary patterns. Details of the analysis are presented in Supplementary Material. The Western dietary pattern was mainly characterized by more frequent intakes of red/processed meat, saturated/trans-fat, refined grains, sugar, beer, and spirits, and the prudent dietary pattern was characterized by more frequent intakes of vegetables, fruit, cooking/dressing oil, cereals and legumes, whole grains, rice/pasta, fish, low-fat dairy, poultry, and water (Table 1). Some foods, including low-fat spreads, pizza, ice cream, coffee, tea and wine, were not correlated (factor loadings <0.25) with any of the two dietary patterns and are not listed in Table 1. Factor scores for each dietary pattern were categorized into quintiles (representing very low, low, moderate, high, and very high adherence) in the following data analyses.

Table 1
Pearson correlation coefficients for the relationship between food item intakes and factors representing dietary patterns at baseline in SNAC-K study (n = 2223)

Food grouping	Pattern 1 (Western)	Pattern 2 (prudent)
Vegetables	−0.01	**0.69**
Fruit	−0.05	**0.55**
Fruit juice	**0.36**	0.09
Boiled potatoes	**0.37**	0.16
Fried potatoes	**0.44**	−0.15
Legumes	0.17	**0.30**
High-fat spreads	**0.36**	−0.14
Oil (cooking, salad dressing)	−0.05	**0.47**
Butter in cooking	**0.25**	−0.07
Margarine in cooking	**0.27**	−0.03
Low-fat dairy products	−0.13	**0.44**
Medium-fat dairy products	**0.36**	0.04
High-fat dairy products	**0.39**	−0.03
Cereals	0.10	**0.28**
Refined grains	**0.50**	−0.07
Whole grains	0.09	**0.41**
Rice/Pasta	0.05	**0.47**
Fish	0.18	**0.48**
Poultry	−0.01	**0.38**
Red meat	**0.50**	0.18
Processed meat	**0.50**	0.13
Eggs	**0.27**	0.22
Sugar/sweets	**0.48**	−0.01
Pastry	**0.47**	−0.03
Snacks	**0.26**	−0.04
Soda	**0.30**	−0.12
Beer	**0.33**	−0.06
Spirits	**0.26**	−0.17
Water, mineral water	−0.16	**0.31**

Abbreviations: SNAC-K, Swedish National study on Aging and Care-Kungsholmen.

NOTE. Correlation coefficients were derived from the factor loading matrix with orthogonal rotation, and factor loadings with absolute values ≥0.25 (in bold) were considered in labeling the obtained patterns.

2.6.2. Data analyses

Multiple imputation by chained equation [28] was used for missing values in SFFQ (if less than 20% of answers were missing) with 50 completed data sets generated. All data analyses were performed using the imputed data. Age, sex, education, civil status, BMI, physical activity, smoking, vascular and other chronic diseases, dietary supplement use, and *APOE* ε4 were considered as covariates in data analyses. In addition to listed covariates, MMSE scores at baseline and follow-ups were included in the multiple imputation.

Characteristics of the participants in different quintiles of each pattern were compared using chi-square tests for categorical variables and analysis of variance for continuous variables, with post hoc comparison using the Bonferroni test. The change in MMSE score over the study period was obtained from the repeated measures of individual MMSE scores at baseline and follow-ups, and was considered as the main outcome of interest. Multilevel mixed-effects linear regression models [29] were used to examine the association

of each dietary pattern scores as categorical (quintiles using the first quintile as reference) or continuous variable with MMSE changes. The models take into account both intra- and inter-individual variations in response variable (MMSE score) over time, and are particularly appropriate for analysis of longitudinal data with repeated measurements. Fixed effect of the model included the interaction term between the exposure of interest and time. Random effect included intercept and slope for time. Unstandardized β-coefficients were obtained from the mixed-effects linear models. As most people simultaneously followed both dietary patterns, the combined effect of the Western and prudent patterns on MMSE decline was examined in further analysis.

Flexible parametric survival models were used to estimate the hazard ratios (HR) and 95% confidence intervals (CIs) of death associated with each dietary pattern.

All statistical analyses were performed using Stata SE 13 for Windows (Stata Corporation, Stata statistical software, release 13. College Station, TX: Stata Corporation; 2013).

3. Results

3.1. Characteristics of the study population for each dietary pattern

Of the 2223 participants (mean age 70.6 ± 8.9), 871 (39.2%) were men and 1352 (60.8%) were women. There were 1516 participants (68.2%) in the younger cohorts and 707 (31.8%) in the older cohorts. Participants with the highest adherence to the Western pattern were more likely to be older, male, and married, and had less physical activity, a lower BMI, and more vascular disorders than those with lower adherence to this pattern. In contrast, participants with higher adherence to the prudent pattern were more likely to be younger, female and never-smokers, have higher education and MMSE scores, and more physical activities, and take dietary supplements than those with lower adherence to this pattern (Table 2, Supplementary Tables 1 and 2).

3.2. Association between dietary patterns and MMSE decline

In basic-adjusted (controlling for age, sex, education, and total energy intake) and multi-adjusted (additionally controlling for civil status, smoking, physical activity, BMI, vitamin or mineral supplement intakes, vascular disorders, diabetes, cancer, depression, *APOE* ε4, and the other dietary pattern score) linear mixed-effects models, higher adherence to the Western dietary pattern was associated with higher MMSE decline than the lowest adherence to this pattern. Moreover, higher adherence to the prudent dietary pattern was inversely associated with MMSE decline than the lowest adherence to this pattern. Furthermore, in multi-adjusted models, the Western (β = −0.045; 95% CI, 0.071–0.019) and prudent (β = 0.043; 95% CI, 0.017–0.068) dietary pattern scores

Table 2
Baseline characteristics of the study population by quintiles (1–5, corresponding to very low to very high adherence) of the dietary patterns scores (n = 2223)

Characteristics	Very low, n (%)	Low, n (%)	Moderate, n (%)	High, n (%)	Very high, n (%)	*P* value*
Adherence to the Western dietary pattern						
Age groups (y)						<.001
60–66	162 (36.7)	146 (32.5)	124 (28.2)	121 (26.6)	96 (22.1)	
72–78	188 (42.6)	179 (39.6)	176 (39.9)	178 (39.1)	146 (33.6)	
81–87	83 (18.9)	110 (24.4)	119 (27.0)	122 (26.9)	149 (34.2)	
90+	8 (1.8)	16 (3.5)	22 (4.9)	34 (7.4)	44 (10.1)	
Sex						
Women	346 (78.5)	308 (68.3)	274 (62.1)	250 (55.0)	174 (40.0)	<.001
Men	95 (21.5)	143 (31.7)	167 (37.9)	205 (45.0)	261 (60.0)	
Education						.176
University	166 (37.7)	174 (38.5)	151 (34.1)	151 (33.1)	172 (39.6)	
High school	205 (46.5)	191 (42.5)	200 (45.5)	206 (45.3)	170 (39.0)	
Elementary school	70 (15.8)	86 (19.0)	90 (20.4)	98 (21.6)	93 (21.4)	
Adherence to the prudent dietary pattern						
Age groups (y)						.001
60–66	121 (27.7)	124 (26.9)	121 (27.2)	149 (32.9)	134 (31.3)	
72–78	158 (36.0)	162 (35.3)	181 (40.8)	178 (39.4)	188 (43.8)	
81–87	123 (27.9)	141 (30.7)	120 (27.1)	107 (23.8)	93 (21.6)	
90+	37 (8.4)	33 (7.1)	22 (4.9)	17 (3.9)	14 (3.3)	
Sex						
Women	200 (45.6)	262 (57.0)	267 (60.1)	310 (68.7)	313 (72.9)	<.001
Men	239 (54.4)	198 (43.0)	177 (39.9)	141 (31.3)	116 (27.1)	
Education						<.001
University	113 (25.7)	162 (35.3)	154 (34.7)	194 (43.0)	191 (44.3)	
High school	215 (48.9)	201 (43.5)	200 (45.0)	186 (41.1)	172 (40.2)	
Elementary school	111 (25.4)	97 (21.1)	90 (20.3)	71 (15.9)	66 (15.5)	

*P values are from chi-square (χ^2) test indicating differences in characteristics between quintiles of each dietary pattern.

Table 3
Estimated mean change in mini-mental state examination score (β coefficients) and 95% confidence intervals by quintiles (1–5, corresponding to very low to very high adherence) of the dietary patterns scores over 6 years follow-up (n = 2223)

	Model 1*			Model 2†		
Dietary pattern scores	β	95% CI	*P* value	β	95% CI	*P* value
Western pattern						
Diet (continuous) × time	−0.046	−0.072 to −0.020	.001	−0.045	−0.071 to −0.019	.001
Diet (quintile) × time						
First quintile × time	Reference	Reference	Reference	Reference	Reference	Reference
Second quintile × time	−0.075	−0.155 to 0.004	.062	−0.075	−0.154 to 0.004	.062
Third quintile × time	−0.137	−0.217 to −0.057	.001	−0.137	−0.217 to −0.057	.001
Fourth quintile × time	−0.063	−0.144 to 0.017	.125	−0.063	−0.144 to 0.017	.123
Fifth quintile × time	−0.157	−0.240 to −0.074	<.001	−0.156	−0.240 to −0.073	<.001
Prudent pattern						
Diet (continuous) × time	0.042	0.020, 0.068	.001	0.043	0.017, 0.068	.001
Diet (quintile) × time						
First quintile × time	Reference	Reference	Reference	Reference	Reference	Reference
Second quintile × time	−0.001	−0.085 to 0.084	.986	0.001	−0.085 to 0.083	.985
Third quintile × time	0.060	−0.022 to 0.143	.153	0.061	−0.021 to 0.143	.153
Fourth quintile × time	0.121	0.038 to 0.203	.004	0.122	0.039 to 0.204	.004
Fifth quintile × time	0.105	0.022 to 0.188	.013	0.106	0.024 to 0.189	.011

Abbreviations: MMSE, mini-mental state examination; CI, confidence interval.
*Adjusted for total energy intake, age, sex, and education.
†Adjusted for total energy intake, age, sex, education, civil status, smoking, physical activity, body mass index, vitamin or mineral supplement intakes, vascular disorders, diabetes, cancer, depression, *APOE* ε4, and the other dietary pattern score.

as continuous variables were significantly associated with cognitive changes (Table 3). These results remained significant after adding interaction terms between each dietary pattern score and each covariate in the full-adjusted models.

In multi-adjusted mixed-effects models, MMSE scores with 95% CIs were estimated at each year of follow-up for the participants with very high and very low adherence to each dietary pattern. Individuals with very low adherence to the Western pattern (first quintile) and individuals with very high adherence (fifth quintile) to the prudent pattern showed the least decline in MMSE scores over time. Those with the very high adherence to the Western dietary pattern (fifth quintile) and those with very low adherence (first quintile) to the prudent dietary pattern showed the most decline in MMSE over time (Fig. 1).

On the basis of these results, the combined effect of the Western and prudent patterns on cognitive decline was examined in a joint analysis. Table 4 presents the four groups according to the combination of the quintiles of each pattern (details presented in Supplementary Material). The mean frequencies of food intakes in the four groups are shown in Supplementary Table 3.

Those with low adherence to the prudent diet and high adherence to the Western diet (group 4) showed the greatest cognitive decline, while the decline became less pronounced (53.5%) and nonsignificant among people who had a high adherence to both the prudent and Western patterns (group 2). These results suggest that more frequent intake of the prudent diet may attenuate the potential adverse effect of more frequent intake of the Western diet on cognitive decline (Fig. 2).

3.3. Supplementary analyses

Similar results were obtained when the analyses were repeated only among participants with complete SFFQ data (n = 815), and when participants with missing values on the SFFQ were included after multiple imputation for all missing values (n = 2731; their characteristics presented in Supplementary Material). As social network has been

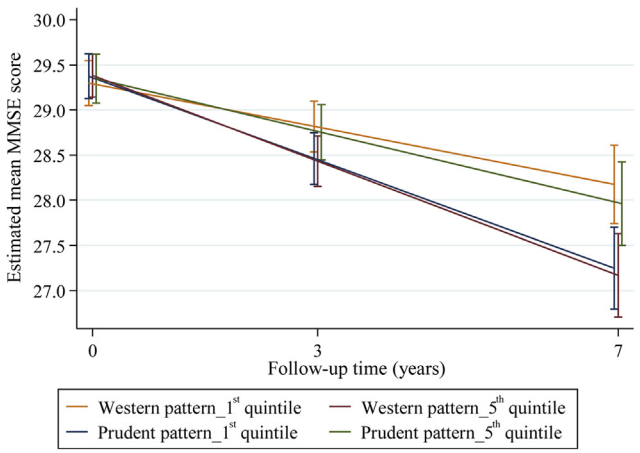

Fig. 1. Estimated mean score of mini-mental state examination with 95% CIs at follow-up year intervals among participants with very high (fifth quintile) and very low (first quintile) adherence to the Western and prudent dietary patterns. The results are adjusted for total energy intake, age, sex, education, civil status, smoking, physical activity, body mass index, vitamin or mineral supplement intakes, vascular disorders, diabetes, cancer, depression, *APOE* ε4, and the other dietary pattern score. The mean follow-up period per person by the end of the second follow-up was slightly more than 6 years. Abbreviation: MMSE, mini-mental state examination.

Table 4
Number (%) of the study participants according to joint classification of the quintiles (Q1–Q5) of adherence to the Western and prudent dietary patterns

Dietary patterns	Prudent pattern					Total
	Low protection				High protection	
Western pattern	Q1	Q2	Q3	Q4	Q5	
Low risk						
Q1	83 (3.7)	87 (3.9)	80 (3.6)	96 (4.3)	95 (4.3)	441 (19.8)
Q2	82 (3.7)	97 (4.4)	97 (4.4)	98 (4.4)	77 (3.5)	451 (20.3)
High risk						
Q3	88 (4.0)	102 (4.6)	94 (4.2)	80 (3.6)	76 (3.4)	441 (19.8)
Q4	92 (4.1)	87 (3.9)	89 (4.0)	94 (4.2)	94 (4.2)	455 (20.5)
Q5	94 (4.2)	87 (3.9)	84 (3.8)	83 (3.7)	87 (3.9)	435 (19.6)
Total	439 (19.7)	460 (20.7)	444 (20.0)	451 (20.3)	429 (19.3)	2223 (100)

associated with dietary intakes and dementia risk in old age [30,31], the analysis was repeated with additional adjustment for social network (instead of civil status), which showed similar results to those from the initial analysis. Furthermore, similar dietary patterns were obtained when the factor analysis was repeated using Promax oblique rotation and unadjusted daily intake frequencies of food groups for total calorie intake.

By the end of the follow-up period (16,181 person-years; mean per person = 7.5 years; maximum = 9.5 years), 399 study participants (17.9%) had died. Association of dietary patterns with mortality was also assessed to explore possible underestimation of the studied association related to death. In the multi-adjusted flexible parametric survival model, Western dietary pattern scores as a continuous variable (HR = 1.18; 95% CI, 1.04–1.34) and the fifth quintile of the scores of this pattern (HR = 1.79; 95% CI, 1.06–3.02) were significantly associated with all-cause mortality in the older age cohorts.

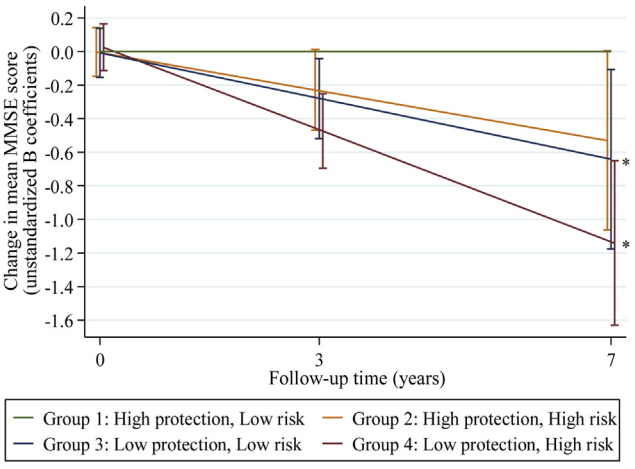

Fig. 2. Estimated changes in mini-mental state examination score over the 6-year follow-up by combined adherence to the Western and prudent dietary patterns. Group 1: High prudent and low Western diet as "high protection and low risk" (reference; n = 366). Group 2: High prudent and high Western diet as "high protection and high risk" (n = 514). Group 3: Low prudent and low Western diet as "low protection and low risk" (n = 526). Group 4: Low prudent and high Western diet as "low protection and high risk" (n = 817) The results are adjusted for total energy intake, age, sex, education, civil status, smoking, physical activity, body mass index, vitamin or mineral supplement intakes, vascular disorders, diabetes, cancer, depression, and *APOE* ε4. The mean follow-up period per person by the end of the second follow-up was slightly >6 years. *P value <.05. Abbreviation: MMSE, mini-mental state examination.

4. Discussion

In this large population-based longitudinal study of older adults, two major dietary patterns were found. The first, the Western pattern, was mainly characterized by more frequent intakes of red/processed meat, saturated/trans-fat, refined grains, sugar, beer, and spirits. The second, the prudent pattern, was characterized by more frequent intakes of vegetables, fruit, cooking/dressing oil, cereals and legumes, whole grains, rice/pasta, fish, low-fat dairy, poultry, and water. During the follow-up, high adherence to the Western dietary pattern was associated with more cognitive decline, whereas high adherence to the prudent pattern was inversely associated with cognitive decline. Moreover, more frequent intake of the prudent diet seemed to attenuate the adverse effects of more frequent intake of the Western diet on cognitive decline.

4.1. Results in relation to other studies

Several studies have shown that dietary patterns assessed by various methods are associated with risk of cardiovascular disease and mortality [32,33]. A few population-based studies have reported the association between specific food combinations and cognitive decline in older adults [34]. A cross-sectional study on older adults in France has shown that a "healthy" diet (rich in fish, fruit, and vegetables) was associated with fewer errors on MMSE, and "biscuits and snacking" intakes were related to more errors on MMSE [35]. In a 3-year follow-up study on older adults in Canada, adherence to a Western diet (similar to the present study) was associated with cognitive decline only among people with low education [36]. However, in a 12-year Swedish follow-up study of older male adults, no significant associations between dietary patterns and cognitive dysfunction were found [37]. In the present study, more frequent

intake of the Western diet was associated with more cognitive decline, whereas more frequent intake of the prudent diet was associated with less cognitive decline.

It is common that people consume a combination of healthy and less healthy foods. In this study population, around 68% of the participants had mixed adherence to both the Western and the prudent dietary patterns. Nevertheless, no previous studies have, so far, examined the joint effect of different dietary patterns on cognition. In the present study, different levels of adherence to the Western and prudent dietary patterns were combined to assess the effect of mixed dietary patterns on cognitive decline. This study showed that the cognitive decline associated with more frequent intake of the Western diet was reduced by almost 50% when it was combined with more or the most frequent intake of the prudent diet. This suggests that potential detrimental effects of more frequent intake of less healthy foods on cognitive decline may be significantly counteracted by more frequent intake of healthy foods.

Dietary pattern analysis considers overall diet rather than individual nutrients or foods. This approach more closely parallels real-world food and nutrient intake than does an exclusive focus on single nutrients or foods. It can also take into account complicated interactions among nutrients and non-nutrient substances. On the other hand, as there are many potential overlaps in nutrient content between dietary patterns, this approach cannot be specific about the particular nutrients responsible for the observed differences in disease risk. Thus, dietary pattern analysis may not be very informative about biological relationships between dietary components and diseases [5]. However, findings from this study are consistent with the findings regarding associations between intakes of certain nutrients and foods and cognition reported in previous epidemiologic studies. In particular, higher consumption of fruit and vegetable, whole-grains, and fish has been associated with preserved cognitive function [38,39].

4.2. Potential mechanisms

Multi-dimensional biological effects may lie behind the association between diet and cognitive decline. A less healthy dietary pattern (similar to our Western pattern) is usually rich in calories, saturated/trans-unsaturated fatty acids, sugar, and alcohol (other than red wine). These components are associated with cognitive decline in older adults [40–47]. Moreover, Western diet includes heat-processed foods that contain high levels of advanced glycation end products (AGEs). Elevated levels of AGEs have been associated with increased aggregation and cytotoxicity of amyloid-β (Aβ), which may be a potential mechanism explaining the association between the Western diet and cognitive decline [48]. Animal studies have demonstrated that a Western diet may lead to increased levels of circulating plasma Aβ, which could cause blood-brain barrier degradation and hippocampal dysfunction resulting from accumulation of Aβ in the hippocampus [49]. On the other hand, a healthy dietary pattern that includes fruit and vegetables rich in antioxidants [11,50], fish and other sources of poly-unsaturated fatty acids [40,51–53], and B vitamins [54] has been shown to positively influence cognitive performance and delay the development of cognitive impairment in old age. The components of a healthy diet (similar to the prudent pattern in the present study) may enhance cognitive performance by affecting synaptic plasticity and/or synaptic membrane fluidity, or by affecting glucose utilization or mitochondrial function and reducing oxidative stress [38].

4.3. Strengths and limitations

The strengths of the present study are its community-based design, the relatively large sample and long-term follow-up, and the adjustment for multiple potential confounders. However, some limitations need to be pointed out. First, the SFFQ data were self-reported, and participants filled in the questionnaires on their own. Thus, recall bias could not be ruled out. However, the SFFQ is more applicable than other approaches in population-based studies, and its results are more readily computerized, making it more suitable for large prospective studies. In addition, the SFFQ has been validated in two Swedish studies including older adults [55,56]. Second, in this study, about 18% of the 2731 participants had missing values (<20%) on SFFQ, which were imputed by multiple imputation procedures. However, when the analyses were repeated only in those with complete SFFQ data, the results were similar to those from the initial analysis. Third, in this study, dietary data were collected only at baseline and during different seasons. Because of changes in food preferences or needs and seasonal food variations, dietary patterns could differ over time. However, magnitude of the differences between the reports of food intakes at different times or seasons are generally small and seem to be cancelled out within food groups [57]. Even if the differences exist, such nondifferential misclassification may generally lead to an underestimation of the given association. Fourth, as high adherence to the Western dietary pattern is associated with elevated mortality in older adults in this study, its association with cognitive decline might have been underestimated. Fifth, only MMSE was used for cognitive function assessment. MMSE is a test for global cognitive functioning and was originally developed as a screening instrument for cognitive impairment. Although it is sensitive enough to detect dietary-induced cognitive changes among cognitively intact people [58], it may still lack sensitivity to slight cognitive deteriorations [59]. Thus, the association between dietary patterns and cognitive decline might have been underestimated. Sixth, the observed effects of dietary patterns on MMSE changes are not substantial, but these extents of changes reflect the importance of dietary habits as a potential modifiable element in preventing the multifactorial cognitive impairment and

dementia. As this study targeted the general population of cognitively intact older adults, not patients in a clinical setting, the observed effects of diet on cognitive decline are thus most appropriately interpreted in a public health context, in which small long-term effects on common disorders could have high relevance. Seventh, although a wide range of relevant covariates were considered in all our analyses, residual confounding might not be ruled out. Finally, the participants in SNAC-K were living in a central urban area and had comparable age and sex compositions, as well as a similar health care system as in the whole city. However, the population did differ from the rest of the urban area of Sweden in terms of the proportion of women, and highly educated persons. Caution is needed when generalizing the findings from this study to younger or rural populations.

5. Conclusions

In conclusion, our study provides the evidence that the Western dietary pattern characterized by more frequent intakes of red/processed meat, saturated/trans-fat, refined grains, and sugar may predict cognitive decline, whereas a prudent dietary pattern characterized by more frequent intakes of vegetables, fruit, cooking/dressing oil, cereals and legumes, whole grains, rice/pasta, fish, low-fat dairy, poultry, and water may preserve cognitive function. Results from this study also suggest that the positive association of the Western diet with cognitive decline could be counteracted by higher adherence to the prudent diet. These findings may have practical implications in nutritional intervention and education for the prevention of cognitive impairment and dementia. Indeed, a recent randomized clinical trial suggests that a multi-domain intervention including diet may improve or help maintaining cognitive function in old age [60]. Long-term population-based longitudinal studies on the association between dietary patterns and cognitive functioning in different cognitive domains are warranted.

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Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jalz.2015.08.002.

RESEARCH IN CONTEXT

1. Systematic review: PubMed query (Diet or dietary pattern) and (Mini-Mental State Examination OR MMSE OR cognitive function OR cognitive decline OR mild cognitive impairment) AND (cohort OR longitudinal OR prospective OR follow*). Screening of the titles and abstracts identified 62 relevant articles. Taken together, findings about the impact of dietary patterns, especially mixed patterns, on cognitive decline remain unclear.
2. Interpretation: Our findings from a cohort study support the hypothesis that high adherence to prudent diet (vegetables, fruit, fish, cereals, legumes, whole grains, low-fat dairy, rice/pasta, and poultry) may decrease, but high adherence to Western diet (red/processed meat, saturated/trans-fat, refined grains, sugar, beer, and spirits) may increase cognitive decline. High adherence to prudent diet may counteract the adverse effects of high adherence to Western diet on cognitive decline.
3. Future directions: Population-based longitudinal studies addressing the association between dietary patterns and cognitive functioning in different cognitive domains are needed.

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