

## Original Research



# Association of diet quality score with the risk of mild cognitive impairment in the elderly

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Received: Aug 27, 2021

Revised: Nov 3, 2021

Accepted: Dec 15, 2021

Published online: Jan 17, 2022

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### Funding

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (NRF-2018R1D1A1B07049353).

## ABSTRACT

**BACKGROUND/OBJECTIVES:** Although adherence to a higher diet quality may help prevent cognitive decline in older adults, literature for this in a Korean population is limited. Thus, the aim of this study was to examine the association between diet quality indices and the risk of mild cognitive impairment (MCI) in Korean older adults.

**SUBJECTS/METHODS:** This cross-sectional study included 806 community-dwelling people aged 60 yrs and over in Korea. Diet quality was assessed via the revised Recommended Food Score (RFS) and alternate Mediterranean Diet Score (aMDS). Cognitive function was measured using a Korean version of the Mini-Mental State Examination (MMSE-KC). Associations between diet quality indices and MMSE-KC score were assessed with a general linear model after adjusting for covariates. Logistic regression was used to determine the association between diet quality indices and the risk of MCI.

**RESULTS:** The prevalence of MCI was 35.3%. There were no significant trends between MMSE-KC scores and RFS and aMDS after adjusting for age, gender, education, exercise, living status, social activity, and alcohol drinking. Among total subjects, RFS was inversely associated with the risk of MCI after adjusting for covariates (Q5 vs. Q1; odds ratio [OR], 0.49; 95% confidence interval [CI], 0.28–0.83). Among total subjects and men, aMDS was inversely related to the risk of MCI after adjusting for covariates (Q5 vs. Q1; OR, 0.51; 95% CI, 0.29–0.89 for total subjects; Q5 vs. Q1; OR, 0.36; 95% CI, 0.15–0.83 for men).

**CONCLUSIONS:** Our results demonstrate that high diet quality evaluated by RFS and aMDS is inversely associated with the risk of MCI. Thus, high quality diet may reduce or retard cognitive decline in the old population. Longitudinal studies are needed to determine the causal relationship between diet quality and the risk of MCI in the elderly.

**Keywords:** Mild cognitive impairment; diet; elderly

## INTRODUCTION

With a globally aging population, the United Nations (UN) anticipates that elderly people will double in 2050 [1]. Korea is one of the world's fastest aging countries [1]. According to recent statistics on the elderly from Statistics Korea, the Korean elderly with age over 65 yrs accounts for 15.7% of the population [2]. This is considered an “aged society” according to

**Conflicts of Interest**

The authors declare no potential conflicts of interests.

**Author Contributions**

Conceptualization: Yang YJ, Kim E; Formal analysis: Kim E, Yang YJ; Methodology: Yang YJ, Kim MK, Choi BY; Supervision: Choi BY, Kim MK, Yang YJ; Writing - original draft: Kim E, Yang YJ; Writing - review & editing: Kim E, Yang YJ.

the standards of the UN. Aging is the major risk factor for most neurodegenerative diseases including many types of dementia [3].

Dementia, a syndrome of cognition decline, affects memory, thinking, behavior, and the ability of daily living [4]. Mild cognitive impairment (MCI) is an intermediate phase between normal cognition and dementia [5]. The National Institute of Dementia has estimated that 10.1% and 22.6% of elderly people in Korea are suffering from dementia and MCI, respectively [6]. With increasing prevalence, dementia imposes enormous economic cost on the Korean society [7]. Strategies to prevent and manage dementia are needed to reduce costs of healthcare systems. The exact treatment of dementia remains unclear [8]. Thus, it is crucial to modify risk factors for preventing the progression from MCI to dementia [9].

Diet is known to be able to prevent or delay cognitive decline or dementia by modifying some risk factors such as hypertension, diabetes, and obesity [10]. Some studies have reported associations between single nutrient or food and cognitive decline or dementia. Recent studies have also reported associations of multi-nutrients or dietary patterns with cognitive decline or dementia [11].

The Recommended Food Score (RFS) is one of the diet quality indices and it was constructed from foods recommended in the American dietary guidelines [12]. Kim *et al.* [13] modified the RFS based on Korean dietary guidelines and foods rich in antioxidant nutrients. The modified RFS had inverse associations with urinary malondialdehyde (MDA) as a biomarker of oxidative stress and the risk of type 2 diabetes [13,14].

The Mediterranean Diet Score (MDS) was a dietary index of adherence to the Mediterranean diet, which was developed by Willett *et al.* [15]. Kim *et al.* [13] made alternative Mediterranean Diet Score (aMDS) by modifying MDS based on the Korean diet. A prospective study has shown positive associations of the Mediterranean Diet and Dietary Approaches to Stop Hypertension (DASH) diet with cognitive function [16], which emphasizes natural plant-based foods and limited red meat consumption [17]. A systematic review has reported the Mediterranean Diet can protect or improve the cognitive function [18]. In addition, the Mediterranean Diet can decrease mortality of patients with Alzheimer's disease (AD) [19].

Overall, most studies have been conducted overseas to examine the association of RFS or MDS with cognitive function [20]. To the best of our knowledge, only limited studies have explored the association between dietary pattern and cognitive function in Korea [21,22]. Therefore, the aim of this study was to investigate the association of RFS and aMDS with the risk of MCI in Korean elderly people.

**SUBJECTS AND METHODS**

**Study population**

This cross-sectional study used data collected from Yangpyeong cohort study between July 2009 and August 2010. The study population consisted of 1,638 participants aged over 60 yrs old dwelling in Yangpyeong. Of these participants, those who were evaluated with the Korean version of the Mini-Mental State Examination (MMSE-KC) were selected (n = 808), while those who reported energy intake of less than 500 kcal/day were excluded (n = 2). Finally, a total of 806 subjects (340 men and 466 women) were analyzed for this study. All procedures

were conducted according to the Institutional Review Board (IRB) of Hanyang University (HYI-12-038-revision2). Written informed consent was obtained from all subjects.

### General characteristics and anthropometric variables

An interview was performed to collect information on gender, age, education level, living status, social status, drinking consumption, smoking, use of supplement, and medical history by well-trained interviewers. Data on height, weight, and waist circumference were measured and body mass index (BMI) was calculated as body weight/height<sup>2</sup> (kg/m<sup>2</sup>).

### Dietary assessment

All subjects were interviewed by trained interviewers. Dietary intake was estimated with a 106-item food frequency questionnaire (FFQ). This FFQ reflected 1-yr frequencies of food items and mean portion sizes of their food consumption. Food frequency categories consisted of 'never or less than once per month,' 'once per month,' '2–3 times per month,' '1–2 times per week,' '3–4 times per week,' '5–6 times per week,' 'once per day,' '2 times per day,' and '3 times per day.' Portion size categories consisted of '0.5 serving,' '1 serving,' and '1.5 serving' presented with photographs. We investigated the period of fruit intakes, which could be affected by seasonal consumption. All nutrient intakes were total energy adjusted by residual method.

### RFS

The RFS was developed by Kant *et al.* [12]. The RFS emphasizes the consumption of recommended foods by dietary guidelines. In this study, we used the modified version of RFS reported by Kim *et al.* [13] based on the consumption of foods high in antioxidant nutrients [13]. The modified RFS consists of one component of regular meal intake and 46 components of recommended food items such as whole grains (1), legumes (4), vegetables (17), seaweeds (2), fruits (12), fish (5), dairy products (3), nuts (1), and tea (1). Subjects could get 1 point if they regularly ate 3 meals or consumed recommended food items at least once a week. Total score was the sum of scores from all 47 components. The maximum score was 47, with a higher score indicating a greater quality of diet.

### aMDS

The MDS was developed by Willett *et al.* [15] as a dietary index of adherence to the Mediterranean diet. It included 9 components of vegetables, legumes, fruits and nuts, cereal, fish, meat, poultry and dairy products, alcohol, and the ratio of monounsaturated fatty acid to saturated fatty acid [15]. According to results of some studies related to the risk of chronic disease, modified MDS by Fung *et al.* [23] excluded potato from vegetables, removed dairy products, separated fruits and nuts into different groups, included whole grain products only for cereal, included red and processed meats only for meat, and assigned alcohol consumption between 5 and 15 g per day for 1 point [23]. In this study, we used the aMDS reported by Kim *et al.* [13]. The aMDS included laver and kelp/sea mustard as vegetables and multigrain rice as whole grain products. It excluded the ratio of monounsaturated fatty acid to saturated fatty acid and nuts because of their frequency in Korean consumption or the lack of their dietary information in a diet [13]. Subjects could get one point if they consumed vegetables, legumes, fruits, fish, whole grains above the median consumption among the total study participants. In addition, subjects could get one point if they consumed red and processed meats less than the median consumption of subjects or alcohol consumption was between 5 and 15 g per day. Total score was the sum of scores from 7 components. The maximum score was 7, with higher score indicating a greater diet quality.

### Cognition assessment

Cognition was evaluated using MMSE-KC [24]. The MMSE-KC included orientation (10 items, 10 points), memory (1 item, 3 points), attention (1 item, 5 points), delayed recall (1 item, 3 points), language (2 item, 3 points), executive function (1 item, 3 points), construction (1 item, 1 point), and judgement (2 items, 2 points). Total score ranged from 0 to 30 points, with a higher score indicating a better cognitive function. The subjects were classified by MMSE-KC criteria according to age, gender, and education. The normal cognitive group was classified if MMSE-KC scores  $\geq -1.5$  SD of the mean MMSE-KC score. The MCI group was classified if MMSE-KC scores  $< -1.5$  SD of the mean MMSE-KC score [25].

### Statistical analysis

All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). Categorical variables were presented as frequency and percentage. Continuous variables were presented as mean and SD.  $\chi^2$  test for categorical variables and *t*-test for continuous variables were used to compare general characteristics of subjects. One-way analysis of variance (ANOVA) for continuous variables and  $\chi^2$  test for categorical variables were used to compare general characteristics of subjects across quintiles of diet quality score. General linear model was applied to determine nutrient intakes across quintiles of diet quality score. Tukey's multiple comparison was used for post-hoc analysis to determine group differences. Multivariable logistic regression was used to determine the adjusted odds ratio with 95% confidence intervals (CIs) between each diet quality index and the risk of MCI. Model 1 was adjusted for age, gender, and education. Model 2 was adjusted for age, gender, education, exercise, living status, social activity, and alcohol drinking. All tests were 2-sided and  $P < 0.05$  was considered statistically significant.

## RESULTS

### General characteristics

General characteristics of study subjects are shown in **Table 1**. Mean ages of men and women were  $68.2 \pm 5.4$  yrs and  $67.6 \pm 5.3$  yrs, respectively. Men had higher height and weight, but had lower BMI than women. Men were more educated, lived with spouse or family more, participated in social activity more often, had more current drinkers, and current smokers than women. The proportion of hypertension diagnosed was lower in men than in women. There were no significant differences in waist circumference, exercise, dietary supplement use, diagnosis of diabetes mellitus, diagnosis of stroke, diagnosis of cardiovascular disease, or diagnosis of hyperlipidemia between men and women.

**Table 2** presents general characteristics of subjects according to the quintile of each diet quality. Subjects with higher RFS and aMDS had higher height and weight. They were likely to be men, younger, and more educated. Subjects with high RFS and aMDS were less likely to live alone, were more socially active, exercised more, and took more dietary supplements than those with low RFS and aMDS.

### Nutrient intakes according to RFS and aMDS

Nutrient intakes of study subjects by quintiles of RFS and aMDS are shown in **Table 3**. Subjects with higher RFS consumed higher nutrient intakes except for energy and carbohydrate intakes. Subjects with highest RFS consumed the lowest carbohydrate intakes. Subjects with higher aMDS showed higher nutrient intakes except for saturated fat. There

**Table 1.** General characteristics of study subjects

Characteristic	Men (n = 340)	Women (n = 466)	P-value <sup>1)</sup>
Age (yrs)	68.2 ± 5.4	67.6 ± 5.3	0.143
Height (cm)	163.7 ± 5.8	151.0 ± 5.7	< 0.0001
Weight (kg)	63.3 ± 9.0	57.0 ± 8.6	< 0.0001
Body mass index (kg/m <sup>2</sup> )	23.6 ± 2.8	25.0 ± 3.3	< 0.0001
Waist circumference (cm)	84.8 ± 8.2	84.8 ± 9.1	0.962
Education			< 0.0001
Uneducated	55 (16.3)	234 (50.2)	
Elementary school	124 (36.7)	165 (35.4)	
Middle & high school	130 (38.4)	56 (12.0)	
College or higher	29 (8.6)	11 (2.4)	
Living status			< 0.0001
Alone	26 (7.7)	111 (23.8)	
With spouse or family	311 (92.3)	355 (76.2)	
Social activity			0.0145
Yes	269 (79.6)	335 (72.0)	
No	69 (20.4)	130 (28.0)	
Drinking status			< 0.0001
Non-drinker	77 (22.6)	343 (73.6)	
Former drinker	53 (15.6)	14 (3.0)	
Current drinker	210 (61.8)	109 (23.4)	
Smoking <sup>2)</sup>			< 0.0001
Non-smoker	25 (32.9)	103 (96.3)	
Former smoker	32 (42.1)	3 (2.8)	
Current smoker	19 (25.0)	1 (0.9)	
Exercise			0.225
Yes	106 (31.2)	127 (27.3)	
No	234 (68.8)	339 (72.7)	
Use of supplement <sup>3)</sup>			0.755
Yes	83 (27.6)	116 (28.6)	
No	218 (72.4)	289 (71.4)	
Diabetes mellitus <sup>4)</sup> , yes	32 (16.8)	63 (22.4)	0.139
Hypertension <sup>4)</sup> , yes	89 (46.8)	185 (65.8)	< 0.0001
Stroke <sup>4)</sup> , yes	12 (6.3)	9 (3.2)	0.108
Cardiovascular disease <sup>4)</sup> , yes	27 (14.2)	27 (9.6)	0.124
Hyperlipidemia <sup>4)</sup> , yes	7 (3.7)	16 (5.7)	0.321

Data are presented as number (%) or mean ± SD.

<sup>1)</sup>t-test for continuous variables and  $\chi^2$  test for categorical variables.

<sup>2)</sup>Smoking (n = 183).

<sup>3)</sup>Use of supplement (n = 706).

<sup>4)</sup>Diabetes mellitus, hypertension, stroke, cardiovascular disease, and hyperlipidemia (n = 471).

were no significant differences in carbohydrate, all fat, and monounsaturated fat intakes according to quintiles of aMDS.

### MMSE-KC scores according to RFS and aMDS

Averages of MMSE-KC scores by RFS and aMDS are demonstrated in **Table 4**. Model 1 was adjusted for age gender, and education, Model 2 was adjusted for age, gender, education, exercise, living status, social activity, and alcohol drinking.

In total subjects and men, averages of MMSE-KC scores tended to increase as the RFS level increased in Model 1. In men, averages of MMSE-KC scores tended to increase as the aMDS level increased in Model 1. However, these significant trends disappeared in Model 2. Any significant trends were not found in women.

**Table 2.** General characteristics of study subjects by quintile of RFS and aMDS

Characteristic	RFS				aMDS			
	1st	3rd	5th	P-value <sup>1)</sup>	1st	3rd	5th	P-value
Gender, women (%)	99 (62.7)	80 (53.0)	99 (57.6)	< 0.0001	111 (58.7)	100 (61.0)	73 (53.0)	< 0.0001
Age (yrs)	69.0 ± 5.4	68.4 ± 5.1	66.1 ± 5.0	< 0.0001	69.0 ± 5.9	68.1 ± 5.3	66.3 ± 4.7	< 0.0001
Height (cm)	154.7 ± 9.0	156.8 ± 8.1	158.1 ± 8.7	0.007	155.5 ± 8.9	155.5 ± 8.1	159.6 ± 8.2	< 0.0001
Weight (kg)	57.9 ± 8.8	60.4 ± 9.0	61.3 ± 9.9	0.004	57.8 ± 9.0	58.7 ± 8.3	63.1 ± 9.8	< 0.0001
Body mass index (kg/m <sup>2</sup> )	24.2 ± 3.2	24.6 ± 3.2	24.5 ± 3.2	0.096	23.9 ± 3.3	24.3 ± 2.8	24.8 ± 3.3	0.076
Waist circumference (cm)	85.1 ± 8.5	84.9 ± 8.7	84.4 ± 8.9	0.484	83.8 ± 8.7	84.6 ± 7.5	85.6 ± 9.0	0.204
Education	< 0.001				< 0.0001			
Uneducated	79 (50.3)	56 (37.1)	26 (15.2)		92 (48.9)	59 (36.0)	27 (19.7)	
Elementary school	61 (38.9)	53 (35.1)	60 (35.1)		60 (31.9)	68 (41.5)	43 (31.4)	
Middle & high school	16 (10.2)	35 (23.2)	64 (37.4)		33 (17.6)	33 (20.1)	49 (35.8)	
College or higher	1 (0.6)	7 (4.6)	21 (12.3)		3 (1.6)	4 (2.4)	18 (13.1)	
Living status, alone (%)	45 (28.5)	23 (15.3)	24 (14.0)	< 0.0001	42 (22.2)	23 (14.2)	23 (16.8)	< 0.0001
Social activity, yes (%)	99 (62.7)	108 (72.0)	149 (86.6)	< 0.0001	128 (68.1)	125 (77.2)	109 (79.0)	< 0.0001
Drinking status	< 0.0001				< 0.0001			
Non-drinker	77 (48.8)	74 (49.0)	93 (54.1)		100 (52.9)	83 (50.6)	69 (50.0)	
Former drinker	13 (8.2)	16 (10.6)	15 (8.7)		13 (6.9)	19 (11.6)	8 (5.8)	
Current drinker	68 (43.0)	61 (40.4)	64 (37.2)		76 (40.2)	62 (37.8)	61 (44.2)	
Smoking <sup>2)</sup>	< 0.0001				< 0.0001			
Non-smoker	25 (78.1)	22 (57.9)	30 (76.9)		38 (67.9)	24 (72.7)	22 (68.8)	
Former smoker	5 (15.6)	10 (26.3)	6 (15.4)		12 (21.4)	4 (12.1)	6 (18.8)	
Current smoker	2 (6.3)	6 (15.8)	3 (7.7)		6 (10.7)	5 (15.2)	4 (12.4)	
Exercise, yes (%)	23 (14.6)	38 (25.2)	89 (51.7)	< 0.0001	39 (20.6)	37 (22.6)	66 (47.8)	< 0.0001
Use of supplement <sup>3)</sup> , yes (%)	25 (19.2)	22 (16.3)	69 (44.2)	< 0.0001	34 (20.4)	38 (27.7)	53 (43.1)	< 0.0001
Diabetes mellitus <sup>4)</sup> , yes	19 (19.2)	17 (19.5)	19 (20.7)	0.0001	21 (18.1)	16 (15.5)	16 (22.5)	< 0.0001
Hypertension <sup>4)</sup> , yes	53 (53.5)	52 (59.8)	62 (67.4)	< 0.0001	58 (50.0)	59 (57.3)	48 (67.6)	< 0.0001
Stroke <sup>4)</sup> , yes	3 (3.0)	5 (5.8)	3 (3.3)	0.0014	3 (2.6)	8 (7.8)	3 (4.2)	0.0007
Cardiovascular disease <sup>4)</sup> , yes	12 (12.1)	9 (10.3)	14 (15.2)	0.0002	16 (13.8)	10 (9.7)	5 (7.0)	0.0002
Hyperlipidemia <sup>4)</sup> , yes	4 (4.0)	8 (9.2)	2 (2.2)	< 0.0001	5 (4.3)	3 (2.9)	2 (2.8)	0.0005

Data are presented as number (%) or mean ± SD.

RFS, Recommended Food Score, aMDS, alternative Mediterranean Diet Score.

<sup>1)</sup>χ<sup>2</sup> test for categorical variables and analysis of variance (ANOVA) for continuous variables.

<sup>2)</sup>Smoking (n = 183).

<sup>3)</sup>Use of supplement (n = 706).

<sup>4)</sup>Diabetes mellitus, hypertension, stroke, cardiovascular disease, and hyperlipidemia (n = 471).

### Adjusted odds ratios (ORs) and 95% CI of MCI according to RFS and aMDS

Adjusted ORs and 95% CI of MCI by RFS and aMDS are shown in **Table 5**. In total subjects, higher adherence to RFS and aMDS were associated with a lower risk of MCI. There was a significant inverse relationship between RFS and risk of MCI after adjusting for age, gender, education, exercise, living status, social activity, and alcohol drinking (Q5 vs. Q1; OR, 0.49; 95% CI, 0.28–0.83; *P* for trend = 0.010). aMDS was inversely associated with the risk of MCI after adjusting for age, gender, education, exercise, living status, social activity, and alcohol drinking (Q5 vs. Q1; OR, 0.51; 95% CI, 0.29–0.89; *P* for trend = 0.132). In men, aMDS was inversely related to the risk of MCI after adjusting for age, education, exercise, living status, social activity, and alcohol drinking (Q5 vs. Q1; OR, 0.36; 95% CI, 0.15–0.83; *P* for trend = 0.127). Any significant associations were not found in women.

## DISCUSSION

This cross-sectional study of old adults in Yangpyeong, Korea examined the associations of RFS and aMDS with the risk of MCI. A greater adherence to the RFS was associated with a lower risk of MCI after adjusting for age, gender, education, exercise, living status, social activity, and alcohol drinking in total subjects. The RFS was developed to measure diet

**Table 3.** Nutrient intake of study subjects by quintile of RFS and aMDS<sup>1)</sup>

Nutrient	RFS				aMDS			
	1st	3rd	5th	<i>P</i> -trend <sup>2)</sup>	1st	3rd	5th	<i>P</i> -trend
Energy (kcal/d)	1,347.1 <sup>a</sup> ± 7.7 <sup>3)4)</sup>	1,382.6 <sup>b</sup> ± 7.8	1,352.7 <sup>a</sup> ± 7.4	0.6039	1,343.9 <sup>a</sup> ± 7.0	1,371.8 <sup>ab</sup> ± 7.5	1,368.2 <sup>ab</sup> ± 8.2	0.0324
Carbohydrate (g/d)	267.5 <sup>b</sup> ± 2.3	265.3 <sup>b</sup> ± 2.4	252.3 <sup>a</sup> ± 2.2	< 0.0001	258.8 <sup>a</sup> ± 2.1	261.9 <sup>ab</sup> ± 2.3	260.5 <sup>ab</sup> ± 2.5	0.6938
Protein (g/d)	35.4 <sup>a</sup> ± 0.6	41.4 <sup>bc</sup> ± 0.6	44.6 <sup>d</sup> ± 0.6	< 0.0001	37.5 <sup>a</sup> ± 0.6	41.9 <sup>b</sup> ± 0.6	44.0 <sup>b</sup> ± 0.7	< 0.0001
All fat (g/d)	5.4 <sup>a</sup> ± 0.5	8.7 <sup>b</sup> ± 0.5	9.2 <sup>b</sup> ± 0.5	< 0.0001	8.9 ± 0.4	8.2 ± 0.5	8.2 ± 0.5	0.5934
Cholesterol (mg/d)	64.4 <sup>a</sup> ± 7.6	125.9 <sup>b</sup> ± 7.7	120.0 <sup>b</sup> ± 7.3	< 0.0001	99.5 <sup>ab</sup> ± 7.1	116.9 <sup>ab</sup> ± 7.5	129.3 <sup>b</sup> ± 8.2	0.0003
Saturated fat (g/d)	2.3 <sup>a</sup> ± 0.2	3.8 <sup>b</sup> ± 0.2	4.1 <sup>b</sup> ± 0.2	< 0.0001	4.1 ± 0.2	3.6 ± 0.2	3.2 ± 0.3	0.0406
Monounsaturated fat (g/d)	2.3 <sup>a</sup> ± 0.3	4.0 <sup>b</sup> ± 0.3	4.4 <sup>b</sup> ± 0.2	< 0.0001	3.8 ± 0.2	3.9 ± 0.3	3.8 ± 0.3	0.3774
Polyunsaturated fat (g/d)	1.1 <sup>a</sup> ± 0.1	2.1 <sup>bc</sup> ± 0.1	2.4 <sup>c</sup> ± 0.1	< 0.0001	1.6 <sup>a</sup> ± 0.1	2.1 <sup>b</sup> ± 0.1	2.5 <sup>b</sup> ± 0.1	< 0.0001
Total n-3 PUFAs (g/d)	0.15 <sup>a</sup> ± 0.03	0.39 <sup>b</sup> ± 0.04	0.40 <sup>b</sup> ± 0.03	< 0.0001	0.28 <sup>a</sup> ± 0.03	0.37 <sup>ab</sup> ± 0.03	0.45 <sup>b</sup> ± 0.04	0.0002
Fiber (g/d)	12.3 <sup>a</sup> ± 0.3	14.6 <sup>bc</sup> ± 0.3	16.1 <sup>d</sup> ± 0.3	< 0.0001	12.2 <sup>a</sup> ± 0.3	14.7 <sup>b</sup> ± 0.3	16.5 <sup>c</sup> ± 0.3	< 0.0001
Calcium (mg/d)	229.0 <sup>a</sup> ± 10.8	314.9 <sup>bc</sup> ± 10.9	370.3 <sup>d</sup> ± 10.4	< 0.0001	278.1 <sup>a</sup> ± 10.2	320.8 <sup>bc</sup> ± 10.9	355.4 <sup>c</sup> ± 11.9	< 0.0001
Iron (mg/d)	8.4 <sup>a</sup> ± 1.5	9.6 <sup>b</sup> ± 1.7	10.5 <sup>c</sup> ± 2.1	< 0.0001	8.4 <sup>a</sup> ± 0.1	9.8 <sup>c</sup> ± 0.1	10.8 <sup>d</sup> ± 0.1	< 0.0001
Zinc (mg/d)	6.9 <sup>a</sup> ± 0.1	7.3 <sup>bc</sup> ± 0.1	7.6 <sup>c</sup> ± 0.1	< 0.0001	6.9 <sup>a</sup> ± 0.1	7.3 <sup>bc</sup> ± 0.1	7.6 <sup>c</sup> ± 0.1	< 0.0001
Vitamin A (ug RE/d)	263.4 <sup>a</sup> ± 15.7	403.6 <sup>b</sup> ± 15.9	502.9 <sup>c</sup> ± 15.1	< 0.0001	313.1 <sup>a</sup> ± 14.8	410.5 <sup>b</sup> ± 15.8	508.9 <sup>c</sup> ± 17.3	< 0.0001
β-carotene (ug/d)	1,446.5 <sup>a</sup> ± 92.0	2,189.8 <sup>b</sup> ± 93.1	2,765.3 <sup>c</sup> ± 88.3	< 0.0001	1,619.9 <sup>a</sup> ± 85.1	2,248.1 <sup>b</sup> ± 91.0	2,857.1 <sup>c</sup> ± 99.4	< 0.0001
Vitamin C (mg/d)	46.1 <sup>a</sup> ± 2.5	69.0 <sup>b</sup> ± 2.6	89.7 <sup>c</sup> ± 2.4	< 0.0001	52.7 <sup>a</sup> ± 2.4	69.9 <sup>b</sup> ± 2.5	86.9 <sup>c</sup> ± 2.8	< 0.0001
Vitamin E (mg/d)	4.7 <sup>a</sup> ± 0.1	6.0 <sup>bc</sup> ± 0.1	6.6 <sup>d</sup> ± 0.1	< 0.0001	4.9 <sup>a</sup> ± 0.1	6.0 <sup>b</sup> ± 0.1	7.0 <sup>c</sup> ± 0.1	< 0.0001
Vitamin B <sub>1</sub> (mg/d)	0.78 <sup>a</sup> ± 0.01	0.86 <sup>bc</sup> ± 0.01	0.87 <sup>c</sup> ± 0.01	< 0.0001	0.81 <sup>a</sup> ± 0.01	0.84 <sup>ab</sup> ± 0.01	0.85 <sup>b</sup> ± 0.01	0.0002
Vitamin B <sub>2</sub> (mg/d)	0.44 <sup>a</sup> ± 0.02	0.61 <sup>b</sup> ± 0.02	0.72 <sup>c</sup> ± 0.02	< 0.0001	0.55 <sup>a</sup> ± 0.02	0.61 <sup>ab</sup> ± 0.02	0.67 <sup>b</sup> ± 0.02	< 0.0001
Vitamin B <sub>6</sub> (mg/d)	0.91 <sup>a</sup> ± 0.02	1.06 <sup>bc</sup> ± 0.02	1.17 <sup>d</sup> ± 0.02	< 0.0001	0.93 <sup>a</sup> ± 0.02	1.07 <sup>bc</sup> ± 0.02	1.18 <sup>d</sup> ± 0.02	< 0.0001
Vitamin B <sub>12</sub> (mg/d)	1.12 <sup>a</sup> ± 0.12	2.02 <sup>bc</sup> ± 0.12	2.38 <sup>c</sup> ± 0.11	< 0.0001	1.70 <sup>ab</sup> ± 0.11	2.09 <sup>bc</sup> ± 0.12	2.23 <sup>c</sup> ± 0.13	< 0.0001
Folate (ug DFE/d)	322.8 <sup>a</sup> ± 8.2	375.3 <sup>bc</sup> ± 8.3	415.3 <sup>d</sup> ± 7.9	< 0.0001	324.0 <sup>a</sup> ± 7.4	383.5 <sup>bc</sup> ± 7.9	422.7 <sup>d</sup> ± 8.7	< 0.0001

RFS, Recommended Food Score; aMDS, alternative Mediterranean Diet Score PUFAs, polyunsaturated fatty acids.

<sup>1)</sup>Adjusted for total energy intakes, age, and gender.

<sup>2)</sup>*P*-trend by general linear model.

<sup>3)</sup>LS mean ± SE.

<sup>4)</sup>Tukey's multiple comparison. Mean values within a column with unlike superscript letters were significantly different.

quality based on dietary diversity. Previous studies have reported that higher dietary diversity is associated with higher cognitive function [26] and that higher diversity of vegetable and fruit intakes is associated with higher cognitive functions including executive, memory, and attention [27]. Unlike other diet quality indices, the RFS included a question for eating 3 meals per day. With a previous finding showing that eating breakfast has a beneficial effect on cognitive function in memory (particularly delayed recall) and attention [28], eating 3 meals per day including breakfast might result in better MMSE-KC scores.

aMDS was inversely associated with the risk of MCI after adjusting for age, gender, education, exercise, living status, social activity, and alcohol drinking in total subjects and men. A prospective cohort study reported that higher aMDS was associated with slower cognitive decline in Chinese older adults [29]. This study suggested that some common ground between the Chinese diet and the Mediterranean diet, including a high intake of plant foods and low intake of fat and meats, despite differences in the use of oil sources and the low intake of dairy products, might be attribute to these significant findings [29]. In the present study, the partial correlation coefficient between aMDS and MMSE-KC in men was 0.227 (*P* < 0.0001), which was higher than 0.150 (*P* = 0.001) in women. Due to the relatively high correlation of men, aMDS was significantly associated with the risk of MCI only in men. A follow-up study is needed to determine whether there was a gender difference in the relationship between diet quality score and the risk of MCI.

Over the last several decades, the deposition of Tau protein and amyloid precursor protein in the brain has been reported as the main pathological hallmark of AD [30]. It has been widely recognized that the amyloid cascade hypothesis explains the critical mechanism

## Diet quality and mild cognitive impairment

**Table 4.** Average of MMSE-KC score by quintile of RFS and aMDS

Diet quality score	MMSE-KC score					P-difference <sup>1)</sup>	P-trend <sup>2)</sup>
	Q1	Q2	Q3	Q4	Q5		
<b>RFS</b>							
Total							
Model 1 <sup>3)</sup>	24.3 ± 0.5 <sup>4)</sup>	24.8 ± 0.4	25.2 ± 0.4	25.0 ± 0.4	25.2 ± 0.4	0.138	0.038
Model 2 <sup>6)</sup>	23.7 ± 0.7	24.2 ± 0.7	24.6 ± 0.7	24.4 ± 0.6	24.4 ± 0.6	0.230	0.157
Men							
Model 1 <sup>7)</sup>	24.3 ± 0.5	24.7 ± 0.6	25.6 ± 0.5	25.3 ± 0.5	25.7 ± 0.5	0.095	0.022
Model 2 <sup>8)</sup>	23.0 ± 0.8	23.8 ± 0.8	24.5 ± 0.8	24.0 ± 0.8	24.4 ± 0.7	0.139	0.079
Women							
Model 1 <sup>7)</sup>	24.7 ± 0.8	25.2 ± 0.8	25.3 ± 0.8	25.3 ± 0.8	25.2 ± 0.7	0.809	0.473
Model 2 <sup>8)</sup>	25.3 ± 0.9	25.9 ± 0.9	26.0 ± 0.9	25.9 ± 0.9	25.6 ± 0.8	0.779	0.713
<b>aMDS</b>							
Total							
Model 1	23.6 ± 0.6	24.0 ± 0.6	23.4 ± 0.6	23.9 ± 0.6	24.5 ± 0.6	0.088	0.100
Model 2	23.6 ± 0.6	24.0 ± 0.6	23.4 ± 0.6	23.8 ± 0.6	24.4 ± 0.6	0.197	0.212
Men							
Model 1	23.1 <sup>a5)</sup> ± 0.6	24.7 <sup>b</sup> ± 0.7	23.5 <sup>ab</sup> ± 0.7	24.1 <sup>ab</sup> ± 0.7	24.8 <sup>b</sup> ± 0.6	0.009	0.031
Model 2	23.5 <sup>a</sup> ± 1.1	25.2 <sup>b</sup> ± 1.1	23.8 <sup>ab</sup> ± 1.1	24.5 <sup>ab</sup> ± 1.1	25.0 <sup>ab</sup> ± 1.1	0.013	0.074
Women							
Model 1	25.4 ± 0.8	24.9 ± 0.8	24.8 ± 0.8	25.2 ± 0.8	25.7 ± 0.8	0.567	0.695
Model 2	25.4 ± 0.8	25.0 ± 0.8	24.8 ± 0.8	25.2 ± 0.8	25.6 ± 0.8	0.677	0.962

MMSE-KC, Korean version of Mini-Mental State Examination; RFS, Recommended Food Score; aMDS, alternative Mediterranean Diet Score.

<sup>1)</sup>P-difference by general linear model.

<sup>2)</sup>P-trend by general linear model.

<sup>3)</sup>Adjusted for age, gender, and education.

<sup>4)</sup>LS mean ± SE.

<sup>5)</sup>Tukey's multiple comparison. Mean values within a column with unlike superscript letters were significantly different.

<sup>6)</sup>Adjusted for age, gender, education, exercise, living status, social activity, and alcohol drinking.

<sup>7)</sup>Adjusted for age and education.

<sup>8)</sup>Adjusted for age, education, exercise, living status, social activity, and alcohol drinking.

**Table 5.** Adjusted ORs and 95% CI of mild cognitive impairment by quintile of RFS and aMDS

Diet quality score	Adjusted ORs and 95% confidence interval of cognitive impairment					
	Q1	Q2	Q3	Q4	Q5	P-trend <sup>1)</sup>
<b>RFS</b>						
Total						
Model 1 <sup>2)</sup>	1.00 (ref.)	0.73 (0.46–1.17)	0.65 (0.40–1.06)	0.62 (0.39–1.00)	0.49 (0.29–0.82)	0.007
Model 2 <sup>3)</sup>	1.00 (ref.)	0.71 (0.44–1.14)	0.63 (0.39–1.03)	0.61 (0.37–1.00)	0.49 (0.28–0.83)	0.010
Men						
Model 1 <sup>4)</sup>	1.00 (ref.)	0.93 (0.45–1.92)	0.53 (0.26–1.08)	0.64 (0.32–1.32)	0.49 (0.22–1.12)	0.070
Model 2 <sup>5)</sup>	1.00 (ref.)	0.66 (0.31–1.40)	0.43 (0.20–0.93)	0.60 (0.26–1.35)	0.46 (0.19–1.08)	0.114
Women						
Model 1 <sup>4)</sup>	1.00 (ref.)	0.73 (0.39–1.35)	0.80 (0.44–1.45)	0.67 (0.35–1.30)	0.54 (0.28–1.05)	0.091
Model 2 <sup>5)</sup>	1.00 (ref.)	0.70 (0.37–1.32)	0.80 (0.42–1.53)	0.61 (0.32–1.16)	0.51 (0.25–1.03)	0.064
<b>aMDS</b>						
Total						
Model 1	1.00 (ref.)	0.85 (0.54–1.34)	1.08 (0.69–1.68)	1.01 (0.63–1.61)	0.52 (0.30–0.88)	0.116
Model 2	1.00 (ref.)	0.85 (0.54–1.34)	1.08 (0.68–1.69)	1.02 (0.64–1.63)	0.51 (0.29–0.89)	0.132
Men						
Model 1	1.00 (ref.)	0.37 (0.18–0.76)	0.97 (0.49–1.93)	0.68 (0.33–1.42)	0.34 (0.15–0.77)	0.088
Model 2	1.00 (ref.)	0.36 (0.17–0.77)	1.02 (0.50–2.10)	0.69 (0.33–1.45)	0.36 (0.15–0.83)	0.127
Women						
Model 1	1.00 (ref.)	1.56 (0.85–2.84)	1.22 (0.67–2.22)	1.32 (0.71–2.46)	0.71 (0.34–1.50)	0.567
Model 2	1.00 (ref.)	1.52 (0.83–2.79)	1.27 (0.70–2.33)	1.33 (0.71–2.50)	0.74 (0.35–1.57)	0.669

OR, odds ratio; CI, confidence interval; RFS, Recommended Food Score; aMDS, alternative Mediterranean Diet Score.

<sup>1)</sup>OR and 95% CI were obtained using multiple logistic regression analysis.

<sup>2)</sup>Model 1: adjusted for age, gender, and education.

<sup>3)</sup>Model 2: adjusted for age, gender, education, exercise, living status, social activity, and alcohol drinking.

<sup>4)</sup>Model 1: adjusted for age and education.

<sup>5)</sup>Model 2: adjusted for age, education, exercise, living status, social activity, and alcohol drinking.



of the pathogenesis of AD and the accumulation of amyloid- $\beta$  (A $\beta$ ) peptides triggers AD [31]. Results from a cross-sectional study have suggested that higher adherence to the Mediterranean Diet and higher vegetable intake are associated with lower A $\beta$  levels in the brain and better neuroimaging biomarkers [32]. Oxidative stress is also considered as a major risk factor in AD pathogenesis and progression [33]. When redox-active metal ion like copper binds to the A $\beta$  peptide, reactive oxygen species is produced, which may lead to oxidative damage to the A $\beta$  peptide itself and surrounding molecules including proteins, lipids, and DNA [33]. Inflammation plays an important role in the pathogenesis of atherosclerosis, which is a risk factor for dementia and associated with neurodegenerative diseases such as AD, clinical dementia, and cognitive decline [34].

Our results revealed that MCI was inversely associated with RFS and aMDS. Previous studies have found that higher adherence to RFS and aMDS are associated with higher intake of antioxidant-rich foods counteracting oxidative and inflammatory stress [13,35]. Our results also showed that higher RFS and aMDS were associated with higher intakes of antioxidants such as vitamin A,  $\beta$ -carotene, vitamin C, and vitamin E. Consequently, associations of lower risk of MCI with higher RFS and aMDS could be explained by reduction of oxidative stress. Higher adherence to aMDS were also associated with lower C-reactive protein (CRP) and interleukin levels, which were markers of inflammation and endothelial dysfunction [19]. A previous review has also suggested that an anti-inflammatory and antioxidants diet might decelerate inflammation and AD progression [36]. Our results supported associations of the highest adherence to RFS and aMDS with the highest intakes of total n-3 fatty acids, which have anti-inflammatory effects. In addition, those with higher RFS and aMDS showed higher intakes of most nutrients, which were energy-adjusted. Therefore, adequate nutrient intake in older adults may positively influence cognitive function.

Our study had some limitations. First, this was a cross-sectional study using baseline Yangpyeong cohort data. Thus, this analysis could not provide causality of RFS and aMDS with the risk of MCI. Second, we could not assess the relationship of cognitive function with depression because only 83 subjects were assessed for depression. A previous review has suggested that depression in older adults can cause cognitive impairment [37]. Therefore, further studies are needed to examine the relationship of cognitive function with psychological symptoms including depression. Third, there was a possible recall bias. Participants could misreport their portion sizes of their food consumption when assessing their dietary intakes from FFQ. In addition, older adults with MCI may have poor memory, which may affect RFS and aMDS. Fourth, participants of our study might not represent all Korean elderly people because they were living in Yangpyeong, a rural area of Korea. Compared to those living in urban and metropolitan locations, those living in rural area had lower education levels, lower income, and different dietary patterns [38]. Therefore, our findings cannot be generalized to all Korean older population.

Nevertheless, literature on the relationship between diet quality scores and cognitive function in Korean older adults is limited. Previous studies conducted in Korea used their own analyses such as K-means cluster analysis and reduced rank regression analysis to assess the diet [21,22]. In addition, other studies using a diet quality tool in Korea investigated the relationship with oxidative stress [13], physical activity [39], and metabolic syndrome [40], not cognitive function.

In conclusion, the risk of MCI was lower as the diet quality measured by RFS and aMDS increased in the total subjects. However, when analyzed by gender, aMDS was only associated with the risk of MCI in men, and no significant correlation was found in women.

Further studies are needed to support the casual relationship between diet quality and the risk of MCI. In addition, a follow-up study on dietary quality and cognitive function according to gender is needed.

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