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Dietary patterns and cognitive function in older adults residing in rural China

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ABSTRACT

Background and Objectives: Research has produced inconsistent findings on the association between dietary patterns and cognitive function. In the present study, we examined the association between dietary patterns and cognitive function among rural China's older adults and aimed to identify major dietary patterns. **Methods and Study Design:** This cross-sectional study included 1176 individuals aged 65–85 years. Dietary intake was assessed using a food frequency questionnaire. Factor analysis and the Chinese Dietary Balance Index were respectively employed to determine dietary patterns and assess dietary quality. Cognitive function was evaluated using the Mini-Mental State Examination, and logistic regression analysis was performed to examine the relationship between dietary patterns and cognitive decline. **Results:** Three main dietary patterns were identified and named on the basis of foods with high content: a "healthy dietary pattern," a "multigrain dietary pattern," and a "snack dietary pattern." With the increase in the score of the healthy dietary pattern, the Mini-Mental State Examination total score exhibited a significant downward trend (p<0.001). Moreover, we observed a prominent negative association between the healthy dietary pattern and mild cognitive impairment (4th to 1st quartile, OR=0.36; 95%CI, 0.24–0.54; p<0.001). After we adjusted for potential covariates, the negative correlation remained (4th to 1st quartile, OR=0.48; 95%CI, 0.28–0.81; p=0.006). However, no relation was observed between mild cognitive impairment and either the multigrain or snack dietary patterns. **Conclusions:** The healthy dietary pattern, which is based on the consumption of rice and flour, red meat, chicken, vegetables, seafood, and fruits, protects against cognitive dysfunction.

Key Words: older adults, mild cognitive impairment, factor analysis, dietary pattern, rural areas

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INTRODUCTION

With the development of an aging population, dementia poses a serious challenge to global public health.[1] According to the "World Alzheimer's Disease Report 2019: Attitudes to Dementia," a new patient somewhere in the world is diagnosed as having Alzheimer disease (AD) every 3s. As of 2019, more than 50 million people worldwide had been diagnosed as having AD, and the number of AD patients was estimated to increase to 150 million.[2] Cognitive impairment is a broad term that encompasses conditions of varying severity, from mild cognitive impairment (MCI) to dementia. Among these conditions, MCI in older adults marks a transition from a normal cognitive state to dementia; patients with MCI have mild memory impairment, but other cognitive functions are generally normal, and the patients do not meet the clinical dementia diagnostic criteria.[3] With China's rapid transition from an aging society to an aged society, the prevalence and disease burden of MCI will continue to increase.[4] Unfortunately, effective treatments for dementia are still lacking.

As an influential, modifiable risk factor, diet plays a key role in preventing, delaying, and reducing cognitive decline.[5] Early studies focused on the relationship between a single nutrient or food in the diet of older adults and cognition or dementia.[6] Recently, however, the relationship between dietary patterns (DPs) and cognition or dementia among older adults has attracted considerable attention.[7-12] Approaches to identifying DPs are commonly divided into a priori and a posteriori methods. A priori methods typically include the Mediterranean dietary pattern and the Healthy Diet Index. The Mediterranean dietary pattern is well known as a diet rich in vegetables, fruits, nuts, grains, and olive oil, and several studies have reported that older adults who follow the Mediterranean dietary pattern experience improved cognitive function.[13-15] However, the traditional Asian diet is quite different from the Mediterranean diet due to differences in regional food culture; therefore, identifying beneficial DPs that suit Asian customs is crucial.

A posteriori methods are generally used to derive DPs, which can enable a better understanding of the study population's existing dietary habits.[16] A common method is to collect dietary data of the research population in advance, establish a DP through dimensionality reduction (e.g., factor analysis), and then analyze the DPs of the research population. Factor analysis is used to create DPs that combine various food items, assess the associations between the food items, identify several major DPs that can cover almost all of the data, and reevaluate the relationship between diet and health or a specific disease. Some studies have reported that an association exists between DPs and cognitive function in older adults, including those in Japan and Australia.[1,17] However, the results have been inconsistent due to differences in diet and DPs among countries and cultures.

Few studies have performed factor analysis to evaluate whether a correlation exists between diet and cognitive function in Chinese populations. An analysis that included the data of 894 Chinese people over the age of 50 years demonstrated that a diet rich in fruits, vegetables, and nuts could reduce the risk of cognitive decline.[18] However, to the best of our knowledge, no studies have investigated DPs exclusively among older adults in rural China, which is a population with relatively low income and a relatively simple diet. More older adults live in rural areas than in urban areas. With China's trends in terms of urbanization and population aging, the number of older adults residing in rural areas has increased, and their

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risk of cognitive decline is much higher than that of older adults residing in urban areas. Thus, the purpose of this study was to identify DPs through factor analysis and evaluate the relationship between diet and cognitive function in Chinese older adults.

MATERIALS AND METHODS

Study design and sample

We randomly selected 18 villages, where villagers were mostly farmers, in Licha town, Jiaozhou. Participants included in the study were required to have lived in the area for >10 years. From April to July 2019, trained interviewers with medical knowledge used structured questionnaires to conduct face-to-face interviews with all respondents (the National Basic Public Health Service Project 2019). We included older adults aged 65–85 years and excluded those who could not answer independently or who had a history of dementia or AD. We also excluded people who took medications that have long-term effects on the central nervous system, who had impaired hearing, whose data were missing or incomplete, or who refused to participate. Our study was approved by the Ethics Committee for Medical Research at Qingdao Municipal Center for Disease Control and Prevention, and we obtained written informed consent from all participants.

General condition

Sociodemographic characteristics, such as age, sex, education level, marital status, living situation, medical history, annual net income, and exercise habits, were obtained through self-completed questionnaires and interviews. The participants' education levels were divided into the following classifications: 1) illiteracy, 2) elementary school, and 3) middle school and above. Marital status was divided into three types: 1) unmarried, 2) married, and 3) widowed/divorced; living situation was divided into 1) living alone, 2) living with a spouse or children, or 3) living with other people. Classifications of the participants' annual net income was divided into four nodes of CN¥1,000, CN¥3,000, CN¥5,000, and CN¥8,000 according to the participants' local conditions. Regarding exercise habits, the interviewees were asked to report the times and durations of any physical activities the participants engaged in. We measured the height and weight of the participants and calculated their BMI.

Dietary intake

Participants' dietary intake over the preceding 3 months was assessed using a food frequency questionnaire (FFQ), as previously described.[19] All participants were also given a food diary

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and a measurement table with life-size images of spoons, cups, and bottles for the diaries. Participants whose responses lacked more than 10% of the FFQ data were considered invalid and were not included in this study,[20] whereas other missing foods in FFQ responses were considered not to be consumed. FFQ responses were converted into daily equivalents, and the 97 items were categorized into the following 15 food groups: rice, coarse grains, potatoes, red meat, poultry, seafood, vegetables, fruits, beans, milk, eggs, nuts, pickled foods, tea, and cooking oil. The energy (kcal/d) and selected nutrient intake of the diet were calculated with reference to the "Chinese Food Ingredient Standard Table" using MetaDieta software.

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Dietary balance index

A dietary balance index (DBI) containing seven components from the Dietary Guidelines for Chinese Residents and the Food Guide Pagoda was used to evaluate dietary quality.[20] This DBI contains four indicators: total score (TS), low bound score (LBS), high bound score (HBS), and diet quality distance (DQD).[21] We calculated the DBI-TS by sequentially adding the scores of all the indicators. The DBI-TS reflects overall diet quality and ranged from −58 to 36 points among the participants. Negative and positive values respectively indicated tendencies toward insufficient and excess nutrient intake on average. A value of 0 could indicate either a balanced diet or equal levels of excess and deficiency that quantitatively negated each other. The DBI-LBS represents the final negative score, which is the sum of the absolute values of all points obtained for the negative score indicators, and it reflects the presence, or degree of dietary or nutritional deficiency. The DBI-HBS, which represents the final positive score, is the sum of the absolute value of all the positive scores, and it reflects the presence, or degree of dietary or excessive nutrient intake. The DBI-DQD score is the sum of the absolute value of all the index scores and reflects whether the overall dietary intake is balanced and its degree of balance. The DBI-LBS and DBI-HBS were each divided into three levels: <20, 20–40, and >40 points and <10, 10–20, and >20 points. We differentiated between meal patterns by combining different DBI-LBSs and DBI-HBSs in the meal. The DBI-DQD score ranged from 0 to 84 points, with scores of 1–17, 18–34, 35–50, and >50 points indicating an appropriate balance, mild dietary imbalance, moderate dietary imbalance, and high dietary imbalance, respectively.[8-11]

Assessment of cognitive function

The Mini-Mental State Examination (MMSE) is a global test, and we used the Chinese version of the MMSE to evaluate cognitive function and its state; uniformly trained investigators performed the examination.[22] The scale assesses five cognitive domains: orientation (10 points), memory (3 points), attention and calculation (5 points), recall (3 points), and language ability (9 points). The total MMSE score ranges from 0 to 30,[23] with higher scores indicating better cognitive function. Of the possible scores, the thresholds for the assessment of MCI among participants in the education level categories of illiteracy, primary school, and junior high school or below were 17, 20, and 24 points, respectively.[7]

Statistical analysis

Descriptive statistics are expressed as percentages and means ± SD for enumeration data. A t test and the Mantel–Haenszel chi-square test were used for continuous and categorical variables, respectively. To avoid biased grouping, we calculated the intake values for each nutrient category by using the energy-adjusted density method (the percentage of total energy provided by the three major energy-producing nutrients and the amount per 1000 kcal of energy for other nutrients and foods).

DPs were derived using exploratory factor analysis according to the frequency of consumption of foods in the 15 food groups. We employed the maximum orthogonal rotation of variance for the initial factor loading matrix to highlight the influence of the factors on various variables and thereby improve interpretability. We combined features with values >1 to indicate the percentage of data variation; the results for the scree plot and the interpretability of the results determined the number of common factors extracted. The factor loading represents the correlation coefficient between food variables and DPs. The larger the absolute value, the greater the contribution of the factor to the DP. A factor with an absolute value factor loading of 0.30 was considered the main factor affecting the model. We divided the factor scores for each DP into quartiles (Q1–Q4) to facilitate further comparisons between nutrient intake and lifestyles. We used Spearman correlation analysis to explore the relationship between the total MMSE score and DPs, and we used linear analysis to investigate the relationship between general conditions and the DPs, including a general linear model for continuous variables and a chi-square test for categorical variables. We performed one-way ANOVA and Pearson correlation analysis to evaluate the associations between the intake of different nutrients and each DP. Additionally, we used multiple logistic regression analysis to analyze the relationship between DPs and MCI and to estimate the OR and 95% CI for MCI or noncognitive dysfunction according to the quartile of each factor score. The lowest quartile was used as the reference category. Model 1 was adjusted for age, sex, education level, marital status, chronic diseases, annual net income, and smoking and drinking

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habits. All statistical analyses were performed using SPSS statistical software, version 20.0. All reported *p* values were two-tailed, and $p<0.05$ was considered to be statistically significant.

RESULTS

Characteristics of the study population

The total number of participants aged 65–85 years in these villages was 1470. After we further consulted with village doctors regarding the interviewees' physical conditions and our study's inclusion and exclusion criteria, only 1176 older adults (517 men and 659 women) were included in the final analytical sample. Table 1 lists the general characteristics of the study participants. A t test and chi-square test revealed statistically significant differences in terms of age, education level, annual net income, and marital status between individuals with and without MCI (all $p<0.001$; except marital status, for which $p=0.038$).

DPs

Three DPs were identified (Table 2), and each was described according to the food groups for which it had high loadings. Factor 1, which had high loadings of rice and flour, red meat, chicken, vegetables, seafood, and fruits, was labeled as the "healthy DP." Factor 2, which had high loadings of chicken, coarse grains, potatoes, soy products, tea, and pickled foods, was labeled the "multigrain DP." Factor 3, which had high loadings of nuts, milk, pickled foods, eggs, and cooking oil, was named the "snack DP." Overall, the three identified DPs explained 32.2% of the total variance of the 15 food group variables.

Associations between DPs and participants' general characteristics

Table 3 lists the characteristics of the 1176 study participants according to the quartiles of the three DPs. When the participants were divided into four groups based on the factor scores in each DP, the healthy DP was related to sex, education level, annual net income, drinking habits, age, and total MMSE score (all $p<0.05$). Higher scores in the multigrain DP were associated with sex, annual net income, and total MMSE score (all $p<0.05$). The snack DP was related to education level, living conditions, income, marital status, drinking habits, and chronic diseases (all $p<0.05$). Spearman correlation analysis revealed no significant trend in MMSE scores in the multigrain DP or snack DP according to the quartiles, whereas the total MMSE score in the healthy DP was significantly increased (trend $p<0.001$, Figure 1).

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Association of DPs with dietary quality and nutrient intakes

Table 4 lists the average energy-adjusted nutrient intake and Pearson correlation coefficient for the lowest (Q1) and highest (Q4) quartiles of each DP. Each DP had a different nutritional intake distribution; therefore, we calculated the Pearson correlation coefficient of each DP and the intake of nutrients that could affect cognitive function. After we performed Bonferroni correction, a p value of <0.0029 and Pearson correlation coefficient of >0.2 or <-0.2 were considered significant. The healthy DP was positively correlated with intakes of energy, protein, fats, carbohydrates, RE, vitamin B-1, vitamin B-2, vitamin B-3, vitamin C, Ca, Zn, Se, and Fe. The multigrain DP was positively correlated with intakes of energy, carbohydrates, vitamin B-1, and vitamin B-2, whereas the snack DP was positively correlated with fat and Ca intakes. However, when we compared to the lowest quartiles, only in the healthy DP did the TS, LBS, and HBS exhibit an upward trend and positive correlation. The DQD scores exhibited a downward trend and a negative correlation, and no correlation was noted in the other two DPs.

Association between DPs and MCI

Logistic regression analysis was conducted to examine the relationship between MCI and each DP, as presented in Table 5. A prominent negative association between MCI and the healthy DP (4th to 1st quartile, OR=0.36; 95% CI, 0.24–0.54; $p<0.001$) was observed. Moreover, the negative correlation remained after we adjusted for potential covariates (4th to 1st quartile, OR=0.48; 95% CI, 0.28–0.81; $p=0.006$). However, no such relation was observed between MCI and either the multigrain DP or snack DP.

DISCUSSION

This cross-sectional study is one of the few studies to use dimensionality reduction to analyze diet and subsequently evaluate the relationship between diet and cognitive function in older Chinese adults. Using factor analysis, we identified three DPs: a healthy DP, multigrain DP, and snack DP. The healthy DP, which is based on high contents of rice and flour, red meat, chicken, vegetables, seafood, and fruits, was the only DP that was negatively associated with MCI and positively associated with total MMSE scores. After we adjusted for confounders, a negative association remained between the healthy DP and MCI, indicating that following the healthy DP may improve cognitive function in older adults.

The assessment of diet quality with factor analysis to determine specific DPs was already an established method of DP analysis. Therefore, the impact of the overall DPs on older

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adults' health can be investigated to address the potential synergy of different diet components or investigate the components' effects.[18,24] In our study, the prevalence of MCI among older adults living in rural China was 24.1%, which is higher than the 23.3% prevalence of MCI among people aged >60 years in northern China.[25] The high prevalence of MCI allows our study to serve as a typical study with applicability to areas with an MCI prevalence of >20%. Some observational studies have identified specific DPs related to cognitive function or AD through the use of different diet analysis methods, such as principal component analysis, cluster analysis, relative risk reduction, and index analysis. For example, in a study of French older adults, participants with the highest adherence to the healthy DP, characterized by the high consumption of fruits, whole grains, fresh dairy products, and vegetables, demonstrated better cognitive function than did those with the lowest adherence,[26] and this finding is similar to our results. Moreover, our healthy DP was analogous to the Mediterranean DP.

The Mediterranean DP and our healthy DP differed in that our healthy DP does not include nuts and olive oil but does include red meat, chicken, and seafood, which are not included in the Mediterranean DP. Most studies in developed Western countries have demonstrated an inverse proportionality between adherence to the Mediterranean DP and both MCI and dementia.[10,15,27,28] A prospective cohort study of older adults in China reported that a DP similar to the Mediterranean DP could delay the decline of cognitive function in older adults.[29,30] The consumption of olive oil and nuts was reported to be positively associated with healthy cognition;[31] this association may be related to olive oil's richness in polyunsaturated fatty acids (PUFAs). The connection between PUFAs and cognition is well understood. However, the healthy DP in this study is rich in seafood, vegetables, and fruits, which may compensate for the lack of PUFAs and provide a full range of nutrients.[32,33] Although red meat is often considered to be associated with poor cognitive performance,[34-36] our research suggests that eating a diet rich in meat and fish is associated with improved cognitive function. The relationship between meat-based diets and cognitive impairment has also been confirmed. A cross-sectional study conducted in 2018 showed that a DP based on meat and soybean products can protect against cognitive impairment,[37] and another study also reported an independent link between meat DPs and the prevention of attention loss.[38] Red meat's beneficial effects on cognitive function may be due to the various beneficial nutrients present in lean red meat, including iron, high-quality protein, PUFAs, monounsaturated fatty acids, and other nutrients. Oxidative stress increases with age and is accompanied by declining function of the antioxidant defense system[39]; however, fruits and vegetables are rich in

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antioxidants, such as vitamins C and E, which may prevent neurodegeneration and slow cognitive aging by scavenging free radicals.[40] Moreover, vegetables, fruits, and whole grains contain many vitamin B varieties, which are necessary in preventing DNA methylation and homocysteine accumulation. Additionally, the accumulation of homocysteine may cause neurotoxic effects.[41,42] If vegetables, fruits, whole grains, and cereals can be considered to be components of a healthy diet,[11,43] then our healthy DP could be applied to many other populations.

In addition to the nutritional balance of foods, overall dietary quality may influence the protective effects of DPs against MCI. The DBI-TS can reveal problems in terms of dietary quality for older Chinese people; the LBS and HBS from the DBI-TS reflect deficits and surpluses of food intake, and the DQD score reveals the overall balance of an individual's dietary intake. Using the DQD scale, we found that older Chinese adults had mild to moderate diet imbalance and tended to have an inadequate intake of vegetables, fruits, and dairy products,[10] which is similar to results of a study published in 2018.[44] We observed significant differences and a negative correlation between DQD scores and our healthy DP, indicating that better adherence to the healthy DP may lead to a more balanced diet. The results regarding the relationship between the healthy DP and MCI did not change after we made adjustments for confounders, demonstrating that although age, sex, education level, and other factors could be confounders of MCI and DPs, they did not affect our results. This suggests that our healthy DP can be applied to populations with similar characteristics to those of the study population.

Although a cross-sectional research design often masks causal relationships, such as the relationship between cognitive decline and changes in dietary structure, cross-sectional studies such as ours can serve as a foundation for future longitudinal studies. Additionally, our research was limited to older adults residing in rural areas of Jiaozhou; thus, our study population may not be representative of populations in other regions. However, our research can be extrapolated to other populations on the basis of similarities in dietary habits.

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Conclusion

In summary, this cross-sectional study of rural older adults in Jiaozhou demonstrated that a healthy diet based on rice and flour, red meat, chicken, vegetables, seafood, and fruits can protect against cognitive dysfunction. Thus, a well-structured and varied diet can protect older adults from declines in cognitive function. More cohort studies and clinical trials are necessary to determine how cognitive decline can be effectively delayed in older adults through dietary and nutritional modifications.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

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Table 1. General characteristics of the study subjects

Variables	MCI No (n=892)	MCI Yes (n=284)	$p^{\dagger}$
Sex ‡			0.064
Men	406 (45.5)	111(39.1)	
Women	486 (54.5)	173(60.9)	
Age § (years)	71.2±5.1	73.5±5.7	<0.001*
Education ‡			<0.001*
Illiteracy	361 (40.5)	165(58.1)	
Primary school	342 (38.3)	84(29.6)	
Secondary and above	189 (21.2)	35(12.3)	
Living condition ‡			0.055
Live alone	140 (15.7)	56(19.7)	
Spouse and Children	629 (70.6)	198(69.7)	
Else	123 (13.8)	30(10.6)	
Marital status ‡			0.038*
Spinsterhood	11 (1.2)	6(2.1)	
Get married	695 (77.9)	198(69.7)	
Widowed/divorced	186 (20.9)	80(28.2)	
Chronic disease ‡			0.381
Nothing	406 (45.5)	129(45.4)	
1	359 (40.2)	100(35.2)	
2	90 (10.1)	44(15.5)	
≥3	37 (4.1)	11(3.9)	
Annual net income ‡ (yuan)			<0.001*
<1000	80 (9.0)	31(10.9)	
1001～3000	129 (14.5)	46(16.2)	
3001～5000	154 (17.3)	59(20.8)	
5001～8000	193 (21.6)	60(21.1)	
>8001	336 (37.7)	88(31.0)	
Smoke ‡			0.209
Yes	232 (26.0)	63(22.2)	
No	660 (74.0)	221(77.8)	
Drink ‡			0.317
Yes	245 (27.8)	69(24.3)	
No	647 (72.5)	215(75.7)	
BMI §	24.79±3.77	24.88±3.72	0.758

MCI, mild cognitive impairment; BMI, body mass index.
†T test for continuous variables and Chi-square test for categorical variables.
‡n (%)
§Mean ± SD
*p<0.05.

Table 2. Rotated factor loading matrix for DPs

Food items	Healthy DP	Multigrain DP	Snack DP
Rice and flour	0.528†	0.268	-0.273
Red meat	0.653†	0.074	-0.120
Chicken	0.385†	0.357†	-0.099
Vegetables	0.536†	0.083	0.077
Seafood	0.491†	-0.207	0.284
Fruits	0.478†	0.010	0.165
Coarse grains	0.114	0.571†	0.025
Potatoes	0.124	0.522†	0.021
Tea	-0.071	0.409†	-0.004
Soy products	0.095	0.511†	0.176
Pickled foods	-0.105	0.434†	0.402†
Nuts	0.046	0.137	0.577†
Milk	-0.109	0.096	0.485†
Eggs	0.263	0.107	0.401†
Cooking oil	0.064	-0.115	0.458†
Variance explained (%)	11.677	11.511	8.964

DPs: xxxx. †Absolute values >0.3 .

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Table 3. Characteristics of the subjects in the lowest (Q1) and highest (Q4) quartiles of each DP

Characteristics[†]	Total (n=1176)	Healthy DP			Multigrain DP			Snack DP		
		Q1 (n=294)	Q4 (n=294)	*p*[‡]	Q1 (n=294)	Q4 (n=294)	*p*[‡]	Q1 (n=294)	Q4 (n=294)	*p*[‡]
Sex (%)				0.009[*]			0.007[*]			0.108
Men	517	40.5	52.4		40.1	52.6		48.6	45.2	
Women	659	59.5	47.6		59.9	47.7		51.4	54.8	
Education (%)				<0.001[*]			0.106			<0.001[*]
Illiteracy	526	52.4	35.0		40.1	40.6		43.2	35.4	
Primary school	426	35.7	42.9		38.8	36.9		39.8	39.8	
Secondary and above	224	11.9	22.1		20.7	22.5		17.0	24.8	
Living condition (%)				0.831			0.145			0.059
Live alone	197	17.7	15.3		13.3	16.0		18.7	13.6	
Spouse	832	71.8	72.8		73.8	67.9		66.7	77.6	
Children	136	9.5	10.9		12.2	14.7		12.6	8.2	
Else	11	1.0	1.0		0.7	1.4		2.0	0.7	
Marital status (%)				0.053			0.362			<0.001[*]
Spinsterhood	17	0.3	2.0		1.0	1.4		2.4	1.0	
Get married	893	75.2	79.9		79.9	75.8		74.5	85.7	
Widowed/divorced	266	24.5	18.0		19.9	22.5		23.1	13.3	
Chronic disease (%)				0.313			0.064			0.030[*]
Nothing	535	46.6	43.2		45.2	42.0		41.8	43.2	
1	459	36.7	42.9		40.1	42.3		44.6	37.1	
2	134	11.9	11.2		12.9	11.6		11.2	15.6	
≥3	48	4.8	2.7		1.7	4.1		2.4	4.1	
Annual net income (yuan) (%)				<0.001[*]			<0.001[*]			0.017[*]
<1000	91	17.6	3.1		7.2	8.4		17.1	7.0	
1001-3000	135	27.3	8.3		19.1	10.2		14.5	16.7	
3001-5000	153	27.3	10.5		13.1	18.2		16.7	16.7	
5001-8000	190	13.4	22.3		20.8	24.4		18.8	24.2	
>8001	284	14.4	55.9		39.8	38.7		32.9	35.2	
Smoke (%)				<0.001[*]			0.065			0.163
Yes	295	29.6	31.0		26.2	29.0		29.2	26.2	
No	881	70.4	69.0		73.8	71.0		70.7	73.8	
Drink (%)				0. 006[*]			0.297			0.019[*]
Yes	314	24.8	34.4		24.8	28.7		29.9	30.6	
No	862	75.2	65.6		75.2	71.3		70.1	69.4	
Age	1176	72.2±5.3	71.1±5.2	0.045[*]	71.3±5.2	72.0±5.4	0.316	71.7±5.5	71.7±5.2	0.701
BMI (kg/m^2)	1176	24.7±3.9	25.0±3.7	0.331	24.9±3.4	24.5±4.0	0.467	25.0±3.9	24.7±3.5	0.886
MMSE total score	1176	21.0±5.8	24.0±5.2	<0.001[*]	23.3±5.9	22.7±5.4	<0.001[*]	22.9±5.5	23.1±5.7	<0.001[*]

MMSE, Mini-Mental State Examination; BMI, body mass index

[†]Values are mean ± SD for continuous variables and percentages of subjects for categorical variables.

[‡]One-way analysis of variance and a Mantel-Haenszel chi-square test were used for continues and categorical variables, respectively. [*]$p<0.05$.

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Table 4. Nutrient intakes of subjects in the lowest (Q1) and highest (Q4) quartiles of each DP

Nutrient †	Healthy DP				Multigrain DP			
	Q1 (n=294)	Q4 (n=294)	*p* ‡	r §	Q1 (n=294)	Q4 (n=294)	*p* ‡	r §
Energy (kcal,×10^3)	1.47±0.52	2.22±0.41	<0.001*	0.52**	1.88±5.71	2.02±0.51	<0.001*	0.20**
Protein ††	14.0±3.5	17.2±4.3	<0.001*	0.64**	14.9±4.3	15.9±3.7	<0.001*	0.16
Fat ‡‡	36.9±13.8	28.9±11.1	<0.001*	0.23**	36.8±14.2	29.5±10.8	<0.001*	-0.08
Carbohydrate §§	49.2±12.6	54.0±11.3	0.002*	0.54**	48.4±12.5	54.8±11.3	<0.001*	0.20**
RE (μg) ¶	236±132	442±165	<0.001*	0.50**	310±160	379±180	<0.001*	0.17
Vitamin B-1(mg) ¶	0.6±0.3	1.0±0.5	<0.001*	0.40**	0.6±0.3	1.0±0.5	<0.001*	0.37**
Vitamin B-2(mg) ¶	0.6±0.3	0.9±0.4	<0.001*	0.37**	0.7±0.3	1.0±0.3	<0.001*	0.35**
Vitamin B-3(mg) ¶	9.8±4.9	21.8±6.6	<0.001*	0.64**	14.8±7.2	17.9±7.9	<0.001*	0.17
Vitamin C (mg) ¶	58.2±40.7	120±59.7	<0.001*	0.44**	81.6±57.1	102±57.0	<0.001*	0.16
Ca (mg) ¶	327±187	577±230	<0.001*	0.45**	424±204	511.4±249.7	<0.001*	0.17
Zn (mg) ¶	9.7±3.5	15.8±3.5	<0.001*	0.54**	13.0±4.5	13.7±4.2	<0.001*	0.06
Se (mg) ¶	42.9±18.2	83.4±28.7	<0.001*	0.59**	60.6±27.5	67.5±29.0	<0.001*	0.10
Fe (mg) ¶	13.9±4.6	19.8±4.9	<0.001*	0.48**	16.2±4.7	18.2±5.0	<0.001*	0.18
DBI-TS	-19.8±11.6	-8.8±10.1	<0.001*	0.44**	-13.5±12.4	-15.2±12.0	0.004*	0.00
DBI-LBS	28.0±9.0	19.6±8.6	<0.001*	0.38**	24.4±9.8	25.7±9.3	0.004*	-0.02
DBI-HBS	8.2±4.5	10.7±4.4	<0.001*	0.36**	10.9±5.2	10.5±4.8	0.108	0.03
DBI-DQD	36.2±8.5	30.3±9.2	<0.001*	-0.21**	35.3±9.7	36.2±8.6	0.032*	0.04

Nutrient †	Snack DP			
	Q1 (n=294)	Q4 (n=294)	*p* ‡	r §
Energy (kcal,×10^3)	1.86±0.59	2.00±0.51	<0.001*	0.11
Protein ††	16.3±3.8	14.7±4.1	0.002*	-0.00
Fat †††	26.3±10.8	41.7±12.5	<0.001*	0.45**
Carbohydrate ‡‡	57.8±10.7	43.6±10.8	<0.001*	-0.16
RE (μg) ¶	307±164	373±172	<0.001*	0.17
Vitamin B-1(mg) ¶	0.8±0.4	0.8±0.4	0.183	0.02
Vitamin B-2(mg) ¶	0.8±0.4	0.8±0.4	0.002*	0.10
Vitamin B-3(mg) ¶	15.9±7.6	16.3±7.9	0.003*	0.03
Vitamin C (mg) ¶	87.1±56.9	89.9±55.5	0.039*	0.03
Ca (mg) ¶	401±198	521±237	<0.001*	0.23**
Zn (mg) ¶	12.7±4.4	14.0±4.3	<0.001*	0.13
Se (mg) ¶	65.5±31.9	63.0±24.6	0.884	-0.01
Fe (mg) ¶	17.3±5.5	17.0±4.7	0.773	-0.02
DBI-TS	-16.5±11.9	-11.7±11.6	<0.001*	0.16
DBI-LBS	25.8±9.3	23.4±9.2	<0.001*	0.11
DBI-HBS	9.3±4.9	11.7±4.6	<0.001*	0.18
DBI-DQD	35.2±8.8	35.1±8.6	0.133	-0.02

RE: retinol equivalents; DBI-TS: Chinese diet balance index total score; DBI-LBS: Chinese diet balance index lower bound score; DBI-HBS: Chinese diet balance index higher bound score.

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[†]All nutrients were energy-adjusted using the density method. [‡]One-way analysis of variance was used. [§]Pearson correlation coefficient. [¶]/1000kcal. [††]Protein (% of energy) = (protein intake ×4.0)/total food energy ×100%. [‡‡]Fat (% of energy) = (fat intake ×9.0)/total food energy ×100%. [§§]Carbohydrate (% of energy) = (carbohydrate intake ×4.0)/total energy of food ×100%. [*] $p<0.05$. [**]After Bonferroni correction, $p<0.0029$, and Pearson correlation coefficient of >0.2 or <-0.2 was considered significant.

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Table 5. Risk of MCI across quartiles of DPs adjusted for covariates.

Variables	Crude		Model 1	
	OR	95% CI	OR	95% CI
Healthy DP				
Q1	1.00		1.00	
Q2	0.88	(0.62, 1.25)	0.98	(0.63, 1.54)
Q3	0.60	(0.42, 0.87)	0.69	(0.43, 1.13)
Q4	0.36	(0.24, 0.54)	0.48	(0.28, 0.81)
p for trend	<0.001*		0.006*	
Multigrain DP				
Q1	1.00		1.00	
Q2	1.64	(1.11, 2.40)	1.53	(0.94, 2.50)
Q3	1.68	(1.15, 2.47)	1.50	(0.93, 2.44)
Q4	1.05	(0.70, 1.58)	1.18	(0.72, 1.93)
p for trend	0.820		0.514	
Snack DP				
Q1	1.00		1.00	
Q2	1.87	(1.27, 2.75)	1.98	(1.23, 3.19)
Q3	1.66	(1.12, 2.45)	1.40	(0.85, 2.30)
Q4	1.21	(0.81, 1.82)	1.46	(0.90, 2.38)
p for trend	0.353		0.127	

Model 1: Adjusted for age, sex, marital status, education, chronic disease, annual net income (yuan), smoke and drink.
*$p<0.05$.

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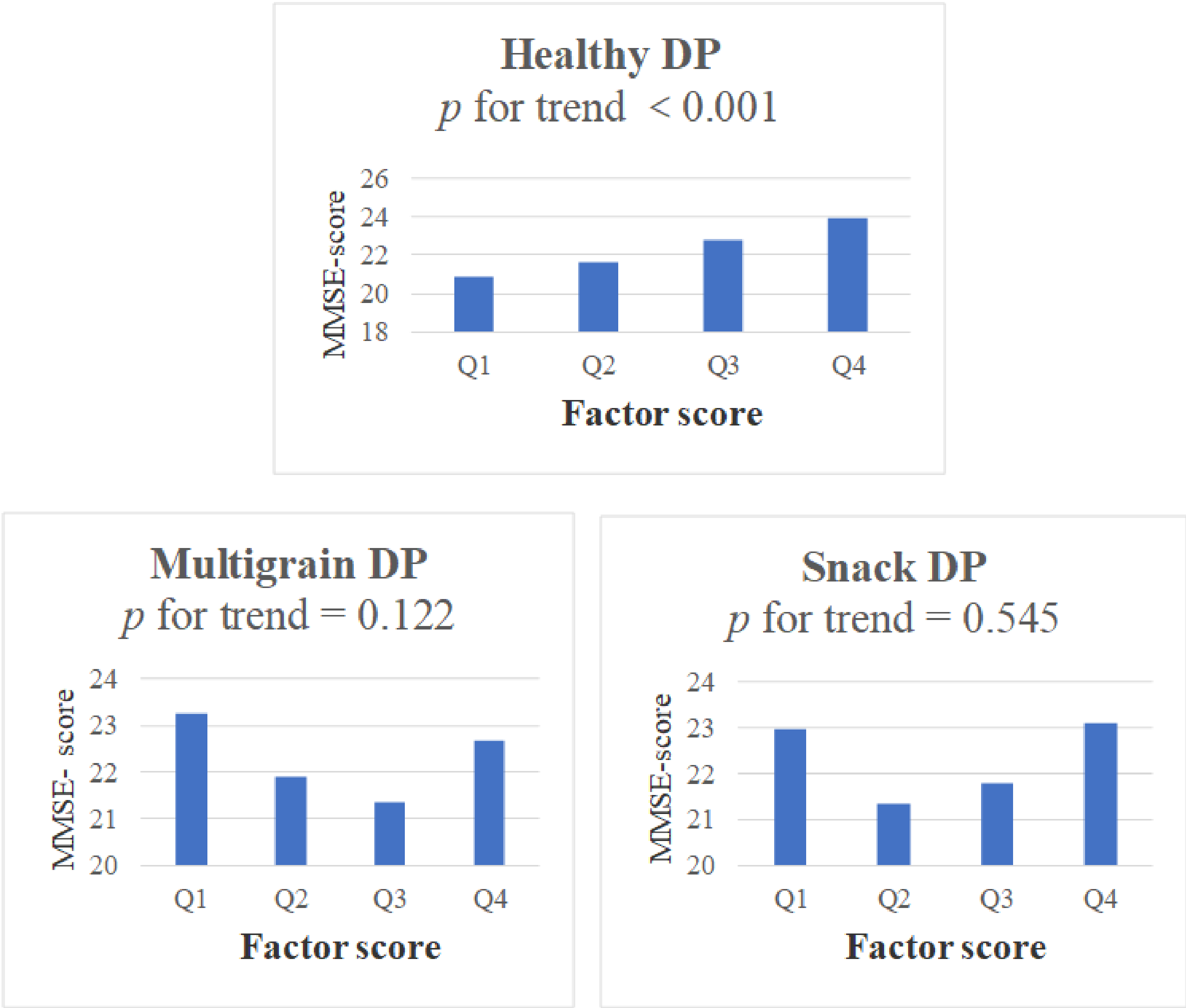

Figure 1. Mini-mental state examination (MMSE) scoring quartiles based on DPs.