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DIETARY DIVERSITY AND COGNITIVE FUNCTION AMONG ELDERLY PEOPLE: A POPULATION-BASED STUDY

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Abstract

Objectives—To explore associations of dietary diversity with cognitive function among Chinese elderly.

Design—This cross-sectional study was conducted in 2011–2012, data were analyzed using multiple linear regression and logistic regression models.

Setting—community-based setting in the 23 provinces in China.

Subjects—8,571 elderly participants, including 2984 younger elderly aged 65–79 and 5587 oldest old aged 80+ participated in this study.

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Ethical standards: The authors declare that all the experiments of this study complied with the current laws of China in which they were performed.

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

Measurement—Intake frequencies of food groups was collected and dietary diversity (DD) was assessed based on the mean of DD score. Cognitive function was assessed using the Chinese version of Mini-Mental State Examination (MMSE), and cognitive impairment was defined using education-based cutoffs. Information about socio-demographics, lifestyles, resilience and health status was also collected.

Results—Poor dietary diversity was significantly associated with cognitive function, with β (95% CI) of $-0.11(-0.14, -0.08)$ for $-\log 31\text{-MMSE}$ score) and odds ratio (95% CI) of 1.29 (1.14, 1.47) for cognitive impairment. Interaction effect of age with DD was observed on cognitive impairment (P interaction=0.018), but not on $-\log 31\text{-MMSE}$ score) (P interaction=0.08). Further separate analysis showed that poor DD was significantly associated with increased risk of cognitive impairment in the oldest old ($p<0.01$), with odds ratio (95% CI) of 1.34 (1.17, 1.54), while not in the younger elderly ($p>0.05$), with OR (95% CI) being 1.09 (0.80, 1.47) in the fully adjusted model. Similar results were obtained when DD was categorized into four groups.

Conclusions—Poor dietary diversity was associated with worse global cognitive function among Chinese elderly, and particularly for the oldest old. This finding would be very meaningful for prevention of cognitive impairment.

Keywords

Dietary diversity; cognitive function; elderly; oldest old

Introduction

The proportion and number of older people have been significantly increased in the past half-century worldwide, owing to decreased fertility and increased life expectancy, consequently, the overall prevalence of age-related health conditions, such as cognitive impairment and dementia, have increased. Indeed, the prevalence of dementia has steadily increased in the past two decades in China (1). Therefore, exploring modifiable risk factors for cognitive impairment is critical for the development of intervention strategies, among which dietary diversity (DD) is likely very important.

Dietary diversity (DD), which is defined as the number of different food groups consumed over a given reference period (2), has been universally recognized as a key element of high quality diets and recommended in dietary guidelines (3). DD may benefit human health in several dimensions, for example, encouraging biodiversity and sustainability and minimizing the adverse effect of foods on health (4), in addition, some studies suggest that DD can serve as an indicator of nutrient adequacy and health status among the elderly (5), and that high nutrient adequacy was possibly associated with better cognitive performance (6). However, very few studies have directly investigated the association of DD with cognitive function in old age (7), especially in Chinese elderly, although there are some studies investigating the associations of diet or dietary patterns with cognitive function (8, 9).

Besides, as studies showed, the risk of cognitive impairment increases with age, the prevalence of cognitive impairment in the oldest old (aged 80 and over) is much higher than

that in the younger elderly (10), but whether association of DD with cognitive function is affected by age stages is never investigated.

In this study, we sought to explore association of DD with cognitive impairment among the Chinese elderly and whether the association was affected by age, using the community-based Longitudinal Healthy Longevity Survey (CLHLS) study.

Methods

Study subjects

Participants were derived from a sample of people aged 65 years and older who underwent the sixth wave assessment of the Chinese Longitudinal Healthy Longevity Survey (CLHLS) conducted in 2011–2012. CLHLS was the first national longitudinal survey on determinants of healthy aging in China; CLHLS compiled extensive longitudinal interview data on a very large population sample of the oldest old (age ≥ 80 years) and younger elderly (age 65–79 years). Details of the study design have been described elsewhere and data quality was reported to be generally good (11). Briefly, of the 9765 persons who participated in the cross-sectional 2011–2012 wave of assessment, 1194 were excluded due to missing data on key variables, such as cognitive function and dietary diversity. Thus, the analytical sample included 8571 persons, of these, 2984 were aged 65–79 (younger elderly group) and 5587 were aged 80+ (oldest-old group).

The CLHLS was approved by the ethics committee of Peking University, and written informed consents were obtained from all participants (or their proxies).

Assessment of Cognitive Function

Global cognitive function was assessed using the Chinese version of the Mini-Mental State Examination (MMSE) that had been validated among Chinese elderly (12). Because performance on the MMSE test was strongly associated with education level (13, 14), we used the validated education-based cutoff scores for the MMSE test to define cognitive impairment, i.e., 19/20 for those without formal education, 22/23 for those with 1–6 years of formal education (primary school), and 26/27 for those with more than 6 years of education (middle school or higher) (15).

Assessment of dietary diversity

In CLHLS, all participants were asked to report intake frequencies of various food groups, including, vegetables, fruits, legumes and its products, nuts, meat, eggs, fish, milk and dairy products, tea, as well as cereals and oil. Because the cereals and oil are absolute necessary food groups in Chinese daily diet, so these two food groups were not included in assessing DD, hence we can construct DD more purposefully, besides, the nine food groups above were shown to be possibly associated with cognition function in prior some studies, which accords with the principle that selection of food groups for assessing DD can be driven by the specific purposes (16). The intake frequency of every food group was measured on a 5-point scale, i.e., ‘almost every day’, ‘once per week at least’, ‘once per month at least’, ‘occasionally’, and ‘rarely or never’. If the response for one food group was ‘almost every

day' or 'once per week at least', then one point was given, otherwise no point was given. The DD score (DDS) was equal to the sum of the points for all nine food groups mentioned above. The total DDS ranged from 0 to 9, with the higher DD score indicating better dietary diversity.

Covariates

Data were collected through face-to-face interviews. Information of socio-demographics (age, sex, education and marital status), lifestyles (smoking, alcohol drinking, physical activities, leisure activities and social activities), resilience, waist circumference, blood pressure, hearing decline, activities of daily life (ADL) disability, diabetes, and stroke were collected. We defined and categorized covariates as previous CLHLS study (17–19).

Marital status was dichotomized as married and non-married, the latter included those divorced, widowed or never married. Alcohol drinking was defined as 'yes' if one drink alcohol one time per month or more in the last year. Physical activities were assessed by two questions: 1. 'Do you currently participate in physical exercise (e.g., walking, playing football, basketball or volleyball, and running etc.)?' We dichotomized the responses into 'yes' and 'no'. 2. Do you conduct some personal outdoor activities? The response was measured by five-point scale, i.e., 'almost every day', 'once per week at least', 'once per month at least', 'occasionally', and 'rarely or never', we dichotomized the response into 'yes' if the answer was 'almost every day' or 'once per week at least', else the response is 'No'. Physical activities were defined as 'yes' if the response of either physical exercise or personal outdoor activities is 'yes'. Leisure activities included growing flowers, raising pets, reading books, playing cards, watching TV and listening to the radio, it was defined as 'yes' if the frequency of any item above is once per week or more. Social activities included support of housekeeping and taking part in organized social activities, and it was defined in the same way with leisure activities (18). Resilience was assessed by a simplified resilience score emphasizing coping and adjusting among the elderly and reflecting personal tenacity, optimism, coping with negative mood, secure relationship, and self-control (20), with the higher scores reflecting greater resilience, and higher resilience defined as a score ≥ 16 . Physical examinations were also conducted by medical personnel. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured twice on the right arm in the sitting position, and the mean values were used. Waist circumference was measured using a non-stretchable tape in centimeters at a level between the lowest rib and Iliac crest (Ilium) with the subjects lightly clothed, the abdominal obesity was defined based on waist circumference using the following criterion: $>90\text{cm}$ for male and $>85\text{cm}$ for the female. Hearing decline was assessed by the question 'Does your hearing decline these years?'. ADL was assessed using the Katz Activities of Daily Living Scale (21). Subjects were asked if they experienced difficulty in performing the following six activities: bathing, dressing, toileting, transfers, continence and eating. ADL disability was defined as 'yes' if they had difficulty in performing any one or more of these ADL tasks. Diabetes and stroke was defined according to self-reported diagnosis of diabetes and stroke, respectively (19).

Statistical analysis

Subject characteristics by cognitive impairment status were compared by t-test for continuous variables and by chi-square tests for categorical variables. Primary analysis showed that the DDS distribution of this sample was normal, and because there are no established cut-off points in terms of number of food groups to indicate adequate or inadequate dietary diversity, so subjects were categorized into two groups, poor DD group and good DD group, based on the mean value of DDS in the sample as FAO suggested (22), those having DDS above the mean value were categorized as 'good', while others were grouped into 'poor'. For every food group, the prevalence of getting one score was analyzed among the good DD group and the poor DD group, respectively.

We used general linear regression analysis to estimate the β coefficient and 95 % confidence interval (CI) of MMSE score associated with DD, in which MMSE score was transformed to $-\log 31\text{-MMSE score}$ because of skewed distribution of the original MMSE score. Logistic regression was used to analyze associations of DD with cognitive impairment, in which the group of good DD was defined as the reference group, odds ratio (OR) and 95% CIs were also calculated to show the risk of cognitive impairment for the poor DD compared with the group of good DD. We reported results from three models: model 1 was adjusted for demographic variables (i.e., age, sex, education, marital status); model 2 was adjusted additionally for smoking, alcohol drinking, physical activities, leisure activities, social activities and resilience; and model 3 was further adjusted for health status, including SBP, abdominal obesity, ADL disability, stroke, and diabetes. These variables were chosen because previous studies showed that these factors were associated with cognitive function. To explore whether there is age difference in the association of DD with cognitive function, we further assessed interaction effect of DD with age on MMSE score and cognitive impairment, respectively. Then we further investigated these associations among the younger elderly and oldest old, separately. Finally, to test the robustness of our results obtained, the subjects were further categorized into four groups based on the internal distribution of DDS, i.e., Best DD group for $DDS \geq 7$, Second DD group for $5 \leq DDS < 7$, Third DD group for $3 \leq DDS < 5$ and the Poorest DD group for $DD \text{ score} < 3$, then the same statistics analysis was conducted.

All statistical analyses were performed with SAS, version 9.2 (SAS Institute Inc., Cary, NC, US). $P < 0.05$ was considered statistically significant, and all P values were two-sided.

Results

The characteristics of study participants by cognitive function status are listed in Table 1. Compared with the subjects with normal cognition, those with cognitive impairment were older and less educated, and they usually reported fewer physical activities, leisure activities and social activities, in addition to poor resilience and a higher prevalence of stroke history, hearing decline and ADL disability. The mean DD score of those with normal cognition was higher than that of those subjects with cognitive impairment (4.61 versus 4.09).

Distribution analysis of getting one score showed that the prevalence of getting one score were higher in the good DD group than those in the poor DD group for every food group

($p < 0.01$ for all food group). Among the good DD group, except the tea drinking and nut intake, the prevalence of getting one point for other seven food groups were higher than 50%. However, among the poor DD group, only for vegetable (79.53%) and meat (55.91%), were the prevalence higher than 50% (Table 2).

Compared with good DD, poor DD was significantly associated with decreased cognitive function, with β (95% CI) of $-0.11(-0.14, -0.08)$ for $-\log 31\text{-MMSE}$ ($p < 0.01$), and odds ratio (95% CI) of 1.29 (1.14, 1.47) for cognitive impairment in the model 3 (Table 3).

We observed statistically significant interaction of age with DD on cognitive impairment (p interaction=0.018), but not on $-\log 31\text{-MMSE}$ (p interaction=0.08). Further separate analysis showed that DD was significantly associated with $-\log 31\text{-MMSE}$ in both the younger elderly and the oldest old ($p < 0.01$), with basically same β (95% CI) values. Poor DD was significantly associated with cognitive impairment only in the oldest old ($p < 0.01$), with odds ratio (95% CI) of 1.34 (1.17, 1.54), while not in the younger elderly ($p > 0.05$), with OR (95% CI) being 1.09 (0.80, 1.47) in the fully adjusted model (Table 4).

When DD was categorized into four groups, similar results were obtained (Supplementary Table 1 and Supplementary Table 2).

Discussion

In this study, we found the mean DD score of this sample was 4.46, the DD score of those with normal cognition was higher than that of subjects with cognitive impairment, results also showed that poor dietary diversity was significantly associated with worse cognitive function, which was consistent with one study conducted among Japanese elderly (7). This finding, if validated in intervention trial, can be taken as one new supplement to those personalized intervention strategies (23),

There are several explanations for our finding. First, DD score was a useful proxy indicator of nutrient adequacy in the elderly (24), good DD is associated with adequate intake of nutrients and better nutritional status (25), and good nutrition-status trajectory is associated with better cognitive function (26); while poor DD may mean malnutrition characterized by poor nutrients intake, less energy reservoir and some adverse effects, for example, impaired immunity, increased risk of infectious diseases and multi-morbidities, while malnutrition was shown predictive for cognitive function decline (5, 27). Second, the action of many nutrients is dependent on the presence of other nutrients from various food groups, only in the context of higher dietary diversity, can nutrient balance be reached, and can the effect of disease prevention be observed (4), so those nutrients that are helpful for cognitive function could not function well if dietary diversity was poor. As shown in this study, the food groups consumed frequently, i.e., whose prevalence of getting one score was more than 50%, were only vegetable and meat in the poor DD group, while the food groups consumed frequently in the good DD group included fruits, legumes and its products, eggs, fish, milk and dairy products, as well as vegetable and meat. Third, poor nutritional status and low dietary diversity are associated with a high level of oxidative stress (28, 29), which would increase the risk of cognitive impairment (30).

Another interesting finding in our study was the interaction effect of age with poor DD on cognitive impairment. The mechanism underlying was not clear, while there are several explanations. First, the physiology function of chewing, salivation secretion, ingestion and absorption, which influence the nutrient intake, will declined with age (31), so the capability of nutrient intake in the oldest old will be worse than that of the younger ones, thus make the oldest old more vulnerable and sensitive to poor DD. Second, because of the higher levels of oxidative stress, lower anti-oxidant reservoirs and declined stress resistance [32–34], as well as the reduced adaptive ability (homeostasis) [35], the ability to maintain normal brain function decreased more in the oldest old, and hence make them more likely to be adversely affected when dietary diversity is poor.

Our finding should be explained with several limitations. First, our analysis was cross-sectional, which meant we could not infer a causal relationship. We should consider the reversal causality -- preexisting cognitive impairment may also result in a reduced ability to choose and prepare a diet having good DD, future researches analyzing longitudinal cohort data will help to explore the causal association. Second, assessment of dietary diversity was based on the intake frequency of food groups, not on the standard food frequency questionnaire (FFQ), which may limit the generalization of our result, while previous research has shown that, for measurement purposes, food group diversity is an appropriate method because of its simplicity (16). Third, we could not adjust blood biomarkers variables, while the important variables related with biomarkers, such as the variables about mental status and diseases prevalence, were adjusted.

Strengths of this study were valued to be mentioned. To our knowledge, very few studies have previously investigated the relationship between DD and cognitive function among a large sample of the elderly. In addition, we also observed the interaction effect of poor DD with age on cognitive impairment.

In this large-scale population-based study, we found that dietary diversity is important for cognitive function in the elderly, especially for the oldest old, which have important public health policy implications, because we can suggest the health professionals strengthen health education on dietary diversity among the elderly and their caregivers, hence reduce the prevalence of cognitive impairment.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Shi and Yi Zeng designed the survey and directed its implementation and revised this manuscript. This work was supported in part by the National institute of Ageing, National institutes of Health, USA [R01 AG023627 to Z.Y. and P30-AG-028716 to V.B.K.], and the National Natural Science Foundation of China [71110107025 71233001, 71490732 to Y.Z.].

References

1. Chan KY, Wang W, Wu JJ, et al. Epidemiology of Alzheimer's disease and other forms of dementia in China, 1990–2010: a systematic review and analysis. *Lancet*. 2013; 81:2016–2023.
2. Krebs-Smith SM, Smiciklas-Wright H, Guthrie HA, et al. The effects of variety in food choices on dietary quality. *J Am Diet Assoc*. 1987; 87:897–903. [PubMed: 3598038]
3. World Health Organization (WHO). WHO; Geneva, Switzerland: 1998. Preparation and Use of Food-Based Dietary Guidelines: Report of a Joint Fao/Who Consultation.
4. Mirmiran P, Azadbakht L, Esmailzadeh A, et al. Dietary diversity score in adolescents-a good indicator of the nutritional adequacy of diets: Tehran lipid and glucose study. *Asia Pac J Clin Nutr*. 2004; 13:56–60. [PubMed: 15003915]
5. Oldewage-Theron WH, Kruger R. Food Variety and Dietary Diversity as Indicators of the Dietary Adequacy and Health Status of an Elderly Population in Sharpeville, South Africa. *J Nutr Elder*. 2008; 7:101–133.
6. Beydoun MA, Gamaldo AA, Beydoun HA, et al. Caffeine and alcohol intakes and overall nutrient adequacy are associated with longitudinal cognitive performance among U.S. adults. *J Nutr*. 2014; 144:890–901. [PubMed: 24744319]
7. Otsuka R, Nishita Y, Tange C, et al. Dietary diversity decreases the risk of cognitive decline among Japanese older adult. *Geriatr Gerontol Int*. 2016
8. Pilleron S, Desport JC, Jésus P, et al. Diet, Alcohol Consumption and Cognitive Disorders in Central Africa: A Study from the EPIDEMCA Program. *J Nutr Health Aging*. 2015; 19:657–667. [PubMed: 26054502]
9. Singh B, Parsaik AK, Mielke MM, et al. Association of mediterranean diet with mild cognitive impairment and Alzheimer's disease: a systematic review and meta-analysis. *J Alzheimers Dis*. 2014; 39:271–282. [PubMed: 24164735]
10. Alexander M, Perera G, Ford L, et al. Age-Stratified Prevalence of Mild Cognitive Impairment and Dementia in European Populations: A Systematic Review. *J Alzheimers Dis*. 2015; 48:355–359. [PubMed: 26401999]
11. Yi, Zeng. Towards Deeper Research and Better Policy for Healthy Aging--Using the Unique Data of Chinese Longitudinal Healthy Longevity Survey. *China Economic Journal*. 2012; 5:2–3. 131–149.
12. Zhang MY, Katzman R, Salmon D, et al. The prevalence of dementia and Alzheimer's disease in Shanghai, China: impact of age, gender, and education. *Ann Neurol*. 1990; 27:428–437. [PubMed: 2353798]
13. Bravo G, Hebert R. Age- and education-specific reference values for the Mini-Mental and modified Mini-Mental State Examinations derived from a non-demented elderly population. *Int J Geriatr Psychiatry*. 1997; 12:1008–1018. [PubMed: 9395933]
14. Grigoletto F, Zappalà G, Anderson DW, et al. Norms for the Mini-Mental State Examination in a healthy population. *Neurology*. 1999; 53:315–320. [PubMed: 10430420]
15. Yin Z, Yan Z, Liang Y, et al. Interactive effects of diabetes and impaired kidney function on cognitive performance in old age: a population-based study. *BMC Geriatr*. 2016; 16:7. [PubMed: 26753625]
16. Ruel MT. Operationalizing Dietary Diversity: A Review of Measurement Issues and Research Priorities. *J Nutr*. 2003; 133:3911S–3926S. [PubMed: 14672290]
17. Yin Z, Shi X, Kraus VB, et al. Gender-dependent Association of Body Mass Index and Waist Circumference with Disability in the Chinese Oldest Old. *Obesity (Silver Spring)*. 22:1918–1925.
18. Yin ZX, Shi XM, Kraus VB, et al. e function in Chinese oldest old. *Age Ageing*. 2012; 41:600–606. (2012). [PubMed: 22447910]
19. Yin ZX, Shi XM, Xu JW, et al. Association between the hypersensitive C-reactive protein and diabetes in the senile elders. *Chinese Journal of Diabetes*. 2012; 20:332–335.
20. Zeng Y, Shen K. Resilience significantly contributes to Exceptional longevity. *Curr Gerontol Geriatr Res*. 2010:525693. [PubMed: 21197075]

21. Katz S, Ford AB, Moscovitz RW, Jackson BA, Jaffe MW. The index of ADL: A standardized measure of biological and psychosocial function. *JAMA*. 1963; 185:914–919. [PubMed: 14044222]
22. Kennedy G, Ballard T, Dop MC. Guidelines for Measuring Household and Individual Dietary Diversity. Rome: FAO of the UN. 2013
23. Fotuhi M, Lubinski B, Trullinger M, et al. A personalized 12-week 'brain fitness program' for improving cognitive function and increasing the volume of hippocampus in elderly with mild cognitive impairment. *J Prev Alz Dis*. 2016; 3:133–137.
24. Rathnayake KM, Madushani P, Silva K. Use of dietary diversity score as a proxy indicator of nutrient adequacy of rural elderly people in Sri Lanka. *BMC Res Notes*. 2012; 5:469. [PubMed: 22931957]
25. Mirmiran P, Azadbakht L, Azizi F. Dietary diversity within food groups: an indicator of specific nutrient adequacy in Teheranian women. *J Am Coll Nutr*. 2006; 25:354–361. [PubMed: 16943458]
26. Wang HP, Liang J, Kuo LM, et al. Trajectories of Nutritional Status and Cognitive Impairment among Older Taiwanese with Hip Fracture. *J Nutr Health Aging*. 2017; 21(1):38–45. [PubMed: 27999848]
27. Chen LY, Liu LK, Hwang AC, et al. Impact of Malnutrition on Physical, Cognitive Function and Mortality among Older Men Living in Veteran Homes by Minimum Data Set: A Prospective Cohort Study in Taiwan. *J Nutr Health Aging*. 2016; 20:41–47. [PubMed: 26728932]
28. Narmaki E, Siassi F, Fariba Koohdani, et al. Dietary diversity as a proxy measure of blood antioxidant status in women. *Nutrition*. 2015; 31:722–726. [PubMed: 25837219]
29. Moreira PL, Villas Boas PJ, Ferreira AL. Association between oxidative stress and nutritional status in the elderly. *Rev Assoc Med Bras*. 2014; 60:75–83. [PubMed: 24918857]
30. Guidi I, Galimberti D, Lonati S, et al. Oxidative imbalance in patients with mild cognitive impairment and Alzheimer's disease. *Neurobiol Aging*. 2006; 27:262–269. [PubMed: 16399211]
31. Phillips RM. Nutrition and depression in the community-based oldest old. *Home Healthc Nurse*. 2012; 30:462–471. [PubMed: 22936044]
32. Andriollo-Sanchez M, Hininger-Favier I, Meunier N, et al. Age-related oxidative stress and antioxidant parameters in middle-aged and older European subjects: the ZENITH study. *Eur J Clin Nutr*. 2005; 59:S58–62. [PubMed: 16254584]
33. Massudi, Hassina, Grant, Ross, Braidy, Nady, Guest, Jade, Farnsworth, Bruce, Guillemin, Gilles J. Age-Associated Changes In Oxidative Stress and NAD+ Metabolism In Human Tissue. *PLoS One*. 2012; 7:e42357. [PubMed: 22848760]
34. Semenchenko GV, Khazaeli AA, Curtsinger JW, Yashin AI. Stress resistance declines with age: analysis of data from a survival experiment with *Drosophila melanogaster*. *Biogerontology*. 2004; 5:17–30. [PubMed: 15138378]
35. Troncale JA. The aging process: physiologic changes and pharmacologic implications. *Postgrad Med*. 1996; 99:111–114. 120–122. [PubMed: 8650079]

Table 1Characteristics of study participants by cognitive impairment status^a

		Cognitive Impairment	Cognitive Impairment	
Characteristics	Total sample	No	Yes	p value
No of subjects	8571	6210	2361	
Age (years), mean (SD)	85.70 (11.11)	82.74(10.21)	93.48 (9.51)	<0.001
Female	4605 (53.73)	3062 (49.31)	1543 (65.35)	<0.001
Education years				
0	4887 (57.02)	3222 (51.88)	1665 (70.52)	<0.001
1–6	2689 (31.37)	2205 (35.51)	484 (20.50)	
>6	995 (11.61)	783 (12.61)	212 (8.98)	
Married	3387 (39.52)	2995 (47.58)	432 (18.30)	<0.001
Han Nationality	7335 (85.58)	5307 (85.46)	2028 (85.90)	0.60
Urban residence	1536 (17.92)	1100 (17.71)	436 (18.47)	0.42
Smoking	1591 (18.56)	1291 (20.79)	300 (12.71)	<0.001
Alcohol drinking	1498 (17.48)	1191 (19.18)	307(13.00)	<0.001
Physical activities	4549 (53.07)	3771 (60.72)	778 (32.95)	<0.001
Physical exercise	2920 (34.07)	2440 (39.29)	480 (20.33)	<0.001
Personal outdoor activities	3802 (44.36)	3182 (51.24)	620 (26.26)	<0.001
Leisure activities	6063 (70.74)	5037 (81.11)	1026 (43.46)	<0.001
Social activities	4580 (53.44)	3975(64.01)	605 (25.62)	<0.001
Higher resilience	4334 (50.57)	3694 (59.48)	640 (27.11)	<0.001
Stroke	1159 (13.52)	804 (12.95)	355 (15.04)	0.01
Diabetes	1082 (12.62)	820 (13.20)	262 (11.10)	<0.05
ADL disability	2061 (24.04)	840 (13.82)	1221 (52.36)	<0.001
SBP (mmHg), mean (SD)	136.68 (21.07)	136.9(20.50)	136.0 (22.47)	0.09
DBP (mmHg), mean (SD)	80.47 (12.21)	80.58(11.58)	80.17(13.71)	0.20
Hearing decline	3948 (46.06)	2211 (35.71)	1737 (73.73)	<0.001
Abdominal obesity	2582 (30.12)	2009(32.35)	573(24.27)	<0.001
DDS, mean (SD)	4.46 (1.99)	4.61(1.97)	4.09 (1.97)	<0.001
Poor DD	4289 (50.04)	2928(47.15)	1361(57.65)	<0.001
MMSE score ^b	26.45 (3.03)	28.34 (2.12)	12.23 (1.58)	<0.001

Abbreviations: ADL, activities of daily living; DBP, diastolic blood pressure; DDS, dietary diversity score; DD: dietary diversity; SBP, systolic blood pressure; SD, standard deviation; MMSE, mini-mental state examination;

^a. Data are shown as n (%) for categorical variables, and shown as mean (SD) for continuous variables;

^b. Transformed back from $-\log(31 - \text{MMSE score})$.

Table 2

Prevalence of getting one score for various food groups among the good DD group and the poor DD group, respectively^a

Food groups	Good DD	Poor DD
Vegetables	96.82%	79.53%
Fruits	59.95%	15.46%
Legumes and its products	79.29%	30.68%
Nuts	21.35%	2.75%
Meat	92.13%	55.91%
Eggs	91.99%	48.92%
Fish	72.42%	19.40%
Milk and dairy products	51.45%	12.68%
Tea drinking	46.94%	15.39%

Abbreviations: DD: dietary diversity;

^a. The difference in prevalence of getting one score for every food group between good DD and poor DD was significant ($p < 0.01$).

Table 3

Association of DD with Mini Mental State Examination (MMSE) score and cognitive impairment (n=8571)

DD	Model 1	Model 2	Model 3
β coefficient (95% CI) of MMSE ^a			
Good	0.00 (reference)	0.00 (reference)	0.00 (reference)
Poor	-0.20 (-0.24, -0.16) **	-0.10 (-0.14, -0.06) **	-0.11(-0.14, -0.08) **
Odds ratio (95% CI) of cognitive impairment			
Good	1.00 (reference)	1.00 (reference)	1.00 (reference)
Poor	1.43 (1.28, 1.59) **	1.20 (1.06, 1.35) **	1.29 (1.14, 1.47) **

Abbreviations: Dietary Diversity (DD) ; CI: confidence interval; Model 1: adjustment for age, sex, education, marital status; Model 2: additionally adjusted for smoking, alcohol drinking, physical activities, leisure activities, social activities and resilience; Model 3: additionally adjusted for health status, including systolic blood pressure, abdominal obesity, hearing decline, activities of daily living (ADL) disability, stroke history and diabetes;

^a. The original MMSE score was transformed as $-\log(31 - \text{MMSE score})$;

* : $p < 0.05$;

** : $p < 0.01$

Table 4

Association of DD with Mini-Mental State Examination (MMSE) score and cognitive impairment among the young elderly and the oldest old, respectively.

	Younger Elderly		Older Elderly	
DD	MODEL 1	FULL MODEL	MODEL 1	FULL MODEL
β coefficient (95% CI) of MMSE ^a				
Good	0.00 (reference)	0.00 (reference)	0.00 (reference)	0.00 (reference)
Poor	-0.20 (-0.26, -0.14) **	-0.11 (-0.17, -0.06) **	-0.20 (-0.25, -0.15) **	-0.12 (-0.17, -0.07) **
OR (95% CI) of cognitive impairment				
Good	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Poor	1.47 (1.11, 1.95) **	1.09 (0.80, 1.47)	1.42 (1.26, 1.60) **	1.34 (1.17, 1.54) **

Abbreviations: DD: dietary diversity; OR: Odds ratio; CI: confidence interval; Model 1: adjustment for age, sex, education, marital status; Full model: additionally adjusted for smoking, alcohol drinking, physical activities, leisure activities, social activities, resilience, systolic blood pressure, abdominal obesity, hearing decline, activities of daily living (ADL) disability, stroke history and diabetes (model 3);

^a. The original MMSE score was transformed as $-\log(31 - \text{MMSE score})$;

* : $p < 0.05$;

** : $p < 0.01$