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Yuebin Lv

Virginia Byers Kraus

Xiang Gao

Zhaoxue Yin

Jinhui Zhou

See next page for additional authors

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Yuebin Lv, Virginia Byers Kraus, Xiang Gao, Zhaoxue Yin, Jinhui Zhou, Chen Mao, Jun Duan, Yi Zeng, Melanie S. Brasher, Wanying Shi, and Xiaoming Shi

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Higher dietary diversity scores and protein-rich food consumption were associated with lower risk of all-cause mortality in the oldest old

Yuebin Lv, Ph.D.¹, Virginia Byers Kraus², Xiang Gao, Ph.D.³, Zhaoxue Yin, M.D.⁴, Jinhui Zhou, M.D.¹, Chen Mao, Ph.D.⁵, Jun Duan, M.D.^{1,6}, Yi Zeng, Ph.D.^{7,8}, Melanie Sereny Brasher, Ph.D.⁹, Wanying Shi, M.D.¹, Xiaoming Shi, Ph.D.¹

¹National Institute of Environmental Health, Chinese Center for Disease Control and Prevention, Beijing, China;

²Duke Molecular Physiology Institute and Division of Rheumatology, Department of Medicine, Duke University School of Medicine, Durham, North Carolina, USA;

³Nutritional Epidemiology Lab, Pennsylvania State University, Philadelphia, Pennsylvania, USA;

⁴Division of Non-Communicable Disease Control and Community Health, Chinese Center for Disease Control and Prevention, Beijing, China;

⁵Division of Epidemiology, School of Public Health, Southern Medical University, Guangzhou, Guangdong, China;

⁶Department of Epidemiology and Health Statistics, School of Public Health, Anhui Medical University, Hefei, Anhui, China;

⁷Center for the study of Aging and Human Development and the Geriatric Division of School of Medicine, Duke University, Durham, North Carolina, USA;

⁸Center for Study of Healthy Aging and Development Studies, Peking University, Beijing, China;

⁹Department of Sociology and Anthropology and Department of Human Development and Family Studies, University of Rhode Island, Kingston, RI, USA

Abstract

Correspondence to: Xiaoming Shi, Ph.D.; National Institute of Environmental Health, Chinese Center for Disease Control and Prevention; #7 Panjiayuan Nanli, Chaoyang, Beijing, 100021, China; shixm@chinacdc.cn; Telephone: (+86) 1050930101; Fax: (+86) 1058900247.

Statement of Authorship

XMS had full access to all of the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. YBL, VBK, XG, XMS were involved in the study concept and design. All of the listed authors made contribution to framework construction, results interpretation, manuscript revision, and approved the final version of the manuscript.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

Background & aims: Dietary diversity is widely advocated in national and international recommendations although whether the beneficial effects on survival or longevity still apply in the final phase of the lifespan remains understudied. We aimed to prospectively examine the association of dietary diversity, food items with all-cause mortality among the oldest old (80+) and determine whether dietary diversity recommendations were appropriate for this population.

Methods: The study included 28,790 participants aged 80+ (9957 octogenarians, 9925 nonagenarians, and 8908 centenarians). A baseline dietary diversity score (DDS) was constructed based on nine food items of a food frequency questionnaire. Cox models with penalized splines evaluated non-linear associations of DDS as continuous variable with mortality to identify cut-offs of DDS.

Results: We documented 23,503 deaths during 96,739 person-years of follow-up. Each one unit increase in DDS was associated with a 9% lower risk of mortality (adjusted hazard ratio (HR): 0.91; 95% confidential interval (CI): 0.90–0.92). Compared to participants whose DDS less than 2 scores, those with a DDS of 2, 3, 4, 5, and higher than 6 scores had a lower mortality risk, the HRs were 0.86 (0.82–0.89), 0.78 (0.75–0.81), 0.69 (0.66–0.72), 0.65 (0.62–0.68), and 0.56 (0.53–0.58) respectively, and a significant trend emerged ($p < 0.001$). Protein-rich food items were associated with prominent beneficial effects on mortality including meat (HR and 95% CI for high vs low frequency: 0.70 (0.68–0.72)), fish and sea food (HR, 0.74 (0.72–0.77)), egg (HR, 0.75 (0.73–0.77)), and bean (HR, 0.80 (0.78–0.82)).

Conclusions: Even after the age of 80, the DDS tool may offer a simple and straightforward mean of identifying and screening individuals at high risk for mortality. Recommendation of dietary diversity, especially consumption of protein-rich food, may be advocated to reduce mortality risk and promote longevity in the oldest old.

Keywords

Dietary diversity; protein-rich food; mortality; cohort study; oldest old; elderly

Introduction

Most previous studies related to development of chronic diseases and under-nutrition, all-cause and cause-specific mortality have investigated the role of single food items, macro- and micro-nutrient intake and bioactive components [1–4]. Although a high correlation and interaction among individual foods and nutrients in typical human diets is recognized, less studies to date have focused on the appraisal of the total diet or broad dietary patterns for human health [5–7].

One widely used approach to evaluation of total diet quality is assessment of dietary diversity, a rapid, user-friendly and cost-effective tool [8, 9]. This tool is able to provide an overall assessment of dietary behaviors, to evaluate the effect of several food items simultaneously on health [8], bypass methodological problems of interactions, and facilitate a more comprehensive approach to disease control and prevention [9]. We previously showed a significant association between the dietary diversity score (DDS), constructed from information on nine food, and cognitive impairment among Chinese elderly and oldest old (80+) [10]. A number of national and international dietary guidelines have advocated

improving the diversity of the diet to meet daily nutrient requirements and reduce the risk of various chronic diseases [11–14], while evidence from observational studies to date that support benefits of higher dietary diversity for health outcome or survival is limited among the elderly, especially among the oldest old.

It is generally acknowledged that multiple factors, such as biological, environmental, and psychosocial factors, act together to promote human longevity [15]. The impact of dietary behavior is considered one of the key modifiable determinants of longevity [16]. A beneficial effect of dietary diversity for reducing mortality risk has been established for middle aged and younger elderly individuals [17]. Whether these effects of dietary diversity still apply in the final phase of the lifespan remains understudied. Consequently, there is currently little consensus regarding dietary behavior and longevity in the oldest old. Much of the evidence on the role of dietary diversity in mortality for this age group is limited by short follow-up periods, small sample sizes, survivor biases for healthier individuals, scarcity of longitudinal studies, and the focus on populations of developed countries [18, 19]. Due to these limitations, the generalizability to the population of Chinese oldest old is unclear.

As a result of a decline in social or economic status and physiological function with aging, the oldest old are most likely to suffer from nutritional deficiencies [20–22]. A deeper understanding of the link of diet diversity to survival could facilitate establishment of evidence-based recommendations for the oldest old to promote longevity and improve their life quality [23]. To examine whether recommendations regarding dietary diversity are appropriate for this population, in the current study, we prospectively examined the associations of the DDS with all-cause mortality in the Chinese Longitudinal Healthy Longevity Study (CLHLS) of 28,790 oldest old, with adjustment for age, sex, residence, occupation, educational background, income, marital status, lifestyle, oral health status, prevalence of diseases, cognitive impairment, and disability in activities of daily living (ADL). Furthermore, the associations between each food item composed of DDS and all-cause mortality were examined to identify key food groups that could be targeted to help achieve and maintain better survival.

Materials and Methods

Study Setting

Participants, derived from CLHLS, were enrolled in 1998, 2000, 2002, 2005, 2008–09, 2011–12, and 2014 and have been followed up ever since. The CLHLS randomly selected 806 cities and counties in 23 provinces of China using multi-stage stratified sampling, and the study areas covering 85% Chinese population. All centenarians who voluntarily agreed to participate in the study were attempted to be interviewed. For each centenarian, one nearby nonagenarian (90–99), octogenarian (80–89) and younger elderly (65–79) of predefined sex were interviewed. To obtain comparable numbers of women and men for each age group, the predefined sex were randomly determined by the randomly assigned centenarians' code numbers [24, 25]. A more detailed description and assessment of the CLHLS data quality have been presented in previous publications [24, 25]. Among 43,487 CLHLS participants recruited from 1998 to 2014, 28,790 (66.2%) oldest old met the inclusion criteria: aged 80 and older, successfully followed up once or more, available

fish and seafood, eggs, beans, fruits, salty vegetables, tea, garlic, and fresh vegetables, adjusted with referred covariates.

In sensitivity analysis, participants lost to follow-up in the second or later follow-up survey were removed to examine possible attrition bias; Cox proportional hazard models were re-estimated excluding deaths in the first year; or excluding the participants with comorbidity (including heart disease, cerebrovascular disease, respiratory disease, and digestive system diseases); two other potentially confounding factors, body mass index (BMI, was continuous variable) and sufficient income (yes or no, based on the judgment of the participants), were further adjusted in the models. Subgroup analyses were also performed in three age groups (octogenarians, nonagenarians, and centenarians), men and women, participants living in urban or rural areas, participants with different occupation (farmer or non-farmer), participants with different source of income (pension or other), non-smokers or smokers, non-drinkers or drinkers, participants with different teeth number (≥ 5 or <5), participants using artificial denture or not, participants with cognitive impairment or not, participants with disability in ADL or not. Statistical interaction was performed for building Cox model including 2 interaction terms and their product. The maximum of likelihood ratios test was used to detect the significance of the interaction effect. The I^2 statistic, which describes the percentage of variation across studies that is due to heterogeneity rather than chance, was calculated in the heterogeneity tests. $P < 0.05$ (two-sided) was considered statistically significant. SAS (version 9.4, SAS Institute Inc, Cary, NC) and R version 3.4.2 (R foundation for Statistical Computing, Vienna, Austria) were used for the statistical analyses.

Results

Baseline characteristics of participants

Baseline DDS was less than 2 points in 19.8% (5707/28,790) of participants and higher than 6 points in 16.6% (4789/28,790) of participants. The mean age was 92.9 (standard deviation, 7.5) years; 61.8% were women. More description was present in Table 1 and Appendix 2 in the Supplement.

DDS and all-cause mortality

Follow-up time was a mean of 3.4 years, with a standard deviation of 2.7 years, ranging from 0.1 years to 16.3 years. There were 23,503 deaths during 96,739 person-years of follow-up. Kaplan-Meier curves revealed an inverse association of DDS and mortality for six categories of the DDS (log rank test: $P < 0.001$ for <2 , 2, 3, 4, 5, ≥ 6 DDS points). For the whole cohort, the mortality rate was 21.2 per 100 person-years; 15.2, 27.8, and 39.2 per 100 person-years for octogenarians, nonagenarians, and centenarians; and 33.0, 27.6, 25.4, 22.6, 20.7, and 17.5 per 100 person-years for participants with <2 , 2, 3, 4, 5, and ≥ 6 DDS points (Figure 2).

DDS was inversely associated with mortality, each one score increase in DDS corresponded to a 10% lower risk of mortality, with a crude hazard ratio (HR) of 0.90(0.89–0.90), $P < 0.001$. After adjusting a number of confounding factors between DDS and mortality, there was slight attenuation of risk estimates, with an HR of 0.91 (0.90–0.92), $P < 0.001$. Compared

to participants whose DDS was less than 2 points, those with a DDS of 2, 3, 4, 5, and higher than 5 scores had a lower mortality risk, the HRs were 0.86 (0.82–0.89), 0.78 (0.75–0.81), 0.69 (0.66–0.72), 0.65 (0.62–0.68), and 0.56 (0.53–0.58) respectively, and a significant trend emerged ($p<0.001$). Protein-rich food items were associated with prominent beneficial effects on mortality including meat (HR and 95% CI for high vs low frequency: 0.70 (0.68–0.72), $P<0.001$), fish and sea food (HR, 0.74 (0.72–0.77), $P<0.001$), egg (HR, 0.75 (0.73–0.77), $P<0.001$), and bean (HR, 0.80 (0.78–0.82), $P<0.001$). (Figure 3)

Sensitivity analyses and subgroup analyses

Sensitivity analyses, excluding deaths during the first year (Appendix Figure 2 in the Supplement), or excluding the participants lost to follow-up (Appendix Figure 3 in the Supplement), or excluding the participants with comorbidity (Appendix Figure 4 in the Supplement), or further adjusting for sufficient income and BMI (Appendix Figure 5 in the Supplement), showed that the inverse association of DDS with mortality risk was robust. With respect to mortality risk, there were significant interactions of DDS with age group, sex, residence, occupation, exercise practice and cognitive function. The beneficial effects of higher DDS for mortality risk decreased with increments of age (heterogeneity test: $P<0.001$); the HR was 0.87 (0.86–0.88) for octogenarians, $P<0.001$, 0.92 (0.91–0.93) for nonagenarians, $P<0.001$, 0.93 (0.92–0.94) for centenarians, $P<0.001$. Heterogeneity tests showed that the inverse association of DDS with mortality was more prominent for men, participants living in urban areas, non-farmer, participants having pension, participants having 5 teeth. These estimated effects were similar in smokers and non-smokers, alcohol drinkers and non-drinkers, participants using artificial denture or not, participants with and without cognitive impairment, and participants with and without disability in ADL (Figure 4).

Discussion

To our knowledge, this is the first cohort study in a nationally representative sample of Chinese oldest old providing support for a relationship between higher DDS and lower mortality risk in the oldest old. After adjustment for potential confounders, a 44% lower risk of mortality was observed among the participants with the highest DDS than the lowest. Very few studies to date have explored the association of DDS with survival for the population aged 80+. Owing to the high mortality rate of this population and long duration of follow-up, most of the survival status was documented. Cox models with penalized splines were done to investigate potential non-linear association of DDS with mortality, which made it possible to identify the optimal cut-offs of DDS. Additionally, a number of identified confounder of DDS with all-cause mortality were adjusted, sensitivity analyses or subgroup analyses were performed to explore the reverse casualty and selection bias, which made our finding more confident.

Although higher consumption of protein has been associated with an increased mortality risk in the general population [13], our data in Chinese oldest old reveal a protective effect of higher protein consumption. It has been reported that the best way to optimize health span and longevity is likely to be low protein consumption during the younger age and then

moderate to high protein consumption in older age [28]. A high prevalence of insufficient protein intake has been reported in Chinese elderly [29]. Our results are consistent with the common belief that the elderly need more protein. A notable difference of the Chinese relative to other populations, is that as many as 40% of the Chinese oldest old consumed beans often or almost every day. Bean products have protective effects on breast cancer, and decrease mortality risk [30].

Although a variety of diet quality indices and health outcomes have been used in different previous studies; most studies reported an association of a healthier diet with better health outcomes within the general population or younger elderly [31–34]. A recent meta-analysis focusing on elderly in the United States and southern Europe showed that greater adherence to the WHO dietary guidelines was associated with lower cardiovascular disease (CVD) mortality [5]. Among 492,823 Americans between the ages of 50 and 71 years, older adults with a higher dietary index scores reported a 12–28% lower risk of cancer, CVD, and all-cause mortality [6]. In 1743 Taiwanese elderly aged 65 or older, DDS higher than 4 were predictors of lower all-cause and cause-specific mortality [33]. In 826 Dutch elderly aged 65–84 years, a high quality diet was associated with a 40% lower mortality risk and 2.5 years longer life expectancy in elderly men [34].

There is no standardized measure for dietary diversity, while the relationship of dietary diversity with health outcome may differ by inconsistencies in the types and numbers of food groups included. A recent science advisory declared that dietary diversity, composed of a wide range of unhealthy and healthy foods and food groups, does not contribute to a healthy dietary pattern or promote a healthy body weight for the general population [9]. In the present study the index of DDS, mainly composed of healthy food items, may indicate higher diet quality scores, which was developed to assess adequate food consumption and diet healthfulness [35]. It underlines that understanding different measures of dietary diversity and stratification by food healthfulness is critical to assess the role of dietary diversity in health outcome and survival.

There are several ways in which an increased DDS might improve survival. DDS has been found to be a useful proxy of nutrient intake in the elderly [36]. Higher dietary diversity is associated with a lower likelihood of toxic ingredients in food, optimized telomere length and maintenance of muscle strength [37–39]. A lower DDS may lead to dietary inadequacies of essential nutrients, micronutrients that are a particular concern in elderly people. Both the 2016 Dietary Guidelines for Chinese Residents and the 2015–2020 Dietary Guidelines for Americans included messages about dietary variety [11, 12]. After adjusting for various confounders, such as social-economic status, oral health, and health status in the present study, there was little change in the HR [40, 41]. It shows that confounding factors were not likely explanations for the results observed here.

It is known that dietary variety declines with advancing age [42]. Interestingly, with respect to mortality, an interaction of age with DDS was observed. It was not surprising that a stronger association of DDS and survival was observed for octogenarians than centenarians consistent with a higher capability for nutrient digestion and absorption for this age group. A similar explanation may also be possible for the more prominent protective effect of DDS on

mortality in men, participants living in urban areas, non-farmer, participants having pension, and participants having 5 teeth.

The associations of DDS with mortality in the oldest old may be influenced by methodological issues, for instance, survival bias or selection bias. In the elderly aged 80+, diseases or health deterioration likely lead to a change of lifestyle. The effects of DDS on mortality can be diluted by the misclassification of lifelong exposure levels. Additionally, adults with unhealthier lifestyles or dietary behaviors may have died before the age of 80 [43]. The healthier survivor biases may have caused an underestimation of the effects of DDS in the population aged 80+ [44]. In our sensitivity analyses, exclusion of participants who died within the first year of follow-up, and exclusion of prevalent cases of identified disease or functional impairment made reverse causation or selection bias unlikely.

There were several limitations with regard to the study design and measurements in this study. Firstly, only self-reported information on DDS was collected, which serves as a potential source of recall bias. Social desirability bias may also have occurred due to the subjective and crude categorization of the food items; given that the mean age of the participants was as high as 92.9 years and the low education level, we deemed such categorizations to be the most sensible choices. Secondly, a detailed quantitative dietary intake evaluation was not performed; this made it impossible to adjust for energy intake in the analyses. However, a number of key determinants of energy intake were taken into account, such as age, sex, BMI, comorbidities and physical activity. Thirdly, information on different types of cereals and oils, as two of the most important food categories contribute to dietary diversity, was not collected; this may attenuate the association of DDS with mortality risk. Fourthly, the association of DDS and cause-specific mortality was not explored, due to missing data on death records reviewed by doctors. Fifthly, chronic diseases were self-reported thus residual confounding may still exist.

Conclusions

In the Chinese oldest old, a clear dose-response relationship of DDS with mortality was revealed; higher DDS was associated with significant lower mortality risk. Even among those elderly aged 80 and older, DDS is a simple and straightforward tool for potentially identifying and screening for individuals at higher risk for mortality. This study provides support for recommending dietary diversity, a modifiable behavioral factor, especially consumption of protein-rich food items, for the oldest old to reduce mortality risk.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Abbreviations:

ADL	activities of daily living (ADL)
BMI	body mass index
CLHLS	Chinese Longitudinal Healthy Longevity Survey
CI	confidence interval
DDS	dietary diversity score
HR	hazard ratios
MMSE	Mini-Mental State Examination
SD	standard deviation

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Highlights

- In this prospective cohort, 23,503 deaths were documented during 96,739 person-years of follow-up, higher DDS was associated with significant lower mortality risk.
- Protein-rich food items were associated with prominent beneficial effects on mortality.
- Even after the age of 80, the DDS tool may offer a simple and straightforward mean of identifying and screening individuals at high risk for mortality.
- Recommendation of dietary diversity, especially consumption of protein-rich food, may be advocated to reduce mortality risk and promote longevity in the oldest old.

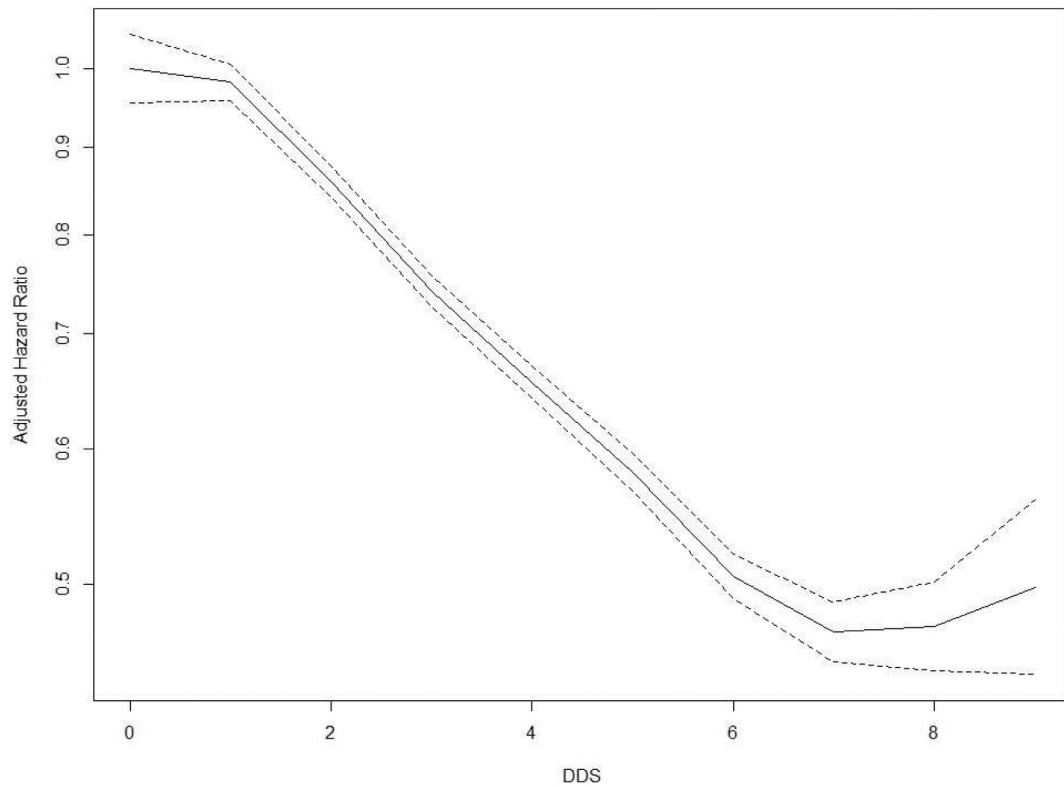


Figure 1. The adjusted hazard ratio of mortality for dietary scores in Cox models with penalized splines

The lines depict the adjusted hazard ratio for risk of mortality; the dotted lines indicate the 95% confidence intervals. Two cut-offs were identified in DDS scores (<2 and 6) based on hazard ratios for mortality that did not significantly change further for scores below or above these cut-offs respectively.

Adjusting for age (continuous variable), sex, residence, occupation, educational background, source of income, current marital status, living pattern, tobacco smoking, alcohol drinking, regular exercise, number of teeth (continuous variable), use of artificial denture, hypertension, heart disease, cerebrovascular disease, respiratory disease, digestive system diseases, cognitive impairment, and disability in ADL.

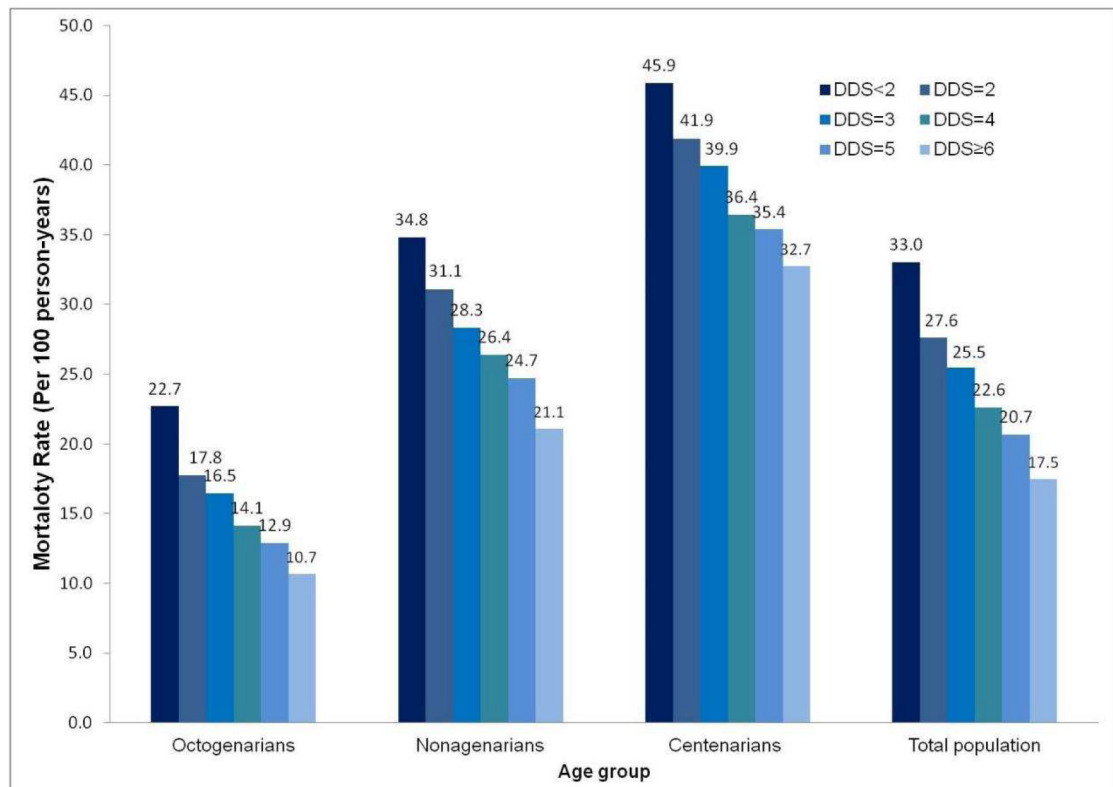


Figure 2. Mortality rate (person-years) in participants with different dietary diversity scores
 For the whole cohort, the mortality rate was 21.2 per 100 person-years, and 33.0, 27.6, 25.4, 22.6, 20.7, and 17.5 per 100 person-years for participants with less than 2, 2, 3, 4, 5, and 6 points of DDS.

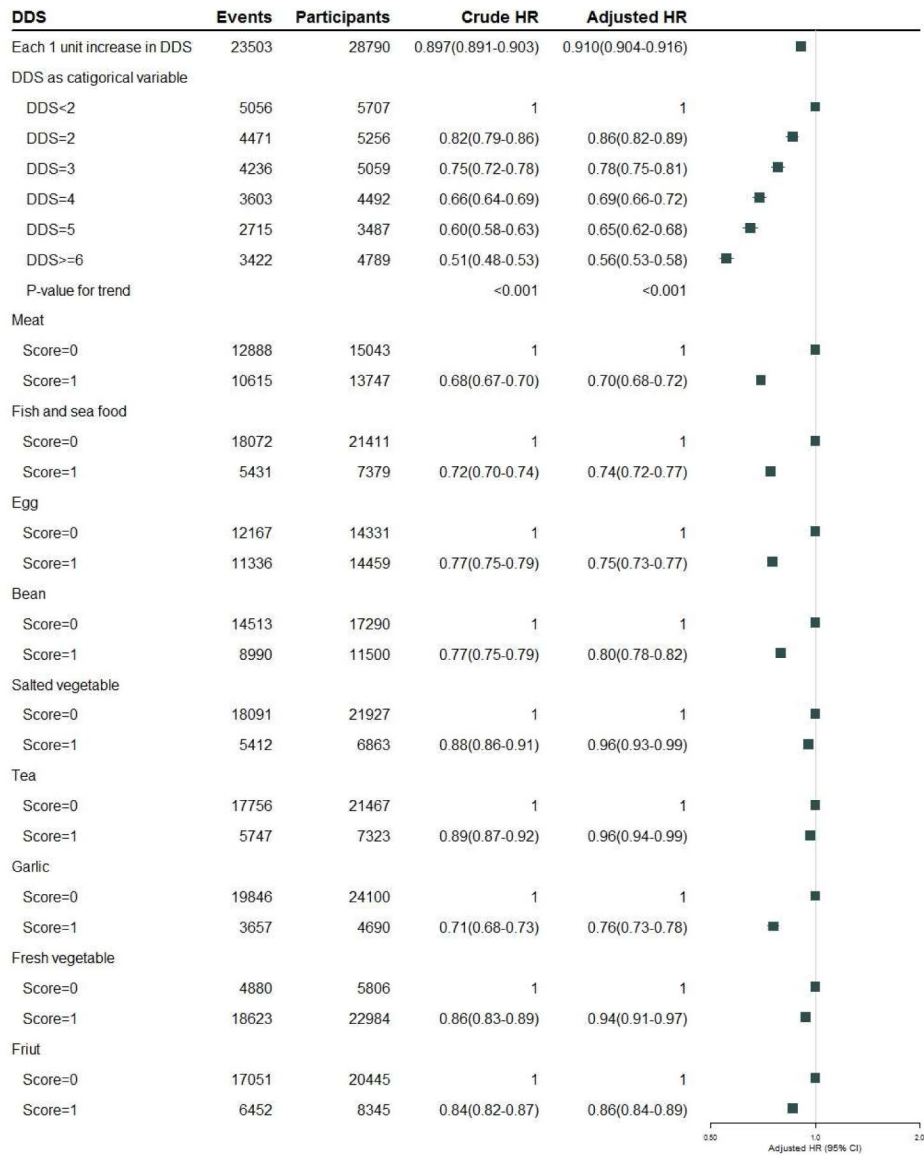


Figure 3. Association of dietary diversity scores with all-cause mortality among the oldest old Adjusting for age (continuous variable), sex, residence, occupation, educational background, source of income, current marital status, living pattern, tobacco smoking, alcohol drinking, regular exercise, number of teeth (continuous variable), use of artificial denture, hypertension, heart disease, cerebrovascular disease, respiratory disease, digestive system diseases, cognitive impairment, and disability in ADL.

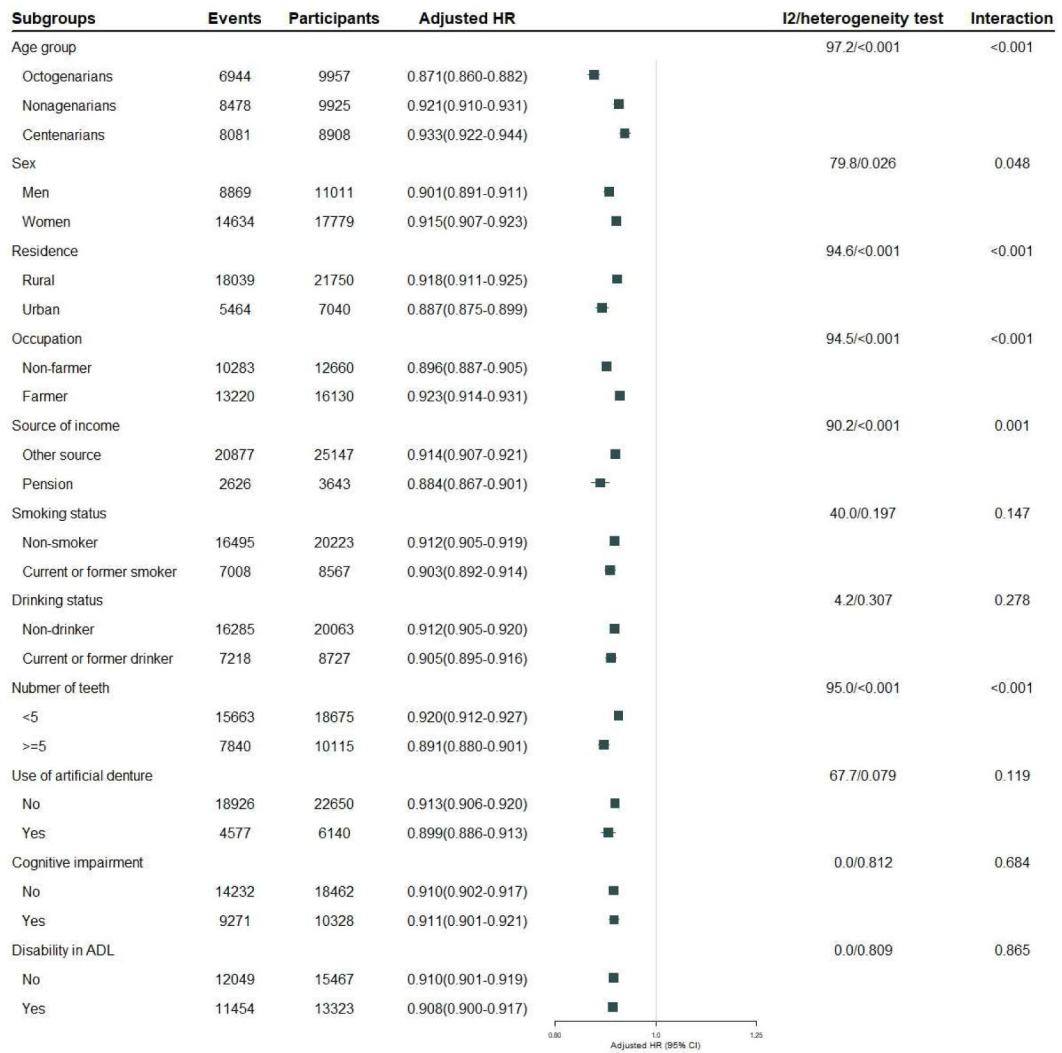


Figure 4. Subgroup analyses for the association of dietary diversity score with all-cause mortality among the oldest old (DDS as continuous variables, ranged from 0 to 9)

Adjusting for age (continuous variable), sex, residence, occupation, educational background, source of income, current marital status, living pattern, tobacco smoking, alcohol drinking, regular exercise, number of teeth (continuous variable), use of artificial denture, hypertension, heart disease, cerebrovascular disease, respiratory disease, digestive system diseases, cognitive impairment, and disability in ADL.

Table 1.Baseline characteristics of the 28,790 study participants according to DDS^a

Variable	DDS<2	DDS=2	DDS=3	DDS=4	DDS=5	DDS>5	Total	P Value
Number of participants	5707 (19.8)	5256 (18.3)	5059 (17.6)	4492 (15.6)	3487 (12.1)	4789 (16.6)	28790(100)	
Age, mean (SD), y	93.8±7.3	93.2±7.5	93.0±7.5	92.7±7.5	92.3±7.6	91.8±7.5	92.9±7.5	<.001
Sex								<.001
Men	1963 (34.4)	1857 (35.3)	1899 (37.5)	1760 (39.2)	1437 (41.2)	2095 (43.7)	11011 (38.2)	
Women	3744 (65.6)	3399 (64.7)	3160 (62.5)	2732 (60.8)	2050 (58.8)	2694 (56.3)	17779 (61.8)	
Residence								<.001
Urban	1097 (19.2)	1085 (20.6)	1167 (23.1)	1169 (26.0)	992 (28.4)	1530 (31.9)	7040 (24.5)	
Rural	4610 (80.8)	4171 (79.4)	3892 (76.9)	3323 (74.0)	2495 (71.6)	3259 (68.1)	21750 (75.5)	
Occupation								<.001
Non-farmer	2389 (41.9)	2189 (41.6)	2203 (43.5)	1982 (44.1)	1599 (45.9)	2298 (48.0)	12660 (44.0)	
Farmer	3318 (58.1)	3067 (58.4)	2856 (56.5)	2510 (55.9)	1888 (54.1)	2491 (52.0)	16130 (56.0)	
Educational background								<.001
Illiteracy	4456 (78.1)	3955 (75.2)	3653 (72.2)	3151 (70.1)	2311 (66.3)	3106 (64.9)	20632 (71.7)	
Literacy	1251 (21.9)	1301 (24.8)	1406 (27.8)	1341 (29.9)	1176 (33.7)	1683 (35.1)	8158 (28.3)	
Source of income								<.001
Pension	380 (6.7)	439 (8.4)	584 (11.5)	611 (13.6)	615 (17.6)	1014 (21.2)	3643 (12.7)	
Other	5327 (93.3)	4817 (91.6)	4475 (88.5)	3881 (86.4)	2872 (82.4)	3775 (78.8)	25147 (87.3)	
Sufficient income ^b								<.001
No	1567 (35.4)	1265 (28.0)	1084 (24.1)	825 (19.8)	527 (15.9)	743 (16.0)	6011 (23.5)	
Yes	2860 (64.6)	3259 (72.0)	3417 (75.9)	3339 (80.2)	2780 (84.1)	3896 (84.0)	19551 (76.5)	
Marital status								<.001
In marriage	812 (14.2)	804 (15.3)	835 (16.5)	790 (17.6)	693 (19.9)	1073 (22.4)	5007 (17.4)	
Not in marriage	4895 (85.8)	4452 (84.7)	4224 (83.5)	3702 (82.4)	2794 (80.1)	3716 (77.6)	23783 (82.6)	
Living pattern								<.001
With family members	4601 (80.6)	4306 (81.9)	4272 (84.4)	3778 (84.1)	2973 (85.3)	4079 (85.2)	24009 (83.4)	
Alone or at nursing home	1106 (19.4)	950 (18.1)	787 (15.6)	714 (15.9)	514 (14.7)	710 (14.8)	4781 (16.6)	
Tobacco smoking status								<.001
Non-smoker	4139 (72.5)	3773 (71.8)	3571 (70.6)	3170 (70.6)	2349 (67.4)	3221 (67.3)	20223 (70.2)	
Current smoker	872 (15.3)	820 (15.6)	793 (15.7)	677 (15.1)	554 (15.9)	806 (16.8)	4522 (15.7)	
Former smoker	696 (12.2)	663 (12.6)	695 (13.7)	645 (14.4)	584 (16.7)	762 (15.9)	4045 (14.1)	
Alcohol drinking status								<.001
Non-drinker	4081 (71.5)	3696 (70.3)	3554 (70.3)	3132 (69.7)	2393 (68.6)	3207 (67.0)	20063 (69.7)	
Current drinker	1076 (18.9)	1019 (19.4)	973 (19.2)	878 (19.5)	714 (20.5)	1063 (22.2)	5723 (19.9)	
Former drinker	550 (9.6)	541 (10.3)	532 (10.5)	482 (10.7)	380 (10.9)	519 (10.8)	3004 (10.4)	
Regular exercise								<.001
Yes	2625 (46.0)	2109 (40.1)	1918 (37.9)	1604 (35.7)	1261 (36.2)	1748 (36.5)	11265 (39.1)	
No	3082 (54.0)	3147 (59.9)	3141 (62.1)	2888 (64.3)	2226 (63.8)	3041 (63.5)	17525 (60.9)	

Variable	DDS<2	DDS=2	DDS=3	DDS=4	DDS=5	DDS>5	Total	P Value
Number of teeth, mean (SD)	1(6)	2(7)	2(7)	2(7)	2(8)	2(8)	2(7)	<.001
Use of artificial denture								<.001
No	4891 (85.7)	4330 (82.4)	4031 (79.7)	3460 (77.0)	2603 (74.6)	3335 (69.6)	22650 (78.7)	
Yes	816 (14.3)	926 (17.6)	1028 (20.3)	1032 (23.0)	884 (25.4)	1454 (30.4)	6140 (21.3)	
BMI, mean (SD), kg/m ² ^c	18.7±3.7	18.7±3.6	19.0±3.7	19.2±3.7	19.4±3.6	19.8±3.5	19.1±3.6	<.001
Hypertension								<.001
No	2256 (39.5)	2268 (43.2)	2338 (46.2)	2060 (45.9)	1624 (46.6)	2298 (48.0)	12844 (44.6)	
Yes	3451 (60.5)	2988 (56.8)	2721 (53.8)	2432 (54.1)	1863 (53.4)	2491 (52.0)	15946 (55.4)	
Heart disease								<.001
No	5373 (94.1)	4951 (94.2)	4770 (94.3)	4176 (93.0)	3207 (92.0)	4406 (92.0)	26883 (93.4)	
Yes	334 (5.9)	305 (5.8)	289 (5.7)	316 (7.0)	280 (8.0)	383 (8.0)	1907 (6.6)	
Cerebrovascular disease								0.003
No	5511 (96.6)	5050 (96.1)	4887 (96.6)	4307 (95.9)	3352 (96.1)	4559 (95.2)	27666 (96.1)	
Yes	196 (3.4)	206 (3.9)	172 (3.4)	185 (4.1)	135 (3.9)	230 (4.8)	1124 (3.9)	
Digestive diseases								
No	5505(96.5)	5050(96.1)	4872(96.3)	4308(95.9)	3340(95.8)	4586(95.8)	27661(96.1)	
Yes	202(3.5)	206(3.9)	187(3.7)	184(4.1)	147(4.2)	203(4.2)	1129(3.9)	
Respiratory disease								0.28
No	5072 (88.9)	4672 (88.9)	4461 (88.2)	4028 (89.7)	3096 (88.8)	4278 (89.3)	25607 (88.9)	
Yes	635 (11.1)	584 (11.1)	598 (11.8)	464 (10.3)	391 (11.2)	511 (10.7)	3183 (11.1)	
Cognitive impairment								<.001
No	3332 (58.4)	3299 (62.8)	3221 (63.7)	2931 (65.2)	2312 (66.3)	3367 (70.3)	18462 (64.1)	
Yes	2375 (41.6)	1957 (37.2)	1838 (36.3)	1561 (34.8)	1175 (33.7)	1422 (29.7)	10328 (35.9)	
Disability in ADL								<.001
No	2781 (48.7)	2785 (53.0)	2724 (53.8)	2476 (55.1)	1934 (55.5)	2767 (57.8)	15467 (53.7)	
Yes	2926 (51.3)	2471 (47.0)	2335 (46.2)	2016 (44.9)	1553 (44.5)	2022 (42.2)	13323 (46.3)	

ADL: activities of daily living; BMI: body mass index DDS: dietary diversity score.

^aAmong participants with different DDS scores, differences of categorical variables were examined with the Cochran-Armitage test for trends; differences of continuous variables were examined with analysis of variance

^b3228/28790 participants without the information on the sufficient income.

^c3389/28790 participants without the information on BMI