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Dietary diversity predicts the mortality among older people: Data from the fifth Thai national health examination survey

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ABSTRACT

Objective: To examine the association between dietary diversity (DD) and mortality among Thai older people and to investigate whether age, sex, and nutritional status modify this association.
Methods: The national survey conducted from 2013 to 2015 recruited 5631 people aged $\geq$60 years. Dietary diversity score (DDS) was assessed for the consumption of eight food groups using food frequency questionnaires. The Vital Statistics System provided the data on mortality in 2021. The association between DDS and mortality was analyzed by Cox proportional hazard model and adjusted for the complex survey design. Interaction terms between DDS and age, sex, and BMI were also tested.
Results: The DDS was inversely associated with mortality (HR_{adj} 0.98, 95%CI: 0.96–1.00). This association was stronger in people aged $\geq$70 years (HR_{adj} 0.93, 95%CI: 0.90–0.96 for aged 70–79 years, and HR_{adj} 0.92, 95%CI: 0.88–0.95 for aged $\geq$80 years). Inverse association between DDS and mortality was also found in the underweight older population (HR_{adj} 0.95, 95%CI: 0.90–0.99). A positive association was found between DDS and mortality in the overweight/obese group (HR_{adj} 1.03, 95%CI: 1.00–1.05). However, the interaction between the DDS with sex to mortality was not statistically significant.
Conclusion: Increasing DD reduces mortality among Thai older people, especially in those above 70, and underweight. In contrast, an increase in DD also meant an increase in mortality among the overweight/obese group. Focus should be placed on the nutritional interventions aimed to improve DD for those 70 and over and underweight to reduce mortality.

1. Introduction

According to the United Nations, the proportion of older people is forecast to increase from 12% in 2015 to reach 22% of the global population by 2050 (World Health Organization, 2021). Although the trend of an aging population originated in high-income countries (HICs), the proportion of the older population in lower-and-middle-income countries (LMICs) is increasing more rapidly than that in HICs (Shetty, 2012). Older people are vulnerable to several adverse health conditions due to their physiologic aging, pathological changes, and socioeconomic constraints (Barbosa, Oliveira & Fernandes, 2019). The goal of care for older people focuses on healthy aging and longevity (Tinetti et al., 2021). Healthy diet is an important component for maintaining physical and mental well-being, preventing several diseases, and achieving healthy aging (Yeung, Kwan & Woo, 2021).

Dietary diversity (DD) is defined as the number of different food groups consumed over a time period (Ruel, 2003). DD represents the variety of nutrient intake, and it is a component of the dietary quality and healthy dietary pattern (Cano-Ibáñez et al., 2019; Taechangam, Pinitchun & Pachotikarn, 2008; Verger et al., 2021). Hence, DD is an affordable and applicable tool to assess the dietary quality in a large population (Lv et al., 2020). Previous studies have demonstrated that increasing DD can reduce mortality in older people. A Survey in Taiwan older people has shown that DD predicts the all-cause and several cause-specific mortalities (Lee, Huang, Su, Lee & Wahlqvist, 2011). A large community-based cohort study among Chinese older people found

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a negative association between DD and all-cause mortality (Tao, Xie & Huang, 2020). Additionally, a cohort study among Japanese older people also reveals the protective effect of DD toward all-cause and cancer mortality (Otsuka et al., 2020). However, these results are still inconclusive, depending on the study setting, the number, and the components of the DD measuring tool. For example, a study among older people in France failed to show the association between DD and mortality (Letois et al., 2016). There are several possible pathways through which DD can reduce mortality among older people. A case-control study in Italy found that DD has a significant negative association with the risk of coronary artery diseases (Amato et al., 2020). Furthermore, a cohort study among Chinese older people examining the changes of DD over 7 years as well as physical function has shown that older people who maintain a high DD have a significantly lower risk of physical function limitation compared to people who have consistently low DD (Aihemaitijiang et al., 2022). Physical function might be a crucial factor for longevity (Hennessy et al., 2015). Furthermore, several factors modified the strength of the association between DD and mortality, such as age, nutritional status, or socioeconomic status (SES) (Lv et al., 2020; Takabayashi et al., 2022; Tao et al., 2020). Recently, most studies have been conducted in HICs, specifically regions in East Asia. However, the difference in dietary pattern and the equality of socioeconomic and healthcare system affects the rate of mortality in older people. Therefore, further studies in LMICs will enhance the comprehensive knowledge on this topic.

Thailand is a middle-income country in the Southeast Asia region. The proportion of older people in Thailand is expected to increase from 16.7% in 2017 to 28.0% by 2031 (Social Statistics Division National Statistical Office, 2018). Health authorities in Thailand recommend a variety of food to achieve healthy eating (Sirichakwal, Sranacharoenpong & Tontisirin, 2011). However, no previous study confirms the association between DD and health outcomes and mortality among Thai older people. Moreover, the difference in socio-demographic and chronic health conditions might affect this association in this setting. Therefore, this study aimed to examine whether DDS predicted mortality among Thai older people. The secondary aim is to investigate whether age, sex, and nutritional status modify this association.

2. Method

2.1. Study design and study population

This study was a retrospective cohort study derived from the fifth Thai National Health Examination Survey (NHES-V). NHES-V was a nationally representative survey conducted from October 2013 to February 2015, using a multistage, stratified sampling of the Thai population. The details of this survey have previously been described elsewhere (Yan et al., 2020). In summary, a total of 23,760 people aged 15 and older were invited to participate in this survey, among whom 8640 were aged 60 years and older. The response rate in the 60 and older group was approximately 85%. Therefore, 7365 older participants were included in this study. Sixty-five older participants were excluded from the analysis because of the incomplete dietary data, including food frequency questionnaires (FFQs). The mortality data of 1669 participants could not be retrieved. A total of 5631 older participants were included in the final analysis (Fig. 1). Information was collected from older participants or their caregivers when older participants could not communicate due to physical or cognitive problems.

The survey was conducted according to the guidelines in the Declaration of Helsinki. This study was approved by the Ethical Review Committee for Research in Human Subjects, Faculty of Medicine, Siriraj hospital, Mahidol University, Thailand (COA Si 076- 2021). Informed

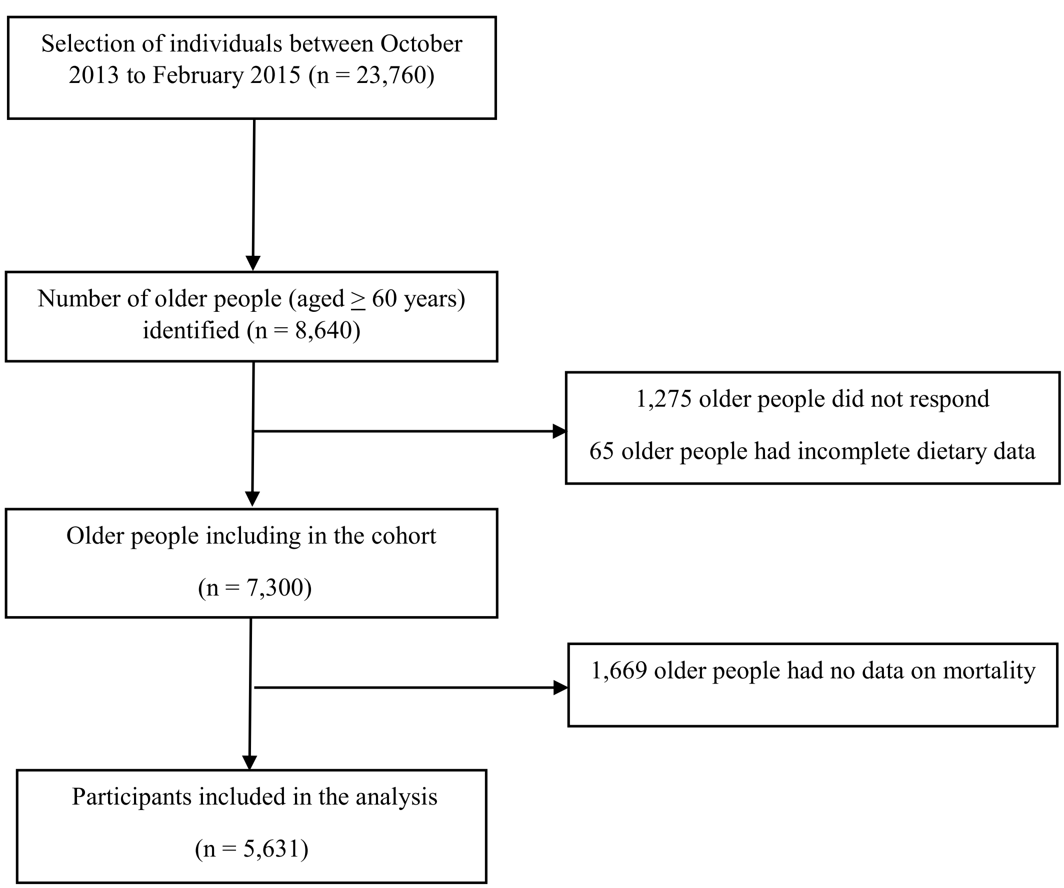

Fig. 1. Flow diagram of older participants included in the analysis.

consent was obtained from all participants or their legal representatives.

2.2. Data collection

2.2.1. Dietary diversity score (DDS)

Individual-level DD was assessed by using a 34-item semi-quantitative FFQs to represent food consumption within 1 month before the survey. Food items in FFQs were developed based on the commonly consumed foods in the Thailand context and have been validated previously (Aekplakorn et al., 2015). FFQs were collected through face-to-face interviews by trained interviewers using pictures of food to assist participant's memory and answers. In case of memory impairment or communication disabilities, data were collected via their caregiver.

Dietary diversity score (DDS) was calculated based on an adapted version of the DDS, which is endorsed by the Food and Agriculture Organization of the United Nations (FAO) (FAO, 2021) and the local food-based dietary guideline (FBDG) of Thailand (Sirichakwal et al., 2011). The details of DDS development were described elsewhere (Chalermsri et al., 2022). In summary, the DDS consisted of eight food groups, namely 1) grains, white roots and tubers, and plantains; 2) pulses, beans, nuts, and seeds; 3) dairy products; 4) meat, poultry, or fish; 5) eggs; 6) vegetables; 7) fruits; and 8) fats and oil. Different food items in FFQ were classified into food groups regardless the amount of food. Each food group was scored depending on the frequency of consumption: never eat or eat less than once per month, assigned as 0 point; eat once to three times per month, assigned as 1 point; eat once to three times per week, assigned as 2 points, eat 4–6 times per week, assigned as 3 points, and eat once or more per day, assigned as 4 points. The DDS was calculated as the sum of the score obtained from each food group. Thus, the DDS ranged from 0 to 32, and a higher DDS represented a higher dietary diversity.

2.2.2. Mortality data

The mortality data were retrieved from the death certificate of the National Civil Registration and Vital Statistics System, Ministry of Interior, Thailand. This database was the most reliable source of the mortality statistics in Thailand (Tangcharoensathien, Faramnuayphol, Teokul, Bundhamcharoen & Wibulpholprasert, 2006). Survival time was counted from the date of survey until October 31, 2021, when data were downloaded from the system by matching the personal identification number.

2.2.3. Covariates

Covariates in the survey were collected by trained personnel. The age of the participants, which was collected from the identification card. In line with previous study and the policy in Thailand (Foundation of Thai Gerontology Research and Development institute (TGRI), 2021; Pekalee, Ingersoll-Dayton, Gray, Rittirong & Völker, 2020), the age of participants, was classified as young old (60–69 years), old-old (70–79 years), or oldest old ($\geq$ 80 years). The education level was categorized into: no formal education, primary education, secondary education, or higher. Marital status was classified as: single, married, and widowed. Economic status was represented by a wealth index for assessing the participants' household assets, and categorized into quintiles (Chalermsri et al., 2022). The place of residence was dichotomized as: urban and rural areas.

Comorbidities included hypertension, diabetes mellitus (DM), and chronic kidney disease (CKD). Hypertension was defined by participants' self-reported use of antihypertensive medications for more than two weeks before the study or if they had systolic blood pressure $\geq$ 140 mmHg or diastolic blood pressure $\geq$ 90 mmHg at the survey date (James et al., 2014). DM was defined by participants' self-reported use of hypoglycemic agents for more than two weeks before the study or fasting plasma glucose $\geq$ 7.0 mmol/L during the survey date (World Health Organization, 2006). CKD was defined as an estimated glomerular filtration rate (eGFR) <60 mL/minute calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation (Inker et al., 2021). Mental health represented with depression, which was diagnosed as five or more symptoms over nine symptoms related to depressed mood, based on the criteria of the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) for at least two weeks (American Psychiatric Association, 2013; Kleebthong, Charoensuk & Kristiansen, 2017). Lifestyle factors included smoking and alcohol consumption. Current smoking was defined as people who smoked within 12 months before the survey date, and current alcohol consumption was defined as people who drank alcohol within 12 months before the survey date. Nutritional status was represented by body mass index (BMI), which was calculated as weight in kilograms divided by height in meters squared. BMI was categorized based on the Asia-Pacific cut-off values: BMI <18.5 kg/m^2 as underweight, 18.5–22.9 kg/m^2 as normal weight, and $\geq$ 23.0 as overweight, and obesity (Pan & Yeh, 2008).

2.3. Data analysis

The data were analyzed by using STATA/SE version 17.0 (StataCorp, College Station, Texas). The data were adjusted for a complex survey design, which accounted for clustering and weighting of older participants. The data used weighting based on the sampling probability against the 2014 registered Thai population (Lynn, 2005; Yan et al., 2020). Descriptive statistics were presented as frequency and percentage for categorical variables. The continuous variables were presented as means with standard error (SE). The year of follow-up was presented with a median. The differences in the background characteristics between participants who survived and those who died were tested by Chi-squared tests. The association between the DDS and mortality was analyzed by using Cox proportional hazard models after testing the assumption based on Schoenfeld residual. The endpoint of the study was time from the survey date to October 31, 2021, and represented as 1000 person-year, hazard ratio (HR) and 95% confidence interval (95%CI). The results were considered statistically significant at a level of *p*-value <0.05.

For the confounder selection, the variables which shown the *p*-value of $<$ 0.2 in bivariate analyses, were entered in the adjusted model. It ensured that all potential confounders were included in the adjusted model. The potential confounders, including age, sex, educational level, wealth index, place of residence, current smoking status, current alcohol consumption, hypertension, DM, CKD, depression, and BMI categories, were entered in the adjusted model. Moreover, this study aimed to examine the effect of age, sex, and BMI on the association between DDS and mortality. Thus, interaction terms between DDS and age, sex, and BMI in categories were also added in the adjusted model. The Wald test was used to detect the significance of the interaction effect. The stratified analyses were also performed when the interaction was significant. The missing data in the wealth index, which was approximately 5.1% was handled by using a missing category indicator (Kim, Egerter, Cubbin, Takahashi & Braveman, 2007). Collinearity between categorical independent variables was checked with the chi-square test. Goodman–gamma Kruskal's (G-K gamma) was used to determine the strength of the association. Sex was strongly associated with current smoking and current alcohol consumption (*p*-value $<$ 0.05, G-K gamma −0.85 for current smoking status and *p*-value $<$ 0.05, G-K gamma −0.66 for current alcohol consumption). Thus, these confounders were not included in the final model. Collinearity was also checked with the generalized variance inflation factor (GVIF) with the package car of using the R program statistical software (R Core Team, 2019; Fox & Monette, 1992). The GVIF did not exceed 1.40 for any potential confounders. Therefore, there was no evidence of collinearity. The result's robustness was determined with the sensitivity analyses by excluding the older participants who died in the first and second years of the follow-up to removing the people who were likely to have a pre-existing condition which might confound the association between the DDS and mortality.

The second sensitivity analysis model was done by analyzing the main model without the interaction terms, and the third sensitivity analysis was performed by excluding the comorbidities (hypertension, DM, and CKD) from the full model.

3. Results

The median (IQR) follow-up time was 7.9 (7.8–7.9) years, with 1087 deaths (weighted% = 20.8%) documented. The mean (SE) of participants' age was 69.6 (0.1) years at baseline. The mortality (95%CI) was 29.1 (26.8–31.6) per 1000 person-year. The mean (SE) of DDS was 18.3 (0.1) and ranged from 2 to 32. Participants who survived had a higher mean of DDS than those who died (18.5 vs. 17.8, p-value <0.001). The baseline characteristics of the older participants are presented in Table 1.

The comparison of DDS between the background characteristics of older participants are presented in Table 2. There was the difference of mean of DDS between age group, the educational level, marital status, economic status, place of residence, lifestyle factors, and comorbidities.

The association between the DDS and mortality in both the unadjusted and adjusted models is presented in Table 3. In the unadjusted model, DDS had an inverse association with mortality in the older population, with HR (95%CI) being 0.96 (0.95–0.97); p-value <0.001. After adjusting for covariates and the interaction terms, each increase in the DDS score reduced the risk of mortality by 2%, with HR_{adj} (95%CI) being 0.98 (0.96–1.00); p-value 0.032.

The interactions between the DDS with age and BMI categories to mortality were statistically significant (p-value 0.002, and 0.009 for the interactions between the DDS with age and BMI categories, respectively), while the interaction between the DDS with sex to mortality was not significant (p-value 0.398). Further analyses were stratified by these variables. When stratified by the age groups, a negative association between the DDS and mortality was observed in people aged 70 years and older but not in those younger than 70 years, with HR_{adj} (95%CI) 0.93 (0.90–0.96); p-value <0.001 for people aged 70–79 years old, and HR_{adj} (95%CI) 0.92 (0.88–0.95); p-value 0.001 for people aged 80 years and older. Regarding the BMI categories, there was a reverse association between the DDS and mortality in the underweight, while there was a positive association between DDS and mortality in the overweight and obesity subgroups. The HR_{adj} (95%CI) among people who were underweight and overweight was 0.95 (0.90–0.99); p-value 0.023 and 1.03 (1.00–1.05); p-value 0.042, respectively. However, there was no significant association between the normal weight sub-group.

The sensitivity analysis excluding participants who died within the first and second years of follow-up showed similar results to the primary analysis, with HR_{adj} (95%CI) being 0.96 (0.94–0.99); p-value 0.004. The second sensitivity analysis of the main model without the interaction terms was also found to be similar, with HR_{adj} (95%CI) being 0.97 (0.96–0.98); p-value <0.001. The last sensitivity analysis, which excluded the comorbidities from the full model, showed similar results as well, with HR_{adj} (95%CI) being 0.97 (0.95–0.99); p-value 0.004. These results demonstrated the robustness of the model.

4. Discussion

This study examined whether the DDS predicted the mortality in Thai older people, using the national representative data. The results found that DDS had an inverse association with mortality. Furthermore, age and BMI categories had significant interactions with the DDS to predict mortality.

Regarding the relationship between the DDS and mortality among older people, this study showed an inverse association between the DDS and mortality in the total older population. This finding is consistent with previous studies (Lv et al., 2020; Otsuka et al., 2020; Tao et al., 2020). Two cohort studies among Chinese community-based older people confirmed the inverse relationship between DDS and mortality

Table 1
Background characteristics of older participants in NHES-V, Thailand*.

Characteristics	Total (n = 5628)	Survived (n = 4541)	Death (n = 1087)	p-value**
Age group, n (%)				< 0.001
60–69 years	3350 (56.5)	3000 (63.7)	350 (28.8)	
70 - 79 years	1735 (30.4)	1277 (27.8)	458 (40.1)	
≥80 years	543 (13.2)	264 (8.5)	279 (31.1)	
Sex, n (%)				< 0.001
Male	2460 (45.4)	1886 (44.2)	574 (50.3)	
Female	3168 (54.6)	2655 (55.8)	513 (49.7)	
Educational level, n (%)				< 0.001
No formal education	496 (9.1)	363 (8.0)	133 (13.4)	
Primary education	4273 (79.7)	3421 (79.6)	852 (80.2)	
Secondary education or higher	837 (11.2)	739 (12.4)	98 (6.4)	
Marital status, n (%)				< 0.001
Single	278 (4.5)	242 (4.8)	36 (3.6)	
Married	3587 (64.7)	2952 (66.8)	635 (56.5)	
Widowed	1710 (30.8)	1301 (28.4)	409 (39.9)	
Wealth index (quintile), n (%)				< 0.001
Poorest	1261 (27.8)	949 (26.3)	312 (13.5)	
Poor	815 (16.8)	638 (16.5)	177 (17.9)	
Average	914 (16.9)	733 (17.1)	181 (16.1)	
Rich	1047 (17.6)	851 (17.6)	196 (17.3)	
Richest	1232 (15.8)	1077 (17.2)	155 (10.6)	
Place of residence, n (%)				0.009
Urban area	2997 (38.9)	2470 (39.7)	527 (36.2)	
Rural	2631 (61.1)	2071 (60.3)	560 (63.8)	
Current smoking, n (%)				0.033
Yes	696 (13.6)	522 (13.2)	174 (15.1)	
No	4932 (86.4)	4019 (86.8)	913 (84.9)	
Current alcohol consumption, n (%)				< 0.001
Yes	1190 (21.6)	1006 (23.1)	184 (16.0)	
No	4418 (78.4)	3516 (76.9)	902 (84.0)	
Hypertension, n (%)				< 0.001
Yes	2237 (38.2)	1738 (37.1)	499 (42.3)	
No	3284 (61.8)	2716 (62.9)	568 (57.7)	
Diabetes mellitus, n (%)				0.084
Yes	712 (12.3)	541 (12.0)	171 (13.3)	
No	4867 (87.7)	3966 (88.0)	901(86.7)	
Chronic kidney disease, n (%)				<0.001
Yes	813 (16.7)	497 (12.5)	316 (32.5)	
No	4617 (83.3)	3885 (87.5)	732 (67.5)	
Depression, n (%)				0.028
Yes	323 (5.8)	238 (5.6)	85 (6.9)	
No	5305 (94.2)	4303 (94.4)	1002 (93.1)	

(continued on next page)

Table 1 (*continued*)

Characteristics	Total (*n* = 5628)	Survived (*n* = 4541)	Death (*n* = 1087)	*p*-value**
BMI category, *n* (%)				<0.001
Underweight	512 (10.8)	317 (8.2)	195 (20.5)	
Normal weight	1894 (35.5)	1514 (35.3)	380 (36.3)	
Overweight and obesity	3222 (53.7)	2710 (56.5)	512 (43.2)	

* All analyses were adjusted and analyzed by complex survey design and represented in weighted number and percentage.
** *p*-value comparing the group that survived and those that died.
NHES-V: the fifth Thai National Health Examination Survey.

Table 2
DDS based on the background characteristics of older participants in the NHES-V, Thailand (n 5631).

Characteristics	Mean (SE)	*P*-value
Age group, *n* (%)		<0.001
60–69 years	18.5 (0.06)	
70–79 years	18.2 (0.06)	
≥80 years	18.0 (0.12)	
Sex, *n* (%)		0.152
Male	18.4 (0.06)	
Female	18.3 (0.07)	
Educational level, *n* (%)		<0.001
No formal education	17.5 (0.12)	
Primary education	18.3 (0.06)	
Secondary education or higher	19.2 (0.10)	
Marital status, *n* (%)		<0.001
Single	18.5 (0.21)	
Married	18.5 (0.05)	
Widowed	18.1 (0.09)	
Wealth index (quintile), *n* (%)		<0.001
Poorest	17.8 (0.11)	
Poor	18.7 (0.08)	
Average	18.2 (0.08)	
Rich	18.5 (0.07)	
Richest	19.0 (0.07)	
Place of residence, *n* (%)		<0.001
Urban	18.6 (0.06)	
Rural	18.2 (0.08)	
Current smoking, *n* (%)		<0.001
Yes	18.9 (0.10)	
No	18.2 (0.06)	
Current alcohol consumption, *n* (%)		<0.001
Yes	18.7 (0.10)	
No	18.3 (0.06)	
Hypertension, *n* (%)		<0.001
Yes	18.1 (0.07)	
No	18.5 (0.06)	
Diabetes mellitus, *n* (%)		<0.001
Yes	17.8 (0.10)	
No	18.5 (0.06)	
Chronic kidney disease, *n* (%)		<0.001
Yes	17.6 (0.10)	
No	18.5 (0.05)	
Depression, *n* (%)		0.045
Yes	18.0 (0.15)	
No	18.4 (0.06)	
BMI category, *n* (%)		0.102
Underweight	18.3 (0.10)	
Normal weight	18.4 (0.08)	
Overweight and obesity	18.3 (0.05)	

NHES-V: the fifth Thai National Health Examination Survey.

(Lv et al., 2020; Tao et al., 2020). Another long follow-up cohort study in Japan investigated the relationship between DDS and the cause-specific mortality among older people. They demonstrated that DDS has an inverse association with mortality and cancer-related mortality, but there is no significant association between DDS and cardiovascular and cerebrovascular related mortality (Otsuka et al., 2020). However, a study among French older people did not show a significant association between DDS and mortality (Letois et al., 2016). However, that study was conducted in only three cities, and the response rate for participating in the study was only 37%. This might have resulted in a selection bias among the participants.

There are several possible explanations for this association between DDS and mortality. The first explanation is that DDS is one component of the dietary quality, and it is highly related to food and nutrient intake (Cano-Ibáñez et al., 2019; Verger et al., 2021). Adequate overall nutrient intake is the key factor in healthy aging (Shlisky et al., 2017). Older people often have inadequate nutrient intake and develop nutritional frailty, which is characterized by weight loss and loss of muscle mass and strength, or loss of body reserves, and higher susceptibility to disabilities. An adequate and varied nutrient intake might improve their health status and enhance their longevity (Shlisky et al., 2017). In addition, DDS had a positive association with physical performance, such as grip strength and gait speed (Yokoyama et al., 2017), but it had a negative association with sarcopenia in female older people (Lim, 2020). Physical performance and sarcopenia are important determinants of better survival (Xu, Wan, Ktoris, Reijnierse & Maier, 2022). The second explanation involved the association between DDS and the gut microbiota. High DD is associated with a more diverse and healthier gut microbiota pattern (Heiman & Greenway, 2016). An unhealthy and unvaried gut microbiota affects inflammation in the body and is associated with several NCDs, such as metabolic syndrome, which are the common causes of death in the older population (Dabke, Hendrick & Devkota, 2019; GBD 2019 Diseases & Injuries Collaborators, 2020).

Age modified the strength of the association between DDS and mortality. In the sub-group analysis, the inverse association between DDS and mortality was observed only in people aged 70 years and older. This finding is consistent with a previous study among Chinese elderly which classified the participants into younger and oldest-old groups (Tao et al., 2020). They found a significant negative association between DDS and mortality, but only among people aged 80 years and older. This finding supports the idea of anorexia of aging, which is accounted as an age-related change and prevalent in older people (Cox et al., 2020). People with increasing age might face such conditions, which are associated with low dietary diversity, poor food intake and adverse health events, thus increasing the prevalence of frailty and mortality (Cox et al., 2020; Landi et al., 2012; Tsutsumimoto et al., 2017). Improving DD might ensure the amount and variety of nutrient intake, and further improve health status. However, the relationship between age and DDS with mortality was inconclusive. A previous study with Chinese participants aged 80 years and older found that the strength of association of DDS among people aged 80–89 years old was stronger than those aged 90 years and older (Lv et al., 2020). This might be explained by the survival bias, which hypothesizes that people with chronic diseases or unhealthy dietary habits may have died prior to reaching age 80.

Furthermore, the association between DDS and mortality was modified with the BMI. Increasing DDS reduces mortality among older people who are underweight, while it increases mortality among older people who are overweight and obese. This finding is similar to a recent study among Japanese elderly, which found a significant interaction between DD and BMI with all-cause mortality (Takabayashi et al., 2022). In the low BMI sub-group, the mortality among older people with medium and high DD was lower than those with low DD. In contrast, in the high BMI sub-group, older people with medium to high DD had higher mortality than those with low DD. This might be because DDS has a positive association with both nutrient and energy intake (Otsuka et al., 2016; Takabayashi et al., 2022). Older people who are underweight are more likely to be nutrient and energy deficient. Therefore, increasing both the nutrient intake and energy might address this deficiency and result in an improvement in the nutritional status, muscle mass, and physical performance (Lim, 2020; Yokoyama et al., 2017). In

Table 3
Association of the dietary diversity score (DDS) and mortality in older participants in NHES-V, Thailand.

	N	Unadjusted model			Adjusted model*		
		HR	95%CI	*p*-value	HR	(95%CI)	*p*-value
All	5628						
DDS**		0.96	0.95–0.97	<0.001	0.98	0.96–1.00	0.031
Sub-groups							
Age							
Age 60–69 years							
DDS		0.99	0.97–1.01	0.205	1.02	0.99–1.05	0.124
Age 70–79 years							
DDS		0.94	0.93–0.96	<0.001	0.93	0.90–0.96	<0.001
Age ≥ 80 years							
DDS		0.97	0.95–0.98	0.001	0.92	0.88–0.95	<0.001
BMI categories							
Underweight	512						
DDS		0.97	0.95–0.98	0.001	0.95	0.90–0.99	0.023
Normal weight	1894						
DDS		0.93	0.92–0.95	<0.001	1.02	0.99–1.04	0.159
Overweight/obese	3222						
DDS		0.98	0.97–0.99	0.003	1.03	1.00–1.05	0.042

* For all participants, the model was adjusted for age; sex; educational level; wealth index; place of residence comorbidities including hypertension, DM, CKD, depression; BMI; and the interactions between DDS and age, sex and BMI. For the age sub-group, the model was adjusted for sex; educational level; wealth index; place of residence; comorbidities, including hypertension, DM, CKD, depression; BMI; and the interactions between DDS and sex, and BMI. For the BMI sub-group, the model was adjusted for age; sex; educational level; wealth index; place of residence; comorbidities, including hypertension, DM, CKD, depression; and the interactions between DDS and sex, and BMI.

** DDS range 0–32.

DDS: dietary diversity score, NHES-V: the fifth Thai National Health Examination Survey, HR (95%CI): hazard ratio and 95% confidence interval.

contrast, overweight and obesity are the consequences of excess energy (Batsis & Zagaria, 2018). The additional energy intake from a more varied food intake might aggravate this situation and is related to mortality. Moreover, the DDS has a positive correlation with unhealthy food consumptions in the overweight and obese population (Madlala et al., 2022). Unhealthy foods might be viewed as a contributor to increased mortality among older people (Yan et al., 2022).

This study had several strengths. One strength is the nationally representative sample with a large sample size and the high response rate, which can represent older people in LMICs. There are many differences between HICs and LMICs with regard to healthcare access, health and disease characteristics, and social determinants of health, such as the educational level, economic status, or social support (Aung, Koyanagi & Yuasa, 2021). Currently, there is limited evidence regarding the association of DDS in older people with LMICs. This study filled this knowledge gap by confirming the inverse association between DDS and mortality among older people in LMICs. Furthermore, this study considered the interactions between DDS and age, sex and BMI. It shows the complex association between DDS and mortality and assists the policymaker in identifying the target groups for further investigation or interventions. In addition, this study was conducted among older people who had a high probability of physical and cognitive limitation. Thus, the data collection method was adapted for this population. For example, the use of pictures of various foods to facilitate the participants' memory and responses to the FFQs. Additionally, the information was obtained from older participants or their caregivers. This can increase the reliability of the information. Another strength is that the follow-up period in this study is almost 8 years. Therefore, these results are more reliable and have a lower probability of reverse causation (Strain et al., 2019).

However, this study also has some limitations. The first limitation is that the DDS in this study was calculated from the simplified FFQ, which could not reflect the amount of each food group. In addition, food groups in DDS were constructed and complied using the Thai context. Thus, generalization of these findings to other settings should be made with caution. Moreover, the dietary data were collected at quite a long period before the outcome. Although older people tend to have a consistent dietary practice, there could be changes in the food intake during the follow-up period, especially in older people with NCDs who were advised to make dietary changes. The second limitation was that the disease-specific mortality was not ascertained in this study. Another limitation was the possibility of residual confounding factors, which affected both food intake and mortality, such as physical activities, caregiving status, and family support, other comorbidities (Fan et al., 2021; Pristavec & Luth, 2020; Shaked et al., 2022). This study was not accounted for several chronic diseases such as coronary artery disease, stroke, or lung diseases due to the low reported prevalence in this community setting. Furthermore, the self-report on many diagnoses may be less accuracy in older people in the community (Steinkirchner et al., 2022). In addition, the caregiver influences the decisions made by older people regarding food purchase and intake, as well as their care. Thus, physical activity and caregiving status affected both the DD and mortality of older people.

5. Conclusions and implications

This national survey shows a significant inverse association between DD and mortality among Thai older people. It suggested that DD should be part of healthy eating and the dietary guidelines for older adults. Moreover, DDS can be used as an indicator to monitor the effectiveness of nutritional strategy or interventions. Furthermore, these associations between DDS and mortality were modified by age and nutritional status. People aged 70 and older, and who had a low BMI, got the most benefit from having a variety in their food consumption. Nutritional interventions, such as a nutritional educational program or meal service program, should be a specific target for each group in the population. However, an increased DDS had an association with increased mortality among older people who were overweight and obese. Therefore, increasing DDS by considering a healthy food intake and appropriate energy intake should be encouraged in this sub-group.

Data availability statement

The datasets used or analyzed are available from the corresponding author upon reasonable request.

Ethics statement

The study was conducted in accordance with the Declaration of Helsinki and was approved by the ethical committee for Research in Human Subjects, Faculty of medicine, Siriraj hospital, Mahidol University, Thailand (COA Si 076/2021). Participation was voluntary, and the participants were told that they could leave the interview at any time. All participants or their legal representatives provided informed consent before commencing the study.

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CRediT authorship contribution statement

Chalobol Chalermsri: Conceptualization, Formal analysis, Methodology, Software, Writing – original draft, Writing – review & editing. **Syed Moshfiqur Rahman:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Eva-Charlotte Ekström:** Supervision, Writing – review & editing. **Shirin Ziaei:** Supervision, Writing – review & editing. **Wichai Aekplakorn:** Investigation, Writing – review & editing. **Warapone Satheannopakao:** Investigation, Writing – review & editing. **Weerasak Muangpaisan:** Conceptualization, Methodology, Formal analysis, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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