Association between healthy eating and depression symptoms among Chinese older adults: A cross-sectional study based on the Chinese Longitudinal Healthy Longevity survey

Xinyue Zhang [a], Wenqin Zhou [b], Hui Wang [c], Yan Bai [d], Fan Zhang [d,*], Wei Lu [b,*]

[a] *Department of Oncology, Longhua Hospital Shanghai University of Traditional Chinese Medicine, Shanghai, China*
[b] *Department of Nursing, Longhua Hospital Shanghai University of Traditional Chinese Medicine, Shanghai, China*
[c] *Department of Anorectology, Longhua Hospital Shanghai University of Traditional Chinese Medicine, Shanghai, China*
[d] *Department of Nephrology A, Longhua Hospital Shanghai University of Traditional Chinese Medicine, Shanghai, China*

ABSTRACT

Introduction: This study aimed to assess the relationship between the healthy eating index (HEI) and depression symptoms in an older adult population using the Chinese Longevity Health Survey.
Methods: The HEI was constructed based on the frequency of intake of 13 dietary variables, with higher scores indicating better diet quality. Depression symptoms was assessed by the Center for Epidemiologic Studies Depression-10 scale. We used multivariate binary logistic regression to explore the association between the HEI and depression symptoms and reported as odds ratio (OR) and 95 % confidence interval (95 % CI).
Results: A total of 12,078 older adults were included. The average HEI for this group of older adults was 26.4 ± 7.1. After adjusting for covariates, compared with participants in the lowest quartile of a healthy eating index, those in the second to the fourth quartile group had a 0.93- (95 % CI: 0.83 to 1.03), 0.84- (95 % CI: 0.75 to 0.95) and 0.69- (95 % CI: 0.62 to 0.77) fold risk of depression symptoms, respectively. Restricted cubic spline curves showed that the risk of depression symptoms decreased with increasing HEI, especially above 26, and for each unit increase in the HEI, the risk of depression symptoms in older adults decreased by 3 % (OR = 0.97; 95 % CI: 0.96 to 0.99).
Conclusions: This study found an association between higher levels of the HEI and reduced risk of depression symptoms in older Chinese adults. This result emphasizes the need to focus on dietary diversity in older adults to promote healthy aging.

1. Introduction

Global aging is rapidly progressing and is expected to reach two billion people over 60 in 2050 (World Health Oragaization, 2022). According to the *World Report on Aging and Health*, China has the largest aging population in the world, far faster than many low- and middle-income and high-income countries (World Health Oragaization, 2015). It was reported that the composition of China's population aged 60 years and older will grow to 28 % of the total population by 2040 (World Health Oragaization, 2022). As the aging process accelerates, the World Health Organization has announced the Decade of Healthy Aging 2021–2030, urging the world to pay more attention to population aging (World Health Oragaization, 2022).

Depression symptoms is a common mental health condition among older adults and one of the public health concerns in the context of healthy aging (World Health Oragaization, 2017). The prevalence of depression symptoms in Chinese older adults over 60 has been reported in the literature to be approximately 40 % (Ni et al., 2017). Depression symptoms is associated with declines in physical, cognitive, and social functioning (Erazo et al., 2020). In addition, most individuals with depression do not receive treatment, and symptom levels fluctuate over time (Beekman et al., 2002), leading to an increased risk of morbidity and suicide (Blazer, 2003). Therefore, improving the mental health of older adults has become an important strategic goal for healthy aging.

Over the last decade, the relationship between dietary patterns and depression symptoms has become the subject of academic debate, with the former better reflecting human dietary complexity and eating behaviors (Zyoud et al., 2023). The 2015–2020 Dietary Guidelines for Americans also emphasize the importance of healthy eating patterns (U. S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). The Mediterranean diet and the Dietary Approaches to Stop Hypertension are the most widely studied dietary patterns and are promoted worldwide as healthy eating programs (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015; Davis et al., 2015; Gee and Ahluwalia, 2016; Rees et al., 2013). The most common food groups and dietary characteristics in both dietary patterns are fruits, vegetables, low fat, salt restriction, and added sugars, but a focus on tea, eggs, and bean food intake is missing (Mozaffarian, 2016).

Several studies have reported associations between dietary patterns and depression in subgroups population. A study by Adjibade et al. showed that after adjusting for potential confounders, Mediterranean diet scores were significantly associated with the development of depressive symptoms in men (odd ratio: 0.91; 95 % confidence interval 0.83 to 0.99), but not in women (Adjibade et al., 2018). Interestingly, a prospective study of middle-aged and older women in the United States found similarly nonsignificant associations between Prudent (high in vegetables) and Western (high in meats) patterns and new-onset symptoms of depression (Chocano-Bedoya et al., 2013). A Korean study reported on the impact of sociodemographic and health-related factors on depression that participants who were current smokers were more likely to report depression (Hwang et al., 2023). However, participants who were married or had higher household income were less likely to report depression. A recent *meta*-analysis reported a significant association between healthy or Western dietary patterns and depression when participants were Asian and/or younger than 50 years of age. (Li et al., 2017) This inconsistency may be due to differences in study populations, gender, ethnicity, and geographic regions (Wu et al., 2023).

Considering that socioeconomic and cultural factors influence eating behaviors, there are differences in the dietary patterns of Western and Asian populations (Pingali, 2007). In the case of China, people favor plant-based foods and tea-tasting behaviors (Ma, 2015), whereas the Western diet is dominated by high-protein and high-calorie foods (Magalhaes et al., 2012). Studies investigating dietary patterns in the Chinese population may provide further scientific insight into the relationship between healthy eating behaviors and depression symptoms.

With this in mind, we constructed a healthy eating index (HEI) and investigated the association between adherence to it and depression symptoms in older Chinese adults based on the Chinese Longitudinal Healthy Longevity Survey (CLHLS) concerning previously published articles and the dietary habits of the Chinese population.

2. Methods

2.1. Study population

CLHLS is a national prospective cohort study of community-dwelling older adults in China. The sampling design of CLHLS used a multi-stage disproportionate targeted random sampling method, allowing for representative and reliable sample data (Zeng et al., 2013). The CLHLS study was approved by the Biomedical Ethics Committee of Peking University (IRB00001052-13074). This study was based on the 2018 CLHLS, and people aged 60 years and older were selected as participants. We removed samples that answered, "not able to answer," "I refuse to answer," "not applicable," and missing values for key variables (healthy eating index and depression). Finally, 12,078 participants were included in the study for analysis (Figure S1). This study followed Strengthening the Reporting of Observational studies in Epidemiology (STROBE) reporting guidelines (Table S1).

2.2. Healthy eating index

During CLHLS follow-up, trained interviewers collect self-reported information on dietary habits from respondents in a survey of community households. The respondents were asked to report their current food frequency for intake of 13 foods: fruits, vegetables, meat, fish, eggs, food made from beans, salt-preserved vegetables, sugar, tea, garlic, nut, mushroom or algae, and milk products. The questionnaires for the first two types of food interviews were set up with four options: almost every day, quite often, occasionally, rarely or never; the rest were set up with five options: almost every day, at least once a week, at least once a month, occasionally, and rarely or never.

Diet quality was assessed using the HEI, comprised of above 13 food components that summed to a total maximum score of 50 points-a higher score indicating a healthier diet. Based on previous knowledge of the relationship between these food groups and health (Yan et al., 2022; Kennedy et al., 1995), each respondent was reverse-scored for salt-preserved vegetables and sugar in the survey. The values assigned to each food group are shown in Table S2. Thus, the scores of the 13 variables were summed to obtain a HEI ranging from 0 to 50, with higher scores considered a healthier dietary pattern. The HEI was further divided into quartiles (Q1: 0–21; Q2: 22–26; Q3: 27–30; Q4: 31–50) with approximately the same number of individuals in each group.

2.3. Depression symptoms

Depression symptoms was measured using the validated Chinese version of the Center for Epidemiologic Studies Depression-10 (CESD-10) scale, with a total score ranging from 0 to 30 (Lewinsohn et al., 1997). The 10 items include: 1) Are you bothered by things that don't usually bother you? 2) Do you have trouble focusing on what you were doing? 3) Do you feel sad, blue, or depressed? 4) Do you feel the older you get, the more useless you are, and have trouble doing anything? 5) Do you feel hopeful about the future? 6) Do you often feel fearful or anxious? 7) Are you as happy as when you were younger? 8) Do you often feel lonely and isolated? 9) Do you feel you could not get "going"? 10) How about the quality of your sleep? On a 4-point Likert scale, the options "always," "often," "sometimes," and "never" were coded as 3, 2, 1, and 0, respectively. The items 5) and 7) were scored in reverse. The total score for the 10-item entry ranged from 0 to 30, with $\geq$ 10 considered depressive symptoms (Mohebbi et al., 2018).

2.4. Covariates

Information on the following 11 covariates was also extracted from the dataset: age ($<$75 or $\geq$ 75), gender, marital status (married or widowed/divorced/single), current smoking status (yes or no), current drinking status (yes or no), current exercise habit (yes or no), and smoking status (yes or no). Additional covariates include self-reported economic status, which is asked of the respondent by the interviewer: how do you rate your economic status compared with others in your local area (rich, average, or difficult), and physical status of respondents (healthy and frailty).

2.5. Statistical analysis

General characteristics were expressed as frequencies and percentages (%) of categorical variables, and chi-square tests were used to compare differences in variables between HEI quartile groups. Univariate and multivariate binary logistic regression was used to calculate the odds ratio (OR) and 95 % confidence intervals (95 % Cl) for the association between the HEI and depression symptoms. We fitted three separate models: Model 1 was unadjusted, Model 2 was adjusted for age and gender, and Model 3 was obtained after adjusting for gender, age, marriage, economic status, smoking, drinking, exercise habits, and physical status. Next, a multivariate restricted cubic spline model was

used to evaluate a potential non-linear relationship between the HEI and depression symptoms. We selected three components at the 25th, 50th, and 75th quartiles (Wang et al., 2023; Lee et al., 2018). Finally, we performed subgroup analyses of logistic regression models including sex (male or female), age (<75 or ≥ 75 years), marriage (married or single), economic status (rich or average or difficult), smoking (no or yes), drinking (no or yes), habitual exercise (no or yes), and physical status (healthy or frailty) to evaluate the consistency of the observed specified outcomes (i.e. OR value) across different levels of subgroup variables. $P < 0.05$ was considered statistically significant.

Missing values of covariates were imputed using the k-nearest neighbors (KNN) algorithm, and the interpolated data set was re-analyzed and compared to the original data for sensitivity analysis. KNN is a commonly used machine learning algorithm that can be used for classification and regression problems (Wang et al., 2014). In data processing, KNN algorithm can also be used for missing value interpolation. All statistical analyses were performed using SPSS 26.0 and R software (https://www.r-project.org; version 4.2.0, The R Foundation).

3. Result

Table 1 provides the sociodemographic characteristics of the study participants. The sample consisted of 12,078 participants, of which 5,627 (46.6 %) were male, and 6,451 (53.4 %) were female. Of all participants, 74.5 % were 75 years and older; 53.1 % were married; 69.4 % were considered economically average; 83.7 % and 84.5 % were current smokers and drinkers, respectively; 65.4 % were physically active; and 88.0 % were considered physically frail. Of the participants, the presence of depressive symptoms as assessed by the CESD-10 was 57.1 %, and the proportions depressive symptoms in HEI quartiles is shown in Figure S2. Additional, mean value of the HEI was 26.38 ± 7.07 (median [quartile]: 26.00 [21.00, 31.00]). Figure S3 reflects the median and interquartile distribution of the 13 foods.

Fig. 1 depicts the 13 diets as a percentage of the participants. The intake of plant-based diets such as vegetables, fruits and mushrooms or algae was high; the demand for high-calorie foods such as meat was not low, while the intake of sugar, fish and milk products was relatively low.

It was also observed that the participants in this group were not as interested in tea-tasting behaviors as they were in nut intake, which may be due to the variety of nuts and the generalization of the respondents. By obtaining a heatmap showing the correlation between 13 foods (Figure S4), it was reported that fruit was the more relevant combination with milk (r = 0.28), mushroom or algae (r = 0.28), vegetables (0.25), fish (r = 0.25).

3.1. Relationship between the HEI and depression symptoms

Results of multivariate logistic regression analyses showed that after adjusting for gender, age, marriage, economic status, smoking, drinking, habitual exercise, and physical status, each standard deviation (7.1) increase in the HEI was associated with a 14 % reduction in the risk of depression symptoms (OR: 0.86, 95 % CI 0.82 to 0.90). When compared with the lowest quartile of the HEI, multivariate ORs for depression symptoms were 0.93 (95 % CI: 0.83 to 1.03) in Q2, 0.84 (95 % CI: 0.75 to 0.95) in Q3, and 0.69 (95 % CI: 0.62 to 0.77) in Q4 ($P_{\text{for trend}} < 0.001$). We imputed the missing covariates via KNN and find very similar results between the imputed and original datasets (Table 2).

3.2. Analysis of the nonlinear correlation between the HEI and depression symptoms in older adults

Dose-response relationships based on restricted cubic spline curves showed a nonlinear negative association between a HEI and the risk of depression symptoms in older adults (non-linear $P < 0.001$). The risk of depression symptoms gradually decreased as the healthy dietary index increased, especially when it was greater than 26 (Fig. 2). In further analysis, we found that a HEI was not associated with the risk of depression symptoms until the turning point (OR = 0.99; 95 % CI: 0.98 to 1.01). When the HEI was ≥ 26, the risk of depression symptoms significantly decreased with increasing HEI (OR = 0.97; 95 % CI: 0.96 to 0.99) (Table 3).
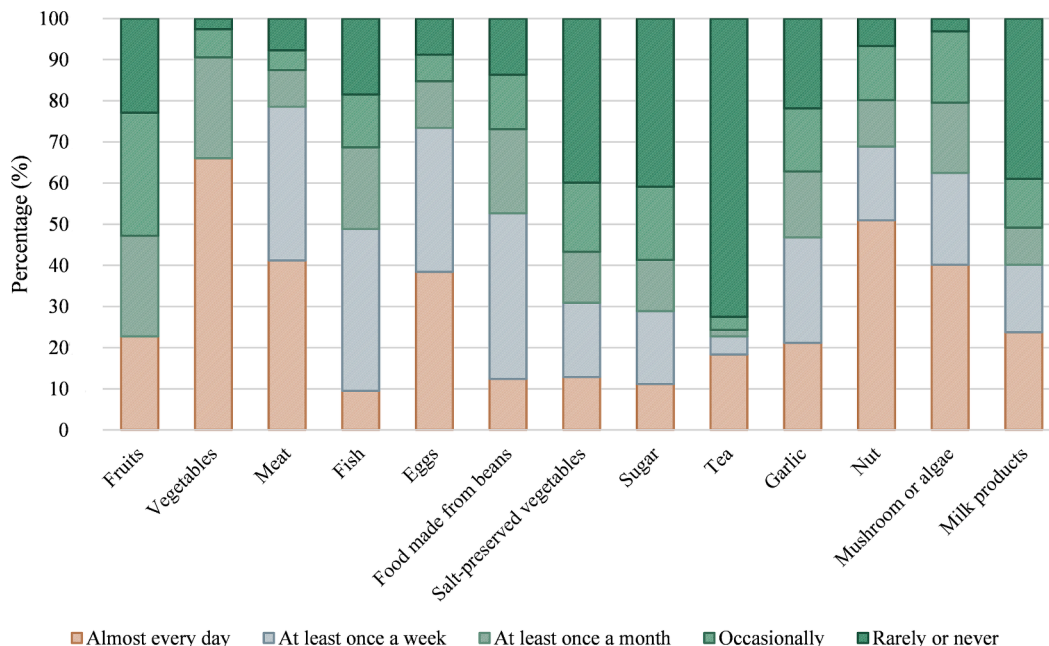
Table 1

Descriptive statistics of Chinese elderly people (age ≥ 65 years) according to quartiles of HEI in 2018 CLHLS.

Variables	Total (n = 12078) Frequency (%)	Q1 (0–21) (n = 3045) Frequency (%)	Q2 (22–26) (n = 3280) Frequency (%)	Q3 (27–30) (n = 2362) Frequency (%)	Q4 (31–50) (n = 3391) Frequency (%)	P-value*
Gender						<0.001
Male	5627 (46.6)	1140 (37.4)	1494 (45.5)	1118 (47.3)	1875 (55.3)	
Female	6451 (53.4)	1905 (62.6)	1786 (54.5)	1244 (52.7)	1516 (44.7)	
Age (year)						<0.001
<75	3083 (25.5)	592 (19.4)	781 (23.8)	624 (26.4)	1086 (32.0)	
≥75	8995 (74.5)	2453 (80.6)	2499 (76.2)	1738 (73.6)	2305 (68.0)	
Marriage, missing 115						<0.001
Married	6354 (53.1)	1846 (61.3)	1843 (56.8)	1210 (51.6)	1455 (43.3)	
Widowed/divorced/single	5609 (46.9)	1166 (38.7)	1401 (43.2)	1133 (48.4)	1909 (56.7)	
Economic status, missing 99						<0.001
Rich	2491 (20.8)	332 (11.0)	579 (17.8)	544 (23.2)	1036 (30.8)	
Average	8312 (69.4)	2120 (70.3)	2344 (72.1)	1644 (70.1)	2204 (65.4)	
Difficult	1176 (9.8)	562 (18.6)	328 (10.1)	157 (6.7)	129 (3.8)	
Smoking, missing 108						0.142
No	1947 (16.3)	451 (14.9)	547 (16.8)	395 (16.9)	554 (16.5)	
Yes	10,023 (83.7)	2569 (85.1)	2703 (83.2)	1948 (83.1)	2803 (83.5)	
Drinking, missing 172						<0.001
No	1848 (15.5)	365 (12.2)	446 (13.8)	405 (17.4)	632 (19.0)	
Yes	10,058 (84.5)	2638 (87.8)	2793 (86.2)	1924 (82.6)	2703 (81.0)	
Habitual exercise, missing 155						<0.001
No	4124 (34.6)	634 (21.1)	944 (29.2)	822 (35.2)	1724 (51.5)	
Yes	7799 (65.4)	2368 (78.9)	2294 (70.8)	1515 (64.8)	1622 (48.5)	
Physical Status, missing 86						<0.001
Healthy	1435 (12.0)	519 (17.2)	425 (13.1)	233 (9.9)	258 (7.7)	
Frailty	10,557 (88.0)	2506 (82.8)	2829 (86.9)	2111 (90.1)	3111 (92.3)	

*P-values indicate differences between quartile groups. HEI, healthy eating index.

Fig. 1. Percentage of 13 dietary habits among Chinese of age ≥ 65 years in 2018 CLHLS. *Note:* Four options for fruits/vegetables and five options for the rest.

Table 2
Association between the HEI and depression symptoms by multivariate logistic regression models among Chinese of age ≥ 65 years in 2018 CLHLS.

	N	Model 1 (OR, 95 % CI)	Model 2 (OR, 95 % CI)	Model 3 (original data) (OR, 95 % CI)	Model 4 (imputed data) (OR, 95 % CI)
Per SD (7.1) increase	12,078	0.73 (0.70 to 0.76)	0.75 (0.72 to 0.78)	0.86 (0.82 to 0.90)	0.85 (0.82 to 0.89)
Per 1-unit increase	12,078	0.96 (0.95 to 0.96)	0.96 (0.96 to 0.97)	0.98 (0.97 to 0.99)	0.98 (0.97 to 0.98)
Quartiles					
Q1 (≤21)	3045	Ref.	Ref.	Ref.	Ref.
Q2 (22–26)	3280	0.80 (0.72 to 0.89)	0.82 (0.74 to 0.91)	0.93 (0.83 to 1.03)	0.92 (0.83 to 1.02)
Q3 (27–30)	2362	0.65 (0.58 to 0.73)	0.67 (0.60 to 0.75)	0.84 (0.75 to 0.95)	0.83 (0.74 to 0.93)
Q4 (≥31)	3391	0.46 (0.42 to 0.51)	0.49 (0.44 to 0.54)	0.69 (0.62 to 0.77)	0.68 (0.61 to 0.75)
$P_{for\ trend}$		<0.001	<0.001	<0.001	<0.001

Note: Data are presented as odds ratio (95% confidence interval). SD, standard deviation; Q, quartiles; Ref., reference.
Model 1 unadjusted.
Model 2 adjusted for age and gender.
Model 3 adjusted for gender, age, marriage, economic status, smoking, drinking, habitual exercise, and physical status.
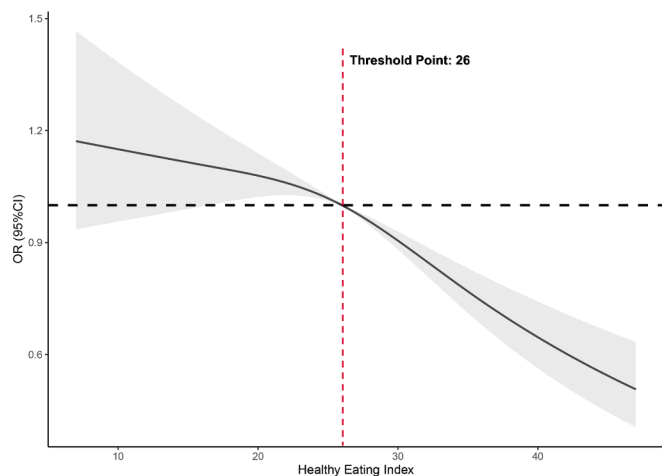Model 4 Same adjustment variables as model 3, but using imputed dataset.

Fig. 2. Adjusted restricted cubic spline model of the association between HEI and risk of depression symptoms among Chinese of age ≥ 65 years in 2018 CLHLS. OR, odds ratio; 95 % CI, 95 % confidence interval.

Table 3
Threshold effect analysis of HEI and the risk of depression symptoms among Chinese of age ≥ 65 years in 2018 CLHLS.

Inflection points of the HEI	OR (95 % CI)	P-value
Total	0.98 (0.97 to 0.99)	<0.001
Segment		
<26	0.99 (0.98 to 1.01)	0.383
≥26	0.97 (0.96 to 0.99)	<0.001

Note: Data are presented as odds ratio (95% confidence interval). HEI, healthy eating index.

3.3. Subgroup analysis

We performed subgroup analyses to stratify the association between the HEI and depression symptoms by age, gender, marriage, economic status, smoking, drinking, exercise habits, and physical status, as shown in Table S3. No interaction was found between subgroup variables and the association between the HEI and the risk of depression symptoms. The inverse relationship remained consistent across subgroups of participants. Restricted cubic spline curves based on gender subgroups showed that the dose–response relationship between the HEI and depression symptoms was similar in males and females (Fig. 3).
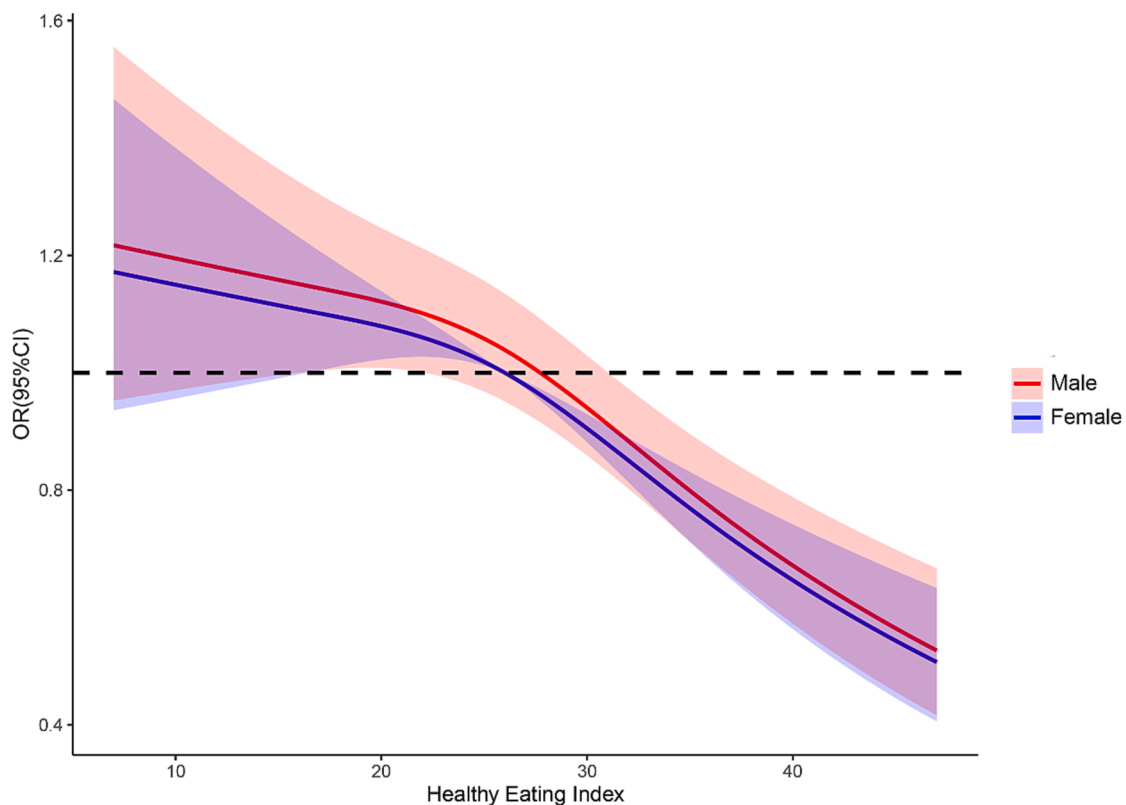
Fig. 3. The nonlinear relationship between the HEI and the risk of depression symptoms among males and females age ≥ 65 years in 2018 CLHLS. OR, odds ratio; 95 % CI, 95 % confidence interval.

4. Discussion

The main finding of this large population-based cross-sectional study was that a higher HEI was associated with a lower risk of depression symptoms in older Chinese adults, both men and women. After adjusting for sociodemographic and lifestyle covariates, each standard deviation (7.1) increase in the HEI was associated with a 14 % lower risk of depression symptoms in older adults (OR = 0.86; 95 % CI: 0.82 to 0.90); compared with the lowest quartile, the risk of depression was lower in the second, third, and fourth quartiles by 7 % (OR = 0.93; 95 % CI: 0.83 to 1.03), 16 % (OR = 0.84; 95 % CI: 0.75 to 0.95) and 31 % (OR = 0.69; 95 % CI: 0.62 to 0.77). Our results prove that healthy dietary patterns are associated with a reduced risk of depression symptoms in older Chinese adults.

From another perspective, quite different from the dietary habits of the elderly population in China, the elderly population in Western countries promotes the use of olive oil as the main source of fat for cooking; a diet rich in plant foods (e.g., fruits, vegetables, legumes, and nuts); consumption of dairy products daily; and regular weekly servings of fish, eggs, and white meat, with occasional red and processed meats, and moderate consumption of wine (Govindaraju et al., 2018; Obeid et al., 2022), i.e., the Mediterranean Diet.

4.1. Comparison with other studies

In analyzing the association between 13 specific food groups and the risk of depression symptoms, our results in the older adults are broadly consistent with previous literature. A cross-sectional survey from Iran showed an 82.4 % lower risk of depression symptoms in the third quartile compared to older adults in the first quartile of the HEI (OR = 0.176; 95 % CI: 0.020 to 1.524) after adjusting for all potential confounders, but no statistical significance was observed, possibly related to the small sample size of the study (Chegini et al., 2022). In another

study, Wang et al. (Wang et al., 2021) analyzed data from the National Health and Nutrition Examination Survey and found that after multivariate adjustment, average HEI (OR = 0.848; 95 % CI: 0.846 to 0.849) and optimal HEI (OR = 0.455; 95 % CI: 0.453 to 0.456) were associated with reduced odds of depression symptoms. This result is similar to the current cross-sectional survey that better HEI is strongly associated with a reduced risk of depression symptoms.

In a recent umbrella review reporting the association between seven dietary patterns and depression (Gianfredi et al., 2023), the authors concluded that there is compelling or suggestive evidence for an inverse association between the Mediterranean diet, a dietary pattern based on vegetables and fruits, fish, grains and beans, and olive oil, and depression. The Hellenic Longitudinal Investigation of Aging and Diet study from Greece showed that after adjusting for age, gender, education, and baseline cognitive status, those in the highest quartile had a 46 % lower risk of depression compared to older adults with the lowest adherence to the Mediterranean diet (hazard ratio = 0.549; 95 % CI: 0.359 to 0.840) (Mamalaki et al., 2023). We also noted that the lack of statistical-level associations between the first quartile of HEI and depressive symptoms may be explained by insufficient covariates adjusted for, and an important factor is physical activity, which has been shown to be strongly associated with the risk of depression (Laird et al., 2023). Interestingly, Liang et al. (Liang et al., 2023; Liang et al., 2023) analyzed the National Health and Nutrition Examination Survey and found that the combination of a healthy diet and sufficient physical activity has an additive interactive effect on the improvement of depressive symptoms in adults. Here, a hypothesis can be put forward whether such a superimposed effect also exists in the elderly population. Unfortunately, physical activity has not been reported in CLHLS, which is a limitation of this study, and therefore, this is a future research direction.

In a systematic review and *meta*-analysis that included eight observational studies involving 38,360 participants, Wu et al. reported that a HEI was associated with a significantly lower risk of depression (OR =

0.70; 95 % CI: 0.57 to 0.87) (Wu et al., 2020). The results of our current study based on 12,078 individuals provide further strong evidence that healthy dietary patterns are associated with a significantly lower risk of depression in the older adults, particularly above 26, and that for each one-unit increase in the HEI, the risk of depression in older people can be reduced by 3 % (OR = 0.97; 95 % CI: 0.96 to 0.99).

In subgroup analyses, we found that the negative correlation between HEI and depressive symptoms was consistent across all subgroup variables and appeared to be more pronounced in males, <75 years, difficult economic situation, non-smoking/drinking, and physically active populations. The reasons for this can be explained as follows. Although female is at higher risk of depression (Velek et al., 2022), the key factor of diet may have a greater impact on male (Bayes et al., 2022). And aging comes with social changes such as retirement, which are also associated with risk for depression (Segel-Karpas et al., 2018). Smoking in adults has been reported to be associated with an increased risk of depression (Bakhshaie et al., 2015), whereas the association between alcohol consumption and depressive symptoms may be dependent on consumption (Bellos et al., 2016). In addition, individuals with exercise habits imply high levels of physical activity, the latter being an important mediator in reducing the risk of depression, as mentioned above.

Several studies have elaborated on the biological mechanisms linking diet and depression. First, a common view is that a healthy diet may be associated with anti-inflammatory properties related to mental illness. A systematic review and *meta*-analysis found that adopting a healthy diet (e.g., Mediterranean) reduced systemic inflammation and oxidative stress (Lassale et al., 2019). Studies have also reported that a nutrient-rich diet enriched with a range of compounds with direct and indirect antioxidant properties is associated with reduced oxidative stress markers such as f2 -isoprostane and plasma oxidized low-density lipoprotein (Marx et al., 2021). Second, the gut microbiota is a potential critical mediating pathway between a healthy diet and mood-altering behavior (Marx et al., 2021). Numerous studies have shown that the gut microbiota modulates physiological processes, including cognitive function, neuropsychiatric disorders, and behavior through the microbiota-gut-brain axis (Taylor and Holscher, 2020). Animal models suggest a direct link between diet, microbiota, and mechanisms associated with depression (Long-Smith et al., 2020). Third, observational studies provide evidence for a direct link between healthy dietary habits and larger hippocampal volumes independent of multiple explanatory factors (e.g., age, gender, education) (Akbaraly et al., 2018), the latter directly related to levels of neurogenesis and cognition and mood. Despite the growing evidence for the importance of healthy eating and other lifestyle behaviors in mental health, some scholars believe that the current more limited clinical studies are still insufficient to support the role of healthy eating patterns in depressive episodes and symptom management and that the mechanisms that have been proposed still need to be validated in large-scale randomized controlled trials (Marx et al., 2022; Molendijk et al., 2022).

Although the design of cross-sectional studies limits causality, prior studies have reported possible reverse effects of depression on eating habits. The clinical manifestations of depression are categorized into three aspects: core symptoms, psychological symptom clusters, and somatic symptom clusters, among which appetite problems are a common clinical somatic symptom of depression. Patients are prone to eating disorders, which are mainly characterized by decreased appetite accompanied by weight loss (Dakanalis et al., 2023). Mild patients show that they do not know how to eat and have no appetite. Severe patients may completely lose the desire to eat, lose interest in favorite foods, or even do not want to mention eating, bloating and stomach discomfort after meals, resulting in significant weight loss, and even malnutrition in patients (Avenevoli et al., 2015). Unfortunately, approximately 67–71 % of people with depression suffer from anorexia nervosa (Liu et al., 2019), which underscores the public health importance of depression in older adults and the urgency of improving the screening and treatment of this population.

4.2. Strength and limitation

We used data from the CLHLS, an extensive population-wide survey in China that allowed us to obtain information on more than 10,000 older adults. However, some limitations need to be considered. First, due to the nature of cross-sectional studies, it was impossible to determine a causal relationship between healthy eating and depression symptoms. Second, dietary habits were based on subjective responses from older adults, which may be subject to recall bias considering the diminished memory of this population. Third, although we rigorously adjusted for sociodemographics and lifestyle habits, our observations may be influenced by unmeasured (e.g., nutritional status) and unknown confounders. Fourth, there was an association between body mass index and depression, however, when we extracted the data, we found more missing values and outliers, and after discussion, this covariate was not included in the model. Fifth, including physical activity, physical status was measured by a very crude self-report questionnaire, and there may be some bias in these covariates.

5. Conclusions

This study found an association between higher levels of the HEI and reduced risk of depression symptoms in older Chinese adults. To promote the mental health of older adults, healthcare providers should advise them to focus on a balanced nutritional intake daily. Clinical caregivers should also pay attention to assessing the dietary habits of older adults and giving them timely and appropriate guidance. This study provides an essential reference for reducing the risk of depression symptoms in older adults, and healthy eating habits are a primary prevention strategy!

CRediT authorship contribution statement

Xinyue Zhang: Writing – original draft. **Wenqin Zhou:** Writing – review & editing. **Hui Wang:** Data curation, Formal analysis. **Yan Bai:** Data curation, Formal analysis. **Fan Zhang:** Conceptualization, Data curation, Formal analysis, Writing – original draft. **Wei Lu:** 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.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2024.102616.

References

Adjibade, M., Assmann, K.E., Andreeva, V.A., Lemogne, C., Hercberg, S., Galan, P., Kesse-Guyot, E., 2018. Prospective association between adherence to the Mediterranean diet and risk of depressive symptoms in the French SU.VI.MAX cohort. Eur. J. Nutr. 57 (3), 1225–1235. https://doi.org/10.1007/s00394-017-1405-3.

Akbaraly, T., Sexton, C., Zsoldos, E., Mahmood, A., Filippini, N., Kerleau, C., Verdier, J. M., Virtanen, M., Gabelle, A., 2018. Ebmeier KP et al.: Association of Long-Term Diet Quality with Hippocampal Volume: Longitudinal Cohort Study. Am. J. Med. 131 (11) https://doi.org/10.1016/j.amjmed.2018.07.001, 1372-1381.e4.

Avenevoli, S., Swendsen, J., He, J.P., Burstein, M., Merikangas, K.R., 2015. Major depression in the national comorbidity survey-adolescent supplement: prevalence, correlates, and treatment. J. Am. Acad. Child Adolesc. Psychiatry 54 (1), 37–44.e32. https://doi.org/10.1016/j.jaac.2014.10.010.

Bakhshaie, J., Zvolensky, M.J., Goodwin, R.D., 2015. Cigarette smoking and the onset and persistence of depression among adults in the United States: 1994–2005. Compr. Psychiatry 60, 142–148. https://doi.org/10.1016/j.comppsych.2014.10.012.

Bayes, J., Schloss, J., Sibbritt, D., 2022. The effect of a Mediterranean diet on the symptoms of depression in young males (the "AMMEND: A Mediterranean Diet in MEN with Depression" study): a randomized controlled trial. Am. J. Clin. Nutr. 116 (2), 572–580. https://doi.org/10.1093/ajcn/nqac106.

Beekman, A.T., Geerlings, S.W., Deeg, D.J., Smit, J.H., Schoevers, R.S., de Beurs, E., Braam, A.W., Penninx, B.W., van Tilburg, W., 2002. The natural history of late-life depression: a 6-year prospective study in the community. Arch. Gen. Psychiatry 59 (7), 605–611. https://doi.org/10.1001/archpsyc.59.7.605.

Bellos, S., Skapinakis, P., Rai, D., Zitko, P., Araya, R., Lewis, G., Lionis, C., Mavreas, V., 2016. Longitudinal association between different levels of alcohol consumption and a new onset of depression and generalized anxiety disorder: Results from an international study in primary care. Psychiatry Res. 243, 30–34. https://doi.org/10.1016/j.psychres.2016.05.049.

Blazer, D.G., 2003. Depression in late life: review and commentary. J. Gerontol. A Biol. Sci. Med. Sci. 58 (3), 249–265. https://doi.org/10.1093/gerona/58.3.m249.

Chegini, M., Shirani, P., Omidvar, N., Eini-Zinab, H., Pour-Ebrahim, F., Rezazadeh, A., 2022. Relationship between diet quality and depression among Iranian older adults in Tehran. BMC Geriatr. 22 (1), 708. https://doi.org/10.1186/s12877-022-03380-1.

Chocano-Bedoya, P.O., O'Reilly, E.J., Lucas, M., Mirzaei, F., Okereke, O.I., Fung, T.T., Hu, F.B., Ascherio, A., 2013. Prospective study on long-term dietary patterns and incident depression in middle-aged and older women. Am. J. Clin. Nutr. 98 (3), 813–820. https://doi.org/10.3945/ajcn.112.052761.

Dakanalis, A., Mentzelou, M., Papadopoulou, S.K., Papandreou, D., Spanoudaki, M., Vasios, G.K., Pavlidou, E., Mantzorou, M., Giaginis, C., 2023. The Association of Emotional Eating with Overweight/Obesity, Depression, Anxiety/Stress, and Dietary Patterns: A Review of the Current Clinical Evidence. Nutrients 15 (5), 1173. https://doi.org/10.3390/nu15051173.

Davis, C., Bryan, J., Hodgson, J., Murphy, K., 2015. Definition of the Mediterranean Diet; a Literature Review. Nutrients 7 (11), 9139–9153. https://doi.org/10.3390/nu7115459.

Erazo, M., Fors, M., Mullo, S., Gonzalez, P., Viada, C., 2020. Internal Consistency of Yesavage Geriatric Depression Scale (GDS 15-Item Version) in Ecuadorian Older Adults, 46958020971184 Inquiry. 57. https://doi.org/10.1177/0046958020971184.

Gee, L.C., Ahluwalia, A., 2016. Dietary Nitrate Lowers Blood Pressure: Epidemiological, Pre-clinical Experimental and Clinical Trial Evidence. Curr. Hypertens. Rep. 18 (2), 17. https://doi.org/10.1007/s11906-015-0623-4.

Gianfredi, V., Dinu, M., Nucci, D., Eussen, S., Amerio, A., Schram, M.T., Schaper, N., Odone, A., 2023. Association between dietary patterns and depression: an umbrella review of meta-analyses of observational studies and intervention trials. Nutr. Rev. 81 (3), 346–359. https://doi.org/10.1093/nutrit/nuac058.

Govindaraju, T., Sahle, B.W., McCaffrey, T.A., McNeil, J.J., Owen, A.J., 2018. Dietary Patterns and Quality of Life in Older Adults: A Systematic Review. Nutrients 10 (8), 971. https://doi.org/10.3390/nu10080971.

Hwang, Y.G., Pae, C., Lee, S.H., Yook, K.H., Park, C.I., 2023. Relationship between Mediterranean diet and depression in South Korea: the Korea National Health and Nutrition Examination Survey. Front. Nutr. 10, 1219743. https://doi.org/10.3389/fnut.2023.1219743.

Kennedy, E.T., Ohls, J., Carlson, S., Fleming, K., 1995. The Healthy Eating Index: design and applications. J. Am. Diet. Assoc. 95 (10), 1103–1108. https://doi.org/10.1016/s0002-8223(95)00300-2.

Laird, E., Rasmussen, C.L., Kenny, R.A., Herring, M.P., 2023. Physical Activity Dose and Depression in a Cohort of Older Adults in The Irish Longitudinal Study on Ageing. JAMA Netw. Open 6 (7), e2322489.

Lassale, C., Batty, G.D., Baghdadli, A., Jacka, F., Sanchez-Villegas, A., Kivimaki, M., Akbaraly, T., 2019. Healthy dietary indices and risk of depressive outcomes: a systematic review and meta-analysis of observational studies. Mol. Psychiatry 24 (7), 965–986. https://doi.org/10.1038/s41380-018-0237-3.

Lee, D.H., Keum, N., Hu, F.B., Orav, E.J., Rimm, E.B., Willett, W.C., Giovannucci, E.L., 2018. Predicted lean body mass, fat mass, and all cause and cause specific mortality in men: prospective US cohort study. BMJ 362, k2575. https://doi.org/10.1136/bmj.k2575.

Lewinsohn, P.M., Seeley, J.R., Roberts, R.E., Allen, N.B., 1997. Center for Epidemiologic Studies Depression Scale (CES-D) as a screening instrument for depression among community-residing older adults. Psychol. Aging 12 (2), 277–287. https://doi.org/10.1037//0882-7974.12.2.277.

Li, Y., Lv, M.R., Wei, Y.J., Sun, L., Zhang, J.X., Zhang, H.G., Li, B., 2017. Dietary patterns and depression risk: A meta-analysis. Psychiatry Res. 253, 373–382. https://doi.org/10.1016/j.psychres.2017.04.020.

Liang, J.H., Huang, S., Pu, Y.Q., Zhao, Y., Chen, Y.C., Jiang, N., Liu, M.L., Bao, W.W., Zhang, Y.S., Hu, L.X., et al., 2023. Whether weekend warrior activity and other leisure-time physical activity pattern reduce the risk of depression symptom in the representative adults? A population-based analysis of NHANES 2007–2020. J. Affect. Disord. 340, 329–339. https://doi.org/10.1016/j.jad.2023.07.113.

Liang, J., Huang, S., Jiang, N., Kakaer, A., Chen, Y., Liu, M., Pu, Y., Huang, S., Pu, X., Zhao, Y., et al., 2023. Association Between Joint Physical Activity and Dietary Quality and Lower Risk of Depression Symptoms in US Adults: Cross-sectional NHANES Study. JMIR Public Health Surveill. 9, e45776.

Liu, P., Li, G., Zhang, A., Sun, N., Kang, L., Yang, C., Wang, Y., Zhang, K., 2019. The prognosis and changes of regional brain gray matter volume in MDD with gastrointestinal symptoms. Neuropsychiatr. Dis. Treat. 15, 1181–1191. https://doi.org/10.2147/ndt.S197351.

Long-Smith, C., O'Riordan, K.J., Clarke, G., Stanton, C., Dinan, T.G., Cryan, J.F., 2020. Microbiota-Gut-Brain Axis: New Therapeutic Opportunities. Annu. Rev. Pharmacol. Toxicol. 60, 477–502. https://doi.org/10.1146/annurev-pharmtox-010919-023628.

Ma, G., 2015. Food, eating behavior, and culture in Chinese society. Journal of Ethnic Foods. 2. https://doi.org/10.1016/j.jef.2015.11.004.

Magalhaes, B., Peleteiro, B., Lunet, N., 2012. Dietary patterns and colorectal cancer: systematic review and meta-analysis. Eur. J. Cancer Prev. 21 (1), 15–23. https://doi.org/10.1097/CEJ.0b013e3283472241.

Mamalaki, E., Ntanasi, E., Hatzimanolis, A., Basta, M., Kosmidis, M.H., Dardiotis, E., Hadjigeorgiou, G.M., Sakka, P., Scarmeas, N., Yannakoulia, M., 2023. The Association of Adherence to the Mediterranean Diet with Depression in Older Adults Longitudinally Taking into Account Cognitive Status: Results from the HELIAD Study. Nutrients 15 (2), 359. https://doi.org/10.3390/nu15020359.

Marx, W., Lane, M., Hockey, M., Aslam, H., Berk, M., Walder, K., Borsini, A., Firth, J., Pariante, C.M., Berding, K., et al., 2021. Diet and depression: exploring the biological mechanisms of action. Mol. Psychiatry 26 (1), 134–150. https://doi.org/10.1038/s41380-020-00925-x.

Marx, W., Lane, M.M., Hockey, M., Aslam, H., Walder, K., Borsini, A., Firth, J., Pariante, C.M., Berding, K., Cryan, J.F., et al., 2022. Diet and depression: future needs to unlock the potential. Mol. Psychiatry 27 (2), 778–780. https://doi.org/10.1038/s41380-021-01360-2.

Mohebbi, M., Nguyen, V., McNeil, J.J., Woods, R.L., Nelson, M.R., Shah, R.C., Storey, E., Murray, A.M., Reid, C.M., Kirpach, B., et al., 2018. Psychometric properties of a short form of the Center for Epidemiologic Studies Depression (CES-D-10) scale for screening depressive symptoms in healthy community dwelling older adults. Gen. Hosp. Psychiatry 51, 118–125. https://doi.org/10.1016/j.genhosppsych.2017.08.002.

Molendijk, M.L., Molero, P., Thomas-Odenthal, F., van der Does, W., 2022. There is not much to mediate [yet] when it comes to diet and depression. Mol. Psychiatry 27 (2), 776–777. https://doi.org/10.1038/s41380-021-01382-w.

Mozaffarian, D., 2016. Dietary and Policy Priorities for Cardiovascular Disease, Diabetes, and Obesity: A Comprehensive Review. Circulation 133 (2), 187–225. https://doi.org/10.1161/CIRCULATIONAHA.115.018585.

Ni, Y., Tein, J.Y., Zhang, M., Yang, Y., Wu, G., 2017. Changes in depression among older adults in China: A latent transition analysis. J. Affect. Disord. 209, 3–9. https://doi.org/10.1016/j.jad.2016.11.004.

Obeid, C.A., Gubbels, J.S., Jaalouk, D., Kremers, S.P.J., Oenema, A., 2022. Adherence to the Mediterranean diet among adults in Mediterranean countries: a systematic literature review. Eur. J. Nutr. 61 (7), 3327–3344. https://doi.org/10.1007/s00394-022-02885-0.

Pingali, P., 2007. Westernization of Asian Diets and the Transformation of Food Systems: Implications for research and policy. Food Policy 32, 281–298. https://doi.org/10.1016/j.foodpol.2006.08.001.

Rees, K., Hartley, L., Flowers, N., Clarke, A., Hooper, L., Thorogood, M., Stranges, S., 2013. 'Mediterranean' dietary pattern for the primary prevention of cardiovascular disease. CD009825 Cochrane Database Syst Rev. 8. https://doi.org/10.1002/14651858.CD009825.pub2.

Segel-Karpas, D., Ayalon, L., Lachman, M.E., 2018. Retirement and depressive symptoms: A 10-year cross-lagged analysis. Psychiatry Res. 269, 565–570. https://doi.org/10.1016/j.psychres.2018.08.081.

Taylor, A.M., Holscher, H.D., 2020. A review of dietary and microbial connections to depression, anxiety, and stress. Nutr. Neurosci. 23 (3), 237–250. https://doi.org/10.1080/1028415X.2018.1493808.

U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015. 2015-2020 Dietary Guidelines for Americans. 8th Edition. Accessed December 10 2023. https://health.gov/our-work/nutrition-physical-activity/dietary-guidelines/previous-dietary-guidelines/2015.

Velek, P., Luik, A.I., Brusselle, G.G.O., Stricker, B.C., Bindels, P.J.E., Kavousi, M., Kieboom, B.C.T., Voortman, T., Ruiter, R., Ikram, M.A., et al., 2022. Sex-specific patterns and lifetime risk of multimorbidity in the general population: a 23-year prospective cohort study. BMC Med. 20 (1), 304. https://doi.org/10.1186/s12916-022-02487-x.

Wang, A., An, N., Chen, G., Li, L., Alterovitz, G., 2014. Accelerating incremental wrapper based gene selection with K-Nearest-Neighbor. In: 2014 IEEE International Conference on Bioinformatics and Biomedicine (BIBM), pp. 21–23.

Wang, X., Si, Z., Wang, H., Meng, R., Lu, H., Zhao, Z., Hu, J., Wang, H., Chen, J., Zheng, Y., et al., 2023. Association of Chinese Visceral Adiposity Index and Carotid Atherosclerosis in Steelworkers: A Cross-Sectional Study. Nutrients 15 (4), 1023. https://doi.org/10.3390/nu15041023.

Wang, K., Zhao, Y., Nie, J., Xu, H., Yu, C., Wang, S., 2021. Higher HEI-2015 Score Is Associated with Reduced Risk of Depression: Result from NHANES 2005–2016. Nutrients 13 (2), 348. https://doi.org/10.3390/nu13020348.

World Health Oragaization, 2015. World report on ageing and health. Accessed January 08, 2024. https://www.who.int/publications/i/item/9789241565042.

World Health Oragaization, 2017. Depression and Other Common Mental Disorders: Global Health Estimates. Accessed December 17, 2024. http://apps.who.int/iris/bitstream/handle/10665/254610/WHO-MSD-MER-2017.2-eng.pdf;jsessionid=C7B2B6883B0900DE75AF937ECFE367A3?sequence=1.

World Health Oragaization, 2022. UN Decade of Healthy Ageing: Plan of Action. Accessed December 20, 2024. https://cdn.who.int/media/docs/default-source/decade-of-healthy-ageing/decade-proposal-final-apr2020-en.pdf?sfvrsn=b4b75ebc_28.

World Health Oragaization, 2022. China country assessment report on ageing and health. Accessed January 10, 2024. https://www.who.int/publications/i/item/9789241509312.

World Health Oragaization, 2022. Ageing and health. Accessed January 10, 2024. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health.

Wu, H., Gu, Y., Meng, G., Zhang, Q., Liu, L., Wu, H., Zhang, S., Zhang, T., Wang, X., Zhang, J., et al., 2023. Relationship between dietary pattern and depressive symptoms: an international multicohort study. Int. J. Behav. Nutr. Phys. Act. 20 (1), 74. https://doi.org/10.1186/s12966-023-01461-x.

Wu, P.Y., Lin, M.Y., Tsai, P.S., 2020. Alternate healthy eating index and risk of depression: A meta-analysis and systemematic review. Nutr. Neurosci. 23 (2), 101–109. https://doi.org/10.1080/1028415X.2018.1477424.

Yan, L.L., Li, C., Zou, S., Li, Y., Gong, E., He, Z., Shao, S., Jin, X., Hua, Y., Gallis, J.A., et al., 2022. Healthy eating and all-cause mortality among Chinese aged 80 years or older. Int. J. Behav. Nutr. Phys. Act. 19 (1), 60. https://doi.org/10.1186/s12966-022-01280-6.

Zeng, Y., Chen, H., Shi, X., Yin, Z., Yang, Z., Gu, J., Blazer, D., 2013. Health consequences of familial longevity influence among the Chinese elderly. J. Gerontol. A Biol. Sci. Med. Sci. 68 (4), 473–482. https://doi.org/10.1093/gerona/gls203.

Zyoud, S.H., Shakhshir, M., Abushanab, A.S., Koni, A., Shahwan, M., Jairoun, A.A., Al-Jabi, S.W., 2023. Bibliometric mapping of the landscape and structure of nutrition and depression research: visualization analysis. J. Health Popul. Nutr. 42 (1), 33. https://doi.org/10.1186/s41043-023-00378-2.