American Journal of Preventive Cardiology 22 (2025) 100963

Contents lists available at ScienceDirect

American Journal of Preventive Cardiology

journal homepage: www.journals.elsevier.com/american-journal-of-preventive-cardiology

The dose-response relationships between all-cause and cardiovascular mortality and the accrual of various dietary habits

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A R T I C L E I N F O

Keywords:
Dietary habits
Mortality
Aging
Obesity
Cardiovascular diseases

A B S T R A C T

Objective: To evaluate the potential dose-response relationships of all-cause and cardiovascular death with the accumulation of various dietary habits.
Setting: A prospective cohort study.
Methods: Twenty-three dietary habits were assessed through face-to-face interviews with 57,737 participants in health check-up programs from 2015 to 2021. The total score of various dietary habits was calculated as the sum of each dietary habit multiplied by its own full-adjusted coefficient (β) for all-cause mortality in Cox proportional hazard models. Cox proportional hazard models were fitted for the associations of total and cause-specific mortality with the scores of various dietary habits.
Results: 1,692 deaths occurred after the earliest check-ups in our center, followed up for a median time of 2.14 years (range: 1.01–7.71 years). Total mortality was 11.23/1,000 person-years, and the mean scores of dietary habits were 2.83±2.14. All-cause mortality increased significantly with the cumulative score of dietary habits (the highest quartile vs. lowest quartile: adjusted hazard ratio [AHR], 1.72; 95 % confidence interval [CI], 1.49–1.99; P_{linear}<0.01). Significance was also found for cardiovascular disease (CVD) mortality (HR, 1.82; 95 % CI, 1.47–2.27; P_{linear}<0.01), cancer mortality (AHR, 1.59; 95 % CI, 1.23–2.04; P_{linear}<0.01), and other-cause mortality (AHR, 2.00; 95 % CI, 1.46–2.73; P_{linear}<0.01). These dose-response trends were more significant in total mortality and CVD mortality among middle-aged adults, and non-obese population.
Conclusions: The greater the accumulation of diverse dietary habits, the higher the total mortality, CVD mortality, cancer mortality, and other mortality. This additive effect was particularly pronounced in the risk of death among middle-aged individuals and those with average body statures.

1. Introduction

Dietary pattern analysis takes interactive and synergistic effect of dietary components into account, which could reflect the overall quality of diet. A healthy dietary pattern, characterized by a high yield of vegetables, fruits, poultry, fish, and whole grains, may be decreases the risk of diabetes mellitus, chronic obstructive pulmonary diseases, coronary heart diseases, fracture, depression, and all-cause and CVD mortality [1–3]. The traditional Chinese dietary patterns demonstrated preventative countermeasures against the development of metabolic syndromes (MetS) and CVD, as they are high in whole grains, tubers, vegetables, fruits, soy and its products [4,5]. However, significant changes in Chinese dietary patterns have emerged over the past few decades, playing a crucial role in the development of non-communicable diseases (NCDs) and related mortality [6].

Although there exists a degree of overlap, dietary patterns and dietary habits are distinct entities. The former pertains to the habitual consumption patterns of an individual, encompassing the frequency of

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https://doi.org/10.1016/j.ajpc.2025.100963
Received 13 December 2024; Received in revised form 5 March 2025; Accepted 15 March 2025
Available online 16 March 2025

consumption, the quantity ingested, and the nature of the food and beverages consumed, which are influenced by a variety of factors, including daily familial selections, availability of food, education pertaining to balanced nutrition, individual tastes and preferences, food intolerance or allergies, religious beliefs, and cultural influences [7]. On the other hand, dietary habits constitute the regular enactment of eating behaviors that evolve into daily, natural practices. These habits encompass both positive and negative aspects; positive dietary habits include the daily inclusion of a nutritious and balanced breakfast, which should consist of all macronutrient groups, such as complex carbohydrates, whole grains, complete proteins, and fats conducive to health. Conversely, negative dietary habits may involve the daily omission of breakfast [8].

Several previous studies have found that some dietary habits also may increase disease risk alone [9–16] or combinations [17,18], such as late-night eating, high-fat meat or animal offal, skipping meals, dining out, and fast foods. Evaluating the impact of a single dietary habit on disease risk can be inefficient, particularly when multiple dietary habits coexist within an individual, especially those associated with poor dietary practices. Therefore, developing a composite score of dietary habits may better assess the accumulation effects of dietary habits. We have constructed a composite score from twenty-three dietary habits via a questionnaire in health check-up programs from 2015 to 2021, which indicated the accumulation of dietary habits contributions to the MetS development [18]. Nevertheless, the causal relationship between MetS and poor dietary habits remains unclear due to the cross-sectional nature of the study design. MetS is characterized as a constellation of risk factors that coexist with CVD, type 2 diabetes mellitus (T2DM), and overall mortality [19,20]. Therefore, our objective was to assess the potential dose-response associations between all-cause mortality and cardiovascular mortality, and the aggregation of diverse dietary practices, through a prospective cohort study conducted within this specific Chinese population.

2. Methods

2.1. Study population

As mentioned before [18], several cross-sectional studies were conducted on 98,838 males and 83,099 females at the Third Xiangya Hospital in Changsha, Hunan Province, China from 2015 to 2021. Participants completed face-to-face questionnaire interviews regarding twenty-three dietary habits by trained physicians or nurses during routine health check-ups. The earliest check-up data were used as the baseline for each participant when multiple check-ups were identified using unique Chinese residential ID card number.

2.2. Inclusive and exclusive criteria

Besides inclusive and exclusive criteria of our previous publication [18], those with at least two check-ups in our center during 2015–2021 were included in this study. Participants were included in the final baseline if they met the following criteria: (1) aged 18 years or older; (2) provided twenty-three dietary habits; (3) had accessible relevant data for MetS diagnosis, including age, sex, systolic blood pressure (SBP), diastolic blood pressure (DBP), waist circumference (WC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), fasting blood glucose (FBG), as well as medical history and drug treatments for hypertension and diabetes; (4) presented with reasonable blood pressures: SBP $\geq$ 70 and $\leq$ 260 mmHg; DBP $\geq$ 40 and $\leq$ 140 mmHg; (5) presented with plausible blood lipid levels: TG $\geq$ 0.2 and $\leq$ 30 mmol/L; HDL-C $\geq$ 0.1 and $\leq$ 10.0 mmol/L.

The death date and death cause of participants were obtained through official death certificates from the Center for Disease Prevention and Control (CDC) of Hunan Province and matched using Chinese residential ID card number. The follow-up time was calculated using the latest check-up date minus the earliest check-up date, if alive.

2.3. Data collection

A structured questionnaire was used to collect social-demographic and behavioral factors, including age, sex, education level, smoking status, drinking status, and physical activities. Physical activities were defined as exercise over three times a week for at least 30 min. Trained physicians conducted physical examinations, including weight, height, waist circumference (WC), hip circumference (HC), systolic blood pressure (SBP), and diastolic blood pressure (DBP) measurements. Fasting blood samples were taken to test total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and fasting blood glucose (FBG) levels using LEADMAN test kits (Beijing LEADMAN Biochemical Co., Ltd. China). Details on these procedures have been previously published [18,21–24]. Any participant deaths are coded by trained staff using the 10th International Classification of Diseases (ICD-10). If necessary, causes of death from official certificates are supplemented by medical record reviews.

2.4. Construction of a total dietary habit score

A structured questionnaire was used to collect information on the twenty-three dietary habits [18], and respective associations were evaluated with total mortality using Cox proportional hazard models (Appendix Table S1). Four independent categories were defined using a cluster analysis, including (1) Special dietary habits (8 specifications): often skip meals, often night eating, often over eating, often dinning out for business, often eating fast foods, often eating snacks, often drinking coffee, and often drinking sweeten beverages; (2) Special taste preference (five specifications): preference for salty, spicy, pickled, fried or hot foods, which were defined as the five dietary flavors due to “Light Eating Possesses Health Benefits” in traditional Chinese concepts; (3) Unbalanced dietary structure (seven specifications): not eating coarse cereals, drinking milk or yogurt $<$3 times per week, eating eggs $<$3 times per week, eating beans $<$3 times per week, eating fruits $<$3 times per week, eating vegetables $<$100 grams per day, not eating fish or seafood; (4) High-fat diets (3 specifications): eating meats $\geq$50 grams per day (e.g., pork, beef, lamb, poultry), eating fat meats per week, and eating animal offal per week. The score of dietary habits was calculated as the sum of each dietary habit multiplied by its own full-adjusted coefficient (β) for all-cause mortality in Cox proportional hazard models, and the final scores were multiplied by 10, whatever significance or not (Appendix Table S2).

2.5. Statistical analyses

The primary outcome is total mortality, and secondary outcomes included CVD mortality and cancer mortality based on ICD-10 codes of primary death cause. Continuous variables were expressed as the mean $\pm$ standard deviation (SD), while categorical variables were presented as percentages (%) and counts. As the primary exposure, the total score of various dietary habits was divided into four groups using sex-specific quartile of the overall study population, with reference to the lowest quartile. As secondary exposures, the four categories were split up, which include special dietary habits, special taste preference, unbalanced dietary structure, and high-fat diet. The comparison among various groups of dietary habit scores was conducted using the Kruskal-Wallis tests for continuous variables and the Mantel-Haenszel Chi-square tests for categorical variables. Cox proportional hazard models were used to calculate the hazard ratios (HR) and their confidence intervals (CIs) of the mortality with various groups for the total score of dietary habits. Covariates were chosen a priori based on previous publications and potential mechanism underlying the associations between dietary and mortality [18,25–28]. Model 1 included age and sex. Model

2 additionally included BMI, current smokers, current drinking, and physical activities, based on Model 1. Model 3 additionally included self-reported hypertension, self-reported diabetes mellitus, and self-reported dyslipidemia, based on Model 2. Subgroup analyses were conducted to evaluate the consistency of the overall associations in each category, specifically on sex (females and males), age group (<40, 40–60, and >60 years), BMI (<24 and 24 kg/m^2), and central obesity (Yes and No). The Statistical Analysis System (SAS 9.4 for Windows; SAS Institute Inc., Cary, NC, US) software was used for all statistical analyses in this study.

3. Results

Among 57,737 participants with at least two check-ups in our center during 2015–2021 (Appendix Figure S1), 1692 deaths occurred after their earliest check-ups, followed up for a median time of 2.14 years (range: 1.01–7.71 years). Total mortality was 11.23/1000 person-years, and the mean scores of dietary habits were 2.83±2.14. The clear dose-response trends between the scores of dietary habits and all-cause mortality were observed from 3.99 % at the highest quartile to 2.29 % at the lowest quartile, especially after aged at 50 years or older (50–59 years: 6.15 % vs. 2.77 %; 60–69 years: 17.74 % vs. 8.63 %; ≥70 years: 47.44 % vs. 34.41 %), which were illustrated in Fig. 1. 56.62 % of overall population are males, which had no difference across various quartile for the total scores of various dietary habits ($P = 0.89$). The mean age of 40.23±12.69 years at the first check- up. Participants with higher dietary habit scores were much older than those with lower scores ($P < 0.01$) (Table 1).

Table 2 displays unadjusted and adjusted hazard ratios and 95 % confidence intervals for all-cause mortality, CVD mortality, cancer mortality, and other-cause mortality according to the quartile (Q) of total dietary habit scores. The clear dose-response trends were shown between all-cause mortality and total scores of dietary habits (adjusted HR for Q4 vs. Q1: 1.72; 95 % CI, 1.49–1.99; P_{trend}<0.01). The higher CVD mortality was associated significantly with the increase of dietary habit scores (adjusted HR for Q4 vs. Q1: 1.82; 95 % CI, 1.47–2.27; P_{trend}<0.01). Significance was also observed for cancer mortality (adjusted HR for Q4 vs. Q1: 1.59; 95 % CI, 1.23–2.04; P_{trend}<0.01) and other-cause mortality (adjusted HR for Q4 vs. Q1: 2.00; 95 % CI, 1.46–2.73; P_{trend}<0.01).

Further subgroup analyses in Fig. 2 illustrates that the total mortality risk raised gradually with increasing dietary habit scores in males, and statistical significance was shown in all three higher quartile compared with the lowest quartile of dietary habit scores (adjusted HR for Q4 vs. Q1: 1.67; 95 % CI, 1.41–1.98). Among females, however, no significance was reached in the second and third quartile of dietary habit scores, while the mortality risk on growth-spurt was found in the highest quartile (adjusted HR, 1.88; 95 % CI, 1.43–2.47). In the population of individuals who are under the age of 40, researchers did not uncover any significant connections or correlations between the overall rates of death and the dietary practices observed across various levels, specifically the different quartiles of dietary scores. However, when focusing on the demographic of middle-aged and older adults, the data revealed that there were indeed statistically significant relationships present. Nice dose-response trend was presented only in middle-aged adults (adjusted HR for Q4 vs. Q1: 1.59; 95 % CI, 1.22–2.06), while this dose-response trend is weaken. The effects of overall and central obesity was further evaluated on the relationships between total mortality and the accrual of dietary habits, and good dose dependent relationships were assumed only in non-obesity people, whatever based on BMI<24 kg/m^2 (adjusted HR for Q4 vs. Q1: 1.85; 95 % CI, 1.49–2.30) or waist circumference<85 cm in females and >90 cm in males (adjusted HR for Q4 vs. Q1: 1.85; 95 % CI, 1.54–2.23).

Fig. 3 exhibits adjusted associations between CVD mortality and dietary habit using similar Cox proportional hazard models. More significant dose-response trends were displayed in males (adjusted HR for Q4 vs. Q1: 1.72; 95 % CI, 1.34–2.21), middle-aged adults (adjusted HR for Q4 vs. Q1: 2.06; 95 % CI, 1.34–3.17), non-overall-obesity people (adjusted HR for Q4 vs. Q1: 1.75; 95 % CI, 1.24–2.47), and non-central-obesity population (adjusted HR for Q4 vs. Q1: 1.92; 95 % CI, 1.44–2.58).

Fig. 4 illustrates the adjusted associations between cancer mortality and dietary habits using similar Cox proportional hazard models. More pronounced dose-response trends were observed in males (adjusted HR for Q4 vs. Q1: 1.59; 95 % CI, 1.23–2.04), non-overweight individuals (adjusted HR for Q4 vs. Q1: 1.69; 95 % CI, 1.18–2.42), and those without central obesity (adjusted HR for Q4 vs. Q1: 1.79; 95 % CI, 1.31–2.45).

Fig. 5 reveals the relationships of total mortality, CVD mortality, and cancer mortality with four sub-categories of dietary habits, including special dietary habits, special taste preference, unbalanced dietary structure, and high-fat diet. Regarding speicial dietary habits, favorable dose dependent tendencies were shown for total mortality (P_{trend}<0.01),

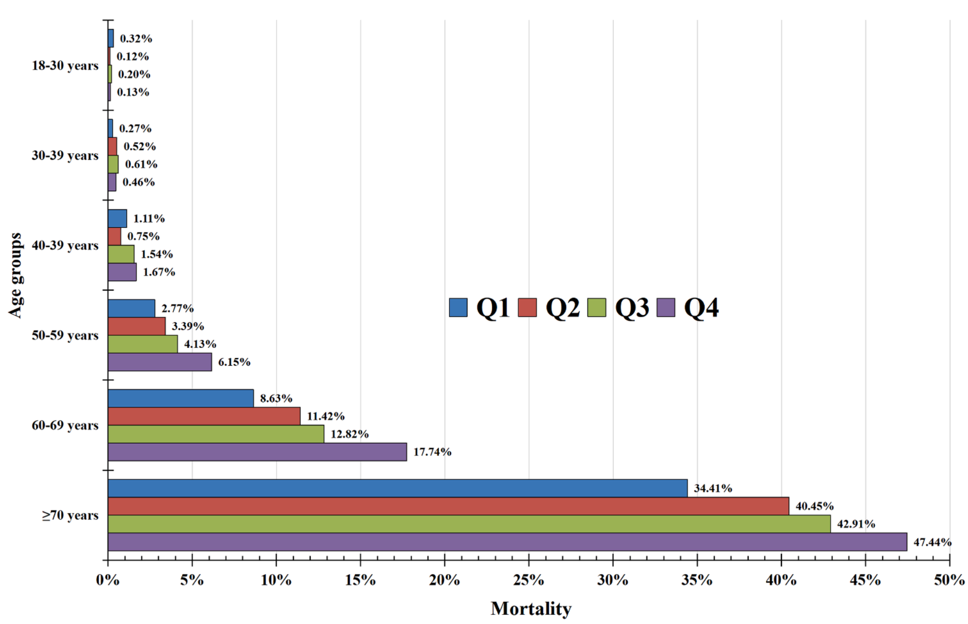

Fig. 1. Mortality by the quartile for total scores of dietary habits and age groups.

Table 1
The characteristics of the overall population by quartile of total dietary habit scores.

Characteristics (Mean±SD)	Quartile of total dietary habits scores				Total (N = 57,737)	P value[1]
	Q1 (n = 14,459)	Q2 (n = 14,480)	Q3 (n = 14,378)	Q4 (n = 14,420)		
Total dietary habit score	0.12±1.13	2.22±0.59	3.49±0.67	5.48±1.07	2.83±2.14	<0.01
Age (years)	39.24±13.05	40.05±12.61	40.52±12.22	41.10±12.81	40.23±12.69	<0.01
Male sex, % (n)	56.59 (8182)	56.84 (8231)	56.36 (8104)	56.66 (8171)	56.62 (32,688)	0.89
College or higher, % (n)	78.18 (11,304)	76.24 (11,039)	73.79 (10,610)	66.78 (9629)	73.75 (42,582)	<0.01
Height (cm)	164.94±8.14	164.36±7.97	163.96±8.04	163.67±8.13	164.23±8.08	<0.01
Weight (kg)	64.92±12.60	64.14±11.97	64.08±12.21	63.72±12.11	64.21±12.23	<0.01
BMI (kg/m^2)	23.72±3.42	23.62±3.29	23.71±3.39	23.66±3.37	23.68±3.37	0.13
WC (cm)	80.38±10.52	80.19±10.06	80.46±10.33	80.56±10.22	80.40±10.29	0.02
HC (cm)	94.15±6.38	93.82±6.13	93.80±6.24	93.75±6.31	93.88±6.27	<0.01
WHR	0.85±0.07	0.85±0.07	0.86±0.10	0.86±0.12	0.85±0.09	<0.01
SBP (mmHg)	120.25±15.15	120.68±15.35	120.83±15.48	121.25±15.96	120.75±15.49	<0.01
DBP (mmHg)	73.95±10.81	74.27±10.90	74.54±11.11	74.65±11.13	74.35±10.99	0.09
FBG (mmol/L)	5.32±1.08	5.38±1.19	5.39±1.20	5.39±1.20	5.37±1.17	<0.01
TC (mmol/L)	4.91±0.96	4.92±0.94	4.97±1.00	4.96±0.96	4.94±0.96	<0.01
TG (mmol/L)	1.61±1.47	1.64±1.48	1.74±1.69	1.70±1.61	1.67±1.57	<0.01
HDL-C (mmol/L)	1.38±0.32	1.38±0.32	1.38±0.32	1.37±0.32	1.38±0.32	0.13
LDL-C (mmol/L)	2.78±0.80	2.78±0.79	2.79±0.82	2.81±0.82	2.79±0.81	0.05
Current smokers[2], % (n)	25.73 (3720)	25.45 (3685)	30.14 (4334)	30.83 (4446)	28.03 (16,185)	<0.01
Current drinkers, % (n)	33.72 (4876)	28.27 (4094)	32.15 (4623)	28.49 (4108)	30.66 (17,701)	<0.01
Physical activities, % (n)	66.21 (9573)	64.71 (9370)	59.09 (8496)	52.09 (7511)	60.53 (34,950)	<0.01
Self-reported disease history, % (n)						
Hypertension	6.62 (957)	5.95 (861)	6.48 (931)	6.91 (997)	6.49 (3746)	0.12
Diabetes mellitus	2.26 (327)	2.27 (329)	2.39 (344)	2.50 (360)	2.36 (1360)	0.14
Dyslipidemia	2.70 (390)	2.13 (308)	2.46 (354)	2.07 (298)	2.34 (1350)	0.01
Self-reported medications, % (n)						
Anti-hypertensive	5.91 (855)	5.50 (797)	5.95 (856)	6.26 (903)	5.91 (3411)	0.09
Hypoglycemic	1.98 (286)	1.87 (271)	1.93 (277)	2.00 (289)	1.95 (1123)	0.80
Lipid-lowering	1.29 (186)	0.98 (142)	1.15 (165)	0.78 (112)	1.05 (605)	<0.01
Died, % (n)	2.29 (331)	2.54 (368)	2.90 (417)	3.99 (576)	2.93 (1692)	<0.01

Note: SD, standard deviance; BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist to hip ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TC, total cholesterol; TG, triglycerides; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol;.

[1] P value was obtained by Kruskal-Wallis tests for continuous variables and Mantel-Haenszel Chi-square tests for categorical variables;.

[2] Passive smokers included.

CVD mortality (P_{trend}=0.09), and cancer mortality (P_{trend}=0.01), but the caner mortality risk reduced to non-significance at the highest quartile of various dietary habits, compared to the lowest quartile. In context of special taste preference, total mortality risk increased with the raise of special taste preference (P_{trend}=0.01), while U-shaped associations were found for CVD mortality (P_{trend}=0.01), and reverse U-shaped associations for cancer mortality (P_{trend}=0.01). The death risk increased quickly at the highest quartile of unbalanced dietary structure, whatever for total death and CVD death (both P_{trend}<0.01), but no significance was observed for cancer mortality (P_{trend}=0.07). High-fat diet seemed in a dose effect manner for neither total mortality nor CVD mortality (P_{trend}>0.05), while a J-shaped association was found for cancer mortality (P_{trend}=0.01).

4. Discussions

To our knowledge, this is the first study to assess the impact of various dietary practices on mortality risk, independent of sociodemographic factors, lifestyle factors, and health status. In this prospective cohort study, dose-response trends were observed between death risk and the accumulation of multiple dietary habits, particularly among individuals aged 50 years or older. Surprisingly, the synergistic harm of various dietary habits is more pronounced in non-obese populations than in overweight and obese populations, regardless of whether central or overall obesity is present. Furthermore, we categorize dietary habits into four distinct groups and investigate their respective impacts on overall mortality, CVD mortality, and cancer mortality. These groups include special dietary habits, special taste preference, unbalanced dietary structure, and high-fat diet. Each of these factors exerts a unique influence on the risk of death, with speical dietary habits exerting the most significant effect.

There is convincing evidence that the significant association was found between dietary patterns and all-cause, CVD mortality, and cancer mortlity [1,26,29–35]. In general, dietary pattern analyses have been widely used as an alternative and complementary approach to assess the complexity and diversity of dietary intake, whose findings were recommended by dietary guidelines [36,37]. However, dietary habits are characterized as the habitual choices in food selection, which share similarities with dietary patterns yet possess distinctions. In addition to advocating balanced diets in terms of nutrient diversity and quality, dietary habits may also emphasize the importance of regular eating behaviors and healthy cooking practices [16–18]. Some studies have reported the associations between individual dietary habits and death risk, including late-night overeating [38], skipping breakfast [12,39,40], meal skipping [41], dining out[42], and so on. To our knowledge, however, no studies reported the contributions of the cumulative effects in multiple dietary habits to the death risk. Our study demonstrated that the dietary habit scores were associated with a significantly elevated risk of all-cause mortality, CVD mortality, cancer mortality, and other mortality. Therefore, beyond concentrating on the ideal blend of diverse foods and nutrients, it is equally imperative to cultivate beneficial dietary habits throughout one's lifetime.

Furthermore, the cumulative effects of multiple dietary habits on mortality predominantly manifest in individuals of middle age. However, the impact of dietary habits persists among the elderly in our study, which appears consistent with previous findings from dietary pattern analyses. Strong evidence had demonstrated that healthy dietary patterns in middle and older adults were associated with decreased risk of all-cause mortality, but insufficient evidence was available in younger populations aged at <35 years [43,44]. As we know, dietary habits are established by mid-adulthood, and any changes are likely to be more challenging to implement [45], unless people encounter significant or

Table 2
Hazard ratios and 95 % confidence intervals for all-cause, cardiovascular disease, and cancer mortality according to quartile (Q) of total dietary habit scores.

Death causes	HRs (95 % CIs) for quartile of total dietary scores				P_{trend}
	Q1	Q2	Q3	Q4	
Person-year of follow-up	37,384	37,563	37,879	37,787	
All-cause mortality					
No. of deaths	331	368	417	576	
Mortality rate[1]	8.85	9.80	11.01	15.24	
Model 1	1.00	1.15 (0.99, 1.34)	1.27 (1.10, 1.47)	1.61 (1.41, 1.85)	<0.01
Model 2	1.00	1.33 (1.14, 1.54)	1.45 (1.25, 1.68)	1.84 (1.61, 2.12)	<0.01
Model 3	1.00	1.29 (1.10, 1.50)	1.39 (1.19, 1.62)	1.72 (1.49, 1.98)	<0.01
Model 4	1.00	1.30 (1.11, 1.52)	1.41 (1.21, 1.64)	1.72 (1.49, 1.99)	<0.01
CVD mortality					
No. of deaths	144	141	161	249	
Mortality rate[1]	3.85	3.75	4.25	6.59	
Model 1	1.00	1.02 (0.80, 1.29)	1.12 (0.89, 1.41)	1.60 (1.30, 1.96)	<0.01
Model 2	1.00	1.23 (0.97, 1.55)	1.33 (1.06, 1.67)	1.92 (1.56, 2.37)	<0.01
Model 3	1.00	1.19 (0.93, 1.52)	1.32 (1.04, 1.67)	1.80 (1.44, 2.24)	<0.01
Model 4	1.00	1.21 (0.95, 1.55)	1.36 (1.07, 1.73)	1.82 (1.47, 2.27)	<0.01
Cancer mortality					
No. of deaths	102	129	142	178	
Mortality rate[1]	2.73	3.43	3.75	4.71	
Model 1	1.00	1.28 (0.98, 1.66)	1.39 (1.08, 1.79)	1.63 (1.27, 2.08)	<0.01
Model 2	1.00	1.40 (1.08, 1.82)	1.53 (1.18, 1.97)	1.75 (1.37, 2.24)	<0.01
Model 3	1.00	1.30 (1.00, 1.70)	1.40 (1.08, 1.82)	1.60 (1.24, 2.06)	<0.01
Model 4	1.00	1.32 (1.01, 1.73)	1.43 (1.10, 1.87)	1.59 (1.23, 2.04)	<0.01
Other-cause mortality					
No. of deaths	68	82	104	132	
Mortality rate[1]	1.82	2.18	2.75	3.49	
Model 1	1.00	1.30 (0.94, 1.80)	1.59 (1.16, 2.17)	1.82 (1.35, 2.46)	<0.01
Model 2	1.00	1.52 (1.09, 2.11)	1.83 (1.34, 2.50)	2.12 (1.57, 2.87)	<0.01
Model 3	1.00	1.51 (1.08, 2.11)	1.72 (1.24, 2.38)	1.97 (1.44, 2.70)	<0.01
Model 4	1.00	1.50 (1.07, 2.10)	1.70 (1.23, 2.37)	2.00 (1.46, 2.73)	<0.01

Note: HR: hazard ratio; CI, confidence interval;.
Model 1: unadjusted.
Model 2: adjusted for age and sex;.
Model 3: Model 2 + additionally adjusted for body mass index, current smokers, current drinking, and physical activities;.
Model 4: Model 3 + additionally adjusted for self-reported hypertension, self-reported diabetes mellitus, and self-reported dyslipidemia.
[1] Mortality rate is calculated using No of death/1000 person-years;.

severe health issues. One recent study, based on the Alternative Healthy Eating Index (AHEI), was conducted among people aged 35–59 years to explore the impact of dietary trajectories on physical function, suggesting that improving diet quality even in middle age may contribute to better health outcomes at older ages, in particular in the "greatly improved" trajectory [46]. To date, no research has been conducted to assess the associations between mortality risk and the dynamic patterns of dietary changes or stability. It remains unclear whether individuals can derive benefits from correcting multiple poor dietary habits among middle-aged people.

Undoubtedly, overweight and obesity could result in premature disability and death, and are related to an increased risk of cardiometabolic diseases, diabetes, dyslipidemia, osteoarthritis, dementia, depression and certain types of cancer [47,48]. Some previous studies investigated the association between mortality and weight changes across adulthood, finding that stable obesity, weight gain, and weight loss across adulthood were associated with increased risks of mortality [49,50]. Our research endeavor is aimed at delving into the potential disparities in the impact of various dietary habits on both overall, CVD mortality, and cancer mortality among individuals who are obese compared to those who are not. It is indeed intriguing to note that the adverse effects of these dietary habits appear to be less pronounced in people who are overweight or obese than in their counterparts with a normal body mass index and waist circumference, whose health issues might be more insidious and not as readily apparent. Consequently, the development and maintenance of good dietary habits are of paramount importance for individuals across the entire spectrum of body weight, whether they are struggling with excess weight or not.

Our study has some remarkable strengths. Firstly, we assess dietary habits using a cumulative score, surpassing the conventional analysis of individual habits or dietary patterns. By creating a composite score from twenty-three dietary habits and examining their synergistic effects, we offer a more comprehensive view of nutritional epidemiology. Secondly, the dose-response analysis across various demographic subgroups, especially the surprising discovery of increased harm in non-obese populations, signifies a substantial progress in comprehending the dietary impact on mortality. Thirdly, we have further categorized dietary habits into four distinct categories, which facilitates a more nuanced understanding of how various types of dietary behaviors contribute to mortality risks. The findings that special dietary habits exhibit the strongest correlation with mortality offer a critical insight that could guide targeted nutritional interventions and public health strategies. However, several limitations warrant a mention. Firstly, the evaluation of dietary habits within this research was limited to a solitary point in time, which may not accurately capture shifts or developments in habits throughout an individual's lifespan. As a result, this limitation hampers the research's ability to achieve a genuinely holistic comprehension of how trajectories of dietary habits might impact mortality risks. Secondly, criteria for judging diet quality may differ due to cultural or regional variations, and potential social desirability, so the generation of a composite dietary habit score may be different from other studies. Thus, the accumulation of multiple dietary habits should be studied by more research teams to evaluate their associations with death and chronic diseases. Compared to validated food frequency questionnaires (FFQ), this data collection method based on multiple-choice questionnaires about dietary habits may diminish the reliability of the dietary habit score and introduce measurement biases into the analysis, while FFQs may not be convenient during routine check-ups. Thirdly, the mortality in the present study was lower compared with previous studies, which might be because the death registration data is not comprehensive enough due to migration and lost to follow-ups. On the other hand, the population in this study is a healthy physical examination population, who generally receive high levels of medical services and health literacy. Fourthly, the majority of participants were urban dwellers in the vicinity of Changsha, which may diverge in dietary customs from rural regions. The uniformity of the sample casts uncertainty on the generalizability of the observed correlations between dietary habits and mortality across various socioeconomic and cultural contexts. Finally, a moderately short follow-up period also presents a limitation in confirming a conclusion. This temporal constraint necessitates further longitudinal research with extended follow-up periods to validate the relationship between dietary habits and mortality.

5. Conclusions

Despite these limitations, this represents a pioneering endeavor to explore whether the cumulative effect of multiple dietary habits may influence all-cause and cause-specific mortality among Chinese adults.

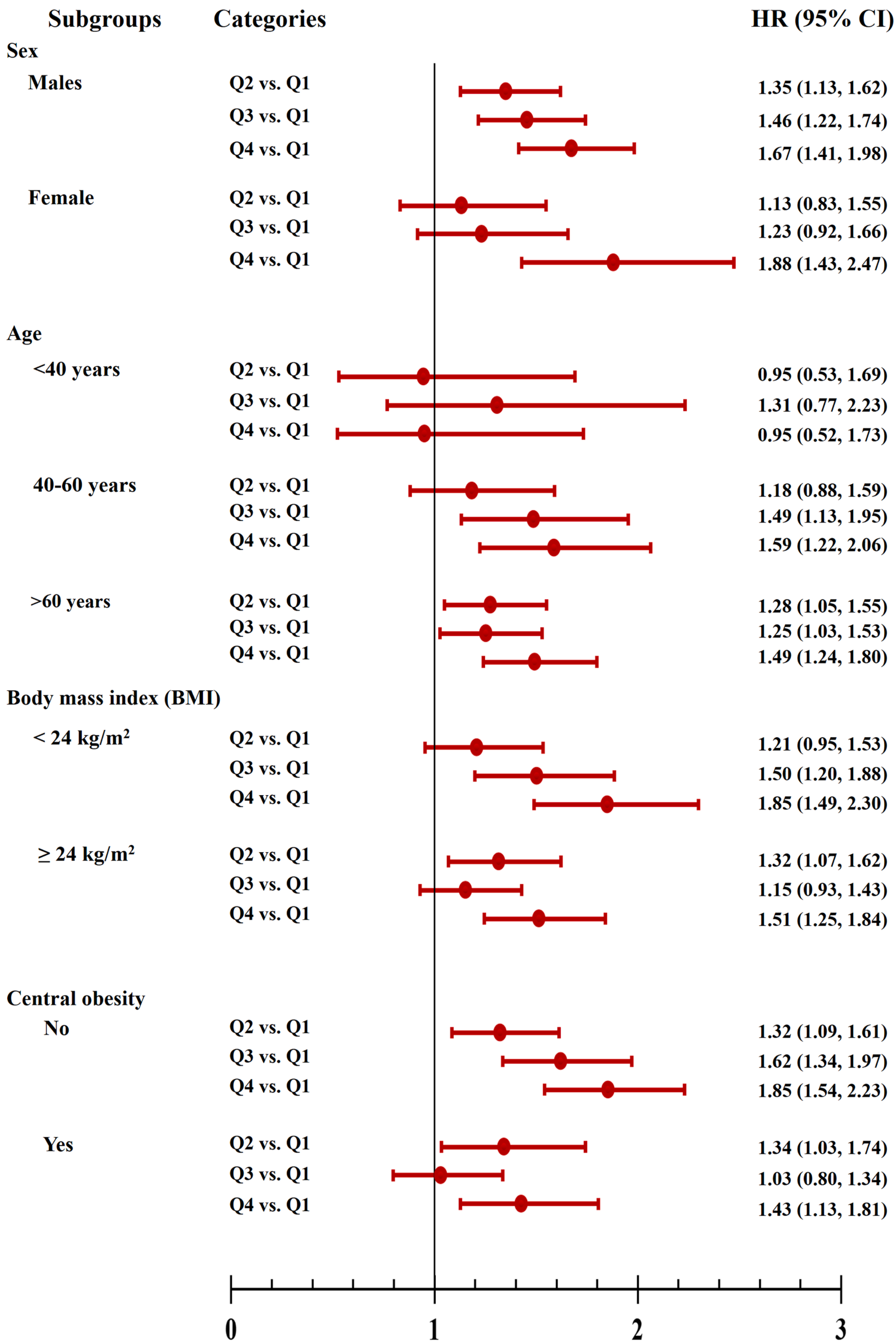

Fig. 2. Subgroup analysis for the associations of total mortality with the quartile for total scores of dietary habits.

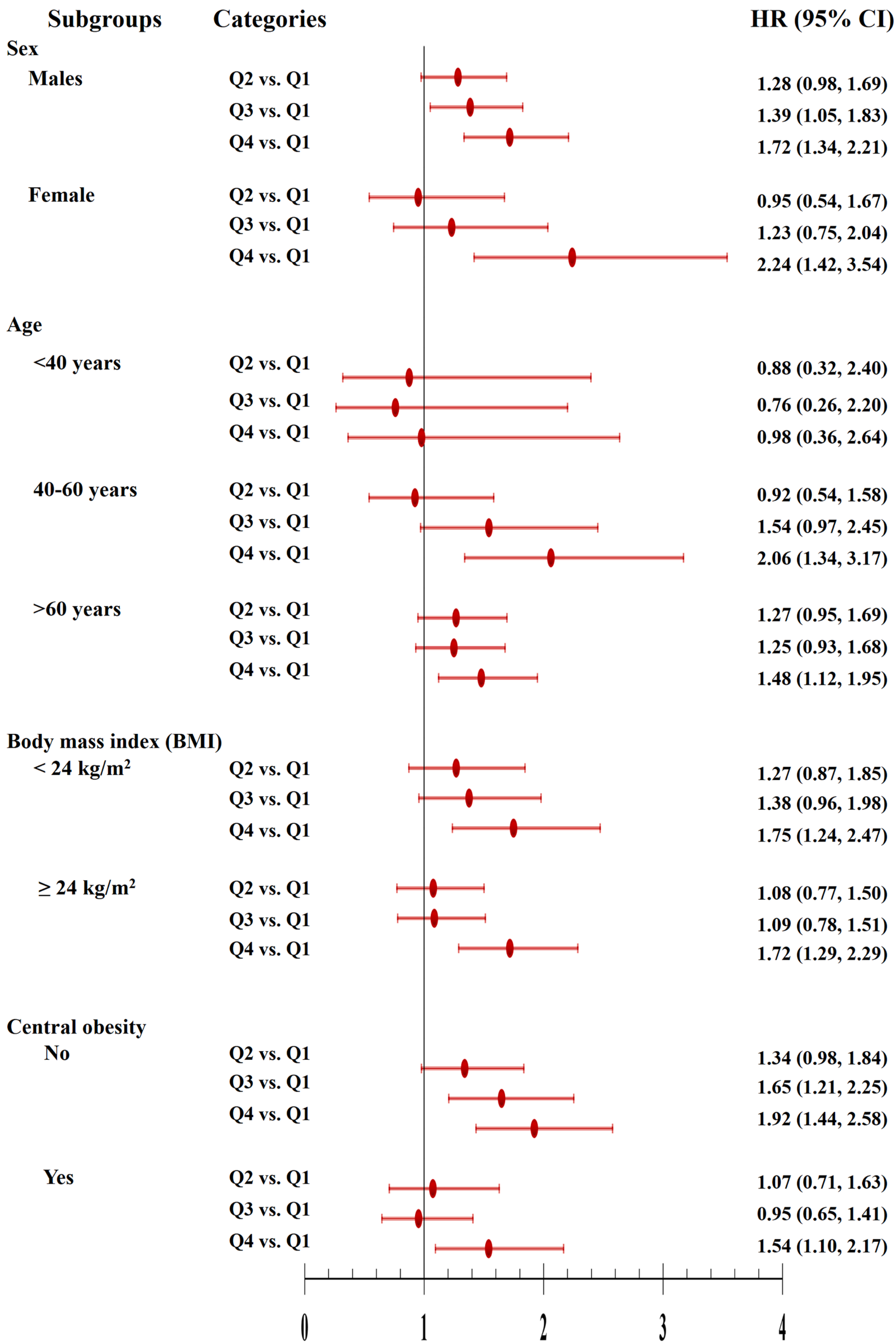

Fig. 3. Subgroup analysis for the associations of CVD mortality with the quartile for total scores of dietary habits.

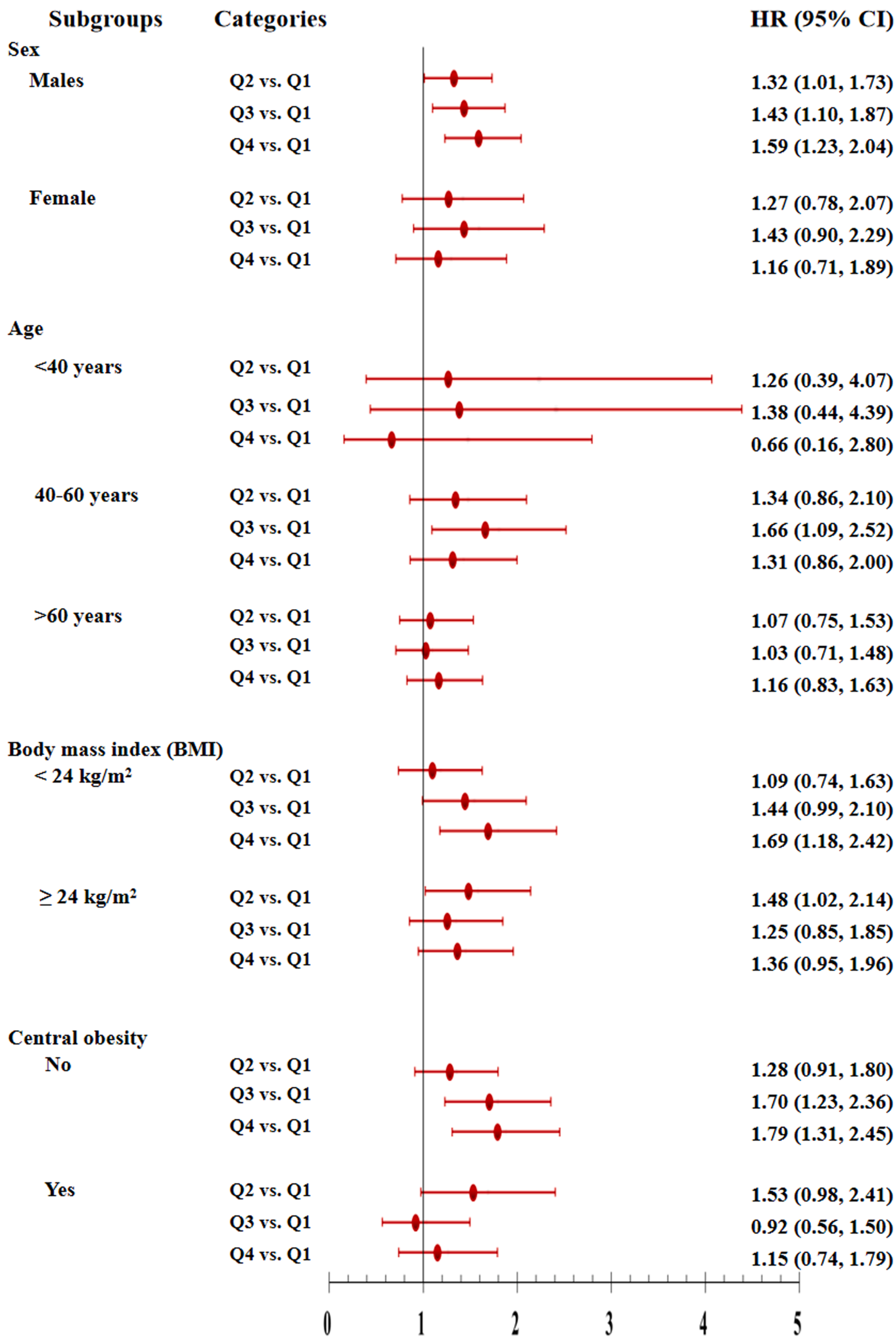

Fig. 4. Subgroup analysis for the associations of cancer mortality with the quartile for total scores of dietary habits.

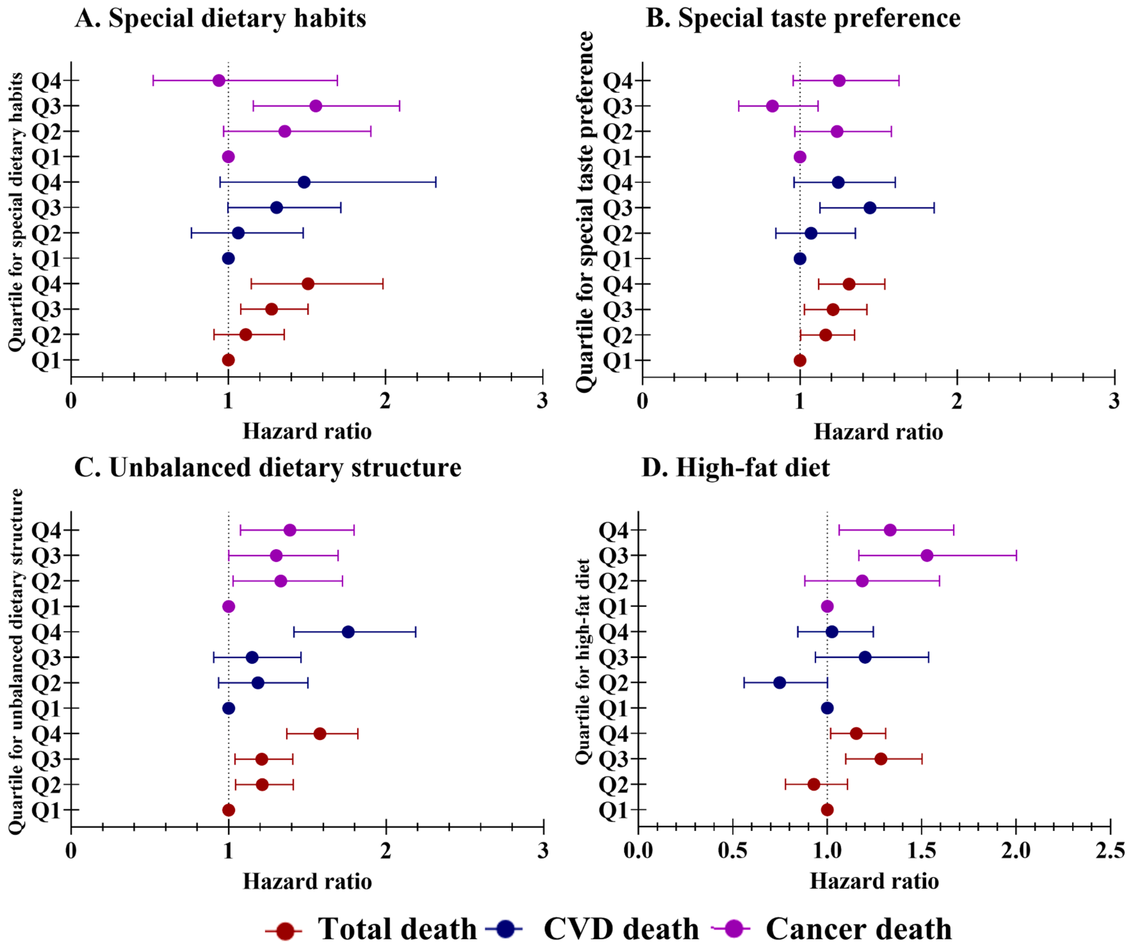

Fig. 5. Adjusted hazard ratios and 95 % confidence intervals for total mortality, CVD mortality, and caner mortality with the quartile of dietary habits by four categories.

Our study successfully observed potential dose-response effects on mortality risk, particularly among middle-aged and elderly adults. Furthermore, the adverse impacts of multiple special dietary habits may also pose a threat to the health of adults with standard physical characteristics. In addition to an unbalanced dietary structure and high-fat diets, further subgroup analyses revealed that irregular dietary habits and a preference for "heavy" flavors posed a heightened risk to health. Therefore, it is imperative for individuals to cultivate beneficial dietary habits throughout their lifetime, in order to mitigate the aggregative effects and potential long-term harm associated with special dietary habits.

Ethical approval

Study protocol and consent forms were approved by the Ethics Committee of the Third Xiangya Hospital (2020-S498). This study complies with the guidelines for human studies in accordance with the World Medical Association Declaration of Helsinki.

Consent for publication

Written informed consent was obtained from all individual participants included in the study.

Funding

This work was supported by funding from the National Natural Science Foundation of China (81973324), Hunan Young Talent grant (2020RC3063), and the Wisdom Accumulation and Talent Cultivation Project of the Third Xiangya Hospital of Central South University (YX 202002).

Availability of data and materials

Data described in the manuscript, code book, and analytic code will be made available upon request pending application and approval.

CRediT authorship contribution statement

Ying Li: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization. **Donghui Jin:** Writing – review & editing, Resources, Investigation, Data curation. **Sidong Li:** Writing – review & editing, Software, Methodology, Formal analysis. **Hao Wu:** Writing – review & editing, Investigation, Data curation. **Jiangang Wang:** Writing – review & editing, Project administration, Investigation, Data curation. **Pingting Yang:** Writing – review & editing, Resources, Project administration, Investigation, Data curation. **Xue He:** Writing – review & editing, Investigation, Data curation. **Lu Yin:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Project administration, Methodology, Formal analysis, Conceptualization.

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.

Acknowledgments

We thank staff at Health Management Medicine Center, Third Xiangya Hospital for carrying out the fieldwork, and all study participants.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ajpc.2025.100963.

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