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Body mass index and risk of all-cause mortality among elderly Chinese: An empirical cohort study based on CLHLS data

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ABSTRACT

The aim of our study was to evaluate the relationship between body mass index (BMI) and all-cause mortality among elderly Chinese. The subjects of our study were a cohort of 13 319 elderly Chinese enrolled between 2008 and 2018. Participants were classified in three groups: underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight and obese (≥25 kg/m^2) according to different BMI levels. Cox proportional-hazards regression model was used to analyze the association between BMI grouping and the risk of mortality among the three groups and each corresponding subgroup. The restricted cubic spline regression was performed to investigate the variation tendency of BMI and mortality in different groups and subgroups. We found that the hazard ratios (HRs) of mortality in the underweight and the normal-weight groups were 1.213 and 1.104, respectively, compared with those in the overweight and obesity groups. HR for mortality decreased as BMI increased, although this phenomenon was not observed as not a linear relationship in all participants. Nonetheless, this nonlinear relationship was significant in type 2 diabetes patients. Among subjects with non-type 2 diabetes, the shape of the negative curve, reflecting the HR for BMI and mortality, decreased when BMI increased. Our findings suggest that an obesity paradox exists in non-type 2 diabetes patients, in which BMI has a nonlinear negative relationship with mortality. Conversely, in type 2 diabetes patients there is a U-shaped association. Obesity may thus be protective for all-cause mortality among non-diabetic older populations.

1. Introduction

The increasing number of elderly people has become one of the most severe demographic challenges in the world (Man et al., 2021). By 2050, around 16% of the global population is expected to be over the age of 65, representing a major percentual shift compared with 9% in 2019 (Chen and Wu, 2022). China is also facing the continuous challenge of population aging, which results in increasing and more prominent health problems associated with the elderly age group (Chen et al., 2019).

Due to changes in lifestyle, overweight and obesity are rapidly increasing and reaching epidemic proportions worldwide (Silveira et al., 2021; Andersen et al., 2016). Obesity is associated with several metabolic abnormalities including insulin resistance, hypertension, non-alcoholic fatty liver disease, type 2 diabetes, metabolic syndrome and cardiovascular diseases (CVDs) (Kwon et al., 2021; Engin, 2017) as well as a decline in life expectancy (Janssen et al., 2021; Blüher, 2019). Body mass index (BMI) is one of the most commonly used classifications to define obesity by researchers and others who study human health, despite the existence of other alternatives (Engin, 2017). While past studies have shown that overweight and obesity are associated with an increased risk of all-cause mortality (Spelta et al., 2018); one cannot disregard the risk of emaciation (BMI ≤ 18.5 kg/m^2) in older adults. In recent years, an increasing number of studies have found that BMI is negatively correlated with the mortality caused by heart failure, hypertension, stroke, chronic kidney disease, cardiovascular disease, and type 2 diabetes, the so-called "obesity paradox" (Spelta et al., 2018; Forlivesi et al., 2021; Elagizi et al., 2018). In fact, the association between BMI and all-cause mortality is still controversial and may differ across populations and races, with several studies having confirmed the relationship between the two with linear, U-shaped and J-shaped curves (Lin et al., 2011; Lee et al., 2018). However, and importantly, it is not clear whether this obesity paradox exists in the association between BMI

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and risk of all-cause death in the elderly Chinese population.

Based on the tracking data set of Chinese Longitudinal Healthy Longevity Survey (CLHLS) from 2008 to 2018, our study aimed to explore the association between BMI and all-cause mortality among the elderly population. Previous studies have confirmed associations between smoking, drinking, diabetes, and hypertension and increased risk of all-cause mortality (Choi et al., 2022; Hajebrahimi et al., 2017). Therefore, we also analyzed the relationship between BMI and all-cause mortality in subgroups based on various factors such as blood pressure, blood glucose, drinking, or smoking status, so as to provide theoretical basis for the prevention of factors related to death in the elderly.

2. Methods

2.1. Study population and design

The data from the present study was extracted from the CLHLS concerning the period between 2008 and 2018 (Yang and Meng, 2020; Zhang et al.). The CLHLS was the first longevity cohort survey in China that aimed at exploring the overall health status of the elderly. This survey recruited around 10,000 elderly people who were distributed across 23 provinces, autonomous regions and municipalities in China and from randomly selected districts, covering about 85% of the Chinese population. This survey was firstly executed in 1998 and followed by follow-up surveys that were conducted in 2000, 2002, 2005, 2008, 2012, 2014 and 2018 (Ren et al., 2021). Data corresponding to the surviving individuals were re-collected by the interviewer and that corresponding to the death participants was obtained by interviews of near relatives. The present study focused on data of 2008 onwards because the data comprising of the period of 1998 to 2005 was short of detailed information. As shown in the flow chart for the selection of subjects, a total of 1475 subjects were excluded due to lack of BMI data and a further 1800 were lost during follow-up (Fig. 1). Thus, 13 319 participants aged ≥65 years were enrolled in the final analysis.

2.2. Data collection and outcome variable

2.2.1. Data collection

CLHLS was approved by the ethics committees of Peking University and Duke University (Zeng et al., 2017). The interviewers, belonging to the Chinese Center for Disease Control and Prevention, were trained before the survey. In order to accurately gather detailed data of participants and attentively care for older adults, interviewers were required to interview participants in their home using a standard questionnaire (available online: https://opendata.pku.edu.cn/). In the questionnaire, the height and weight of the participants were measured. If the participant could not stand, one could estimate their height by the height of their knees (Zhang et al., 1998). The estimation formula used was as follows: for men: height (cm) = 67.78 + 2.01 × knee height (cm); for women: height (cm) = 74.08 + 1.81 × knee height (cm). BMI = weight (kg)/height (m^2).

For exact evaluation of the association between BMI and death, covariate variables were also collected. In the present study, lifestyle and chronic disease history were analyzed in subgroups to assess the interaction effect with BMI. Concerning lifestyle factors, subjects were divided into smokers (including current smokers and ex-smokers) and non-smokers (never smoking) according to smoking status. Accordingly, participants who "smoked more than one cigarette/day, and this status lasted for over one year" were defined as smokers. Concerning the drinking frequency, they were categorized into drinkers (including current and former drinkers) and non-drinkers (never drank). Accordingly, participants drinking alcohol for more than five times in one year and that consumed more than 20 ml of alcohol each time in the past year were considered drinkers. Concerning chronic disease history factors, in particular type 2 diabetes, only individuals who were diagnosed by endocrinologists using precise diagnostic criteria were defined as type 2 diabetes patients; in regards to hypertension, only participants who were taking antihypertensive drugs or were properly diagnosed by the specialized physicians were considered as hypertension patients.

2.2.2. Time of death and survival information

The survey data of each year mainly included the survival status and time of death of the participants. The survival of the subjects was determined through a follow-up analysis, with remaining survivors continuing to answer the questionnaire survey. Family members of the deceased elderly were interviewed using by death questionnaire to collect date of death and other potentially relevant information. The inability to follow-up was defined if a subject's family member could not be no longer contacted.

2.2.3. BMI categories

Based on criteria defined by the World Health Organization (WHO) for overweight and obesity, participants were categorized into three main groups: underweight or malnutrition (BMI < 18.5 kg/m^2), normal weight (BMI 18.5–24.9 kg/m^2), overweight and obese (BMI ≥ 25 kg/m^2) (Di Angelantonio et al., 2016).

2.3. Statistical analysis

The STATA 14.0 statistical packages and R 4.0.3 were used to analyze data. The $\chi 2$ test was used to analyze the differences of categorical data among the three groups. The Cox proportional-hazards regression model was performed to analyze the relationship between BMI categories and the risk of mortality among the three groups and

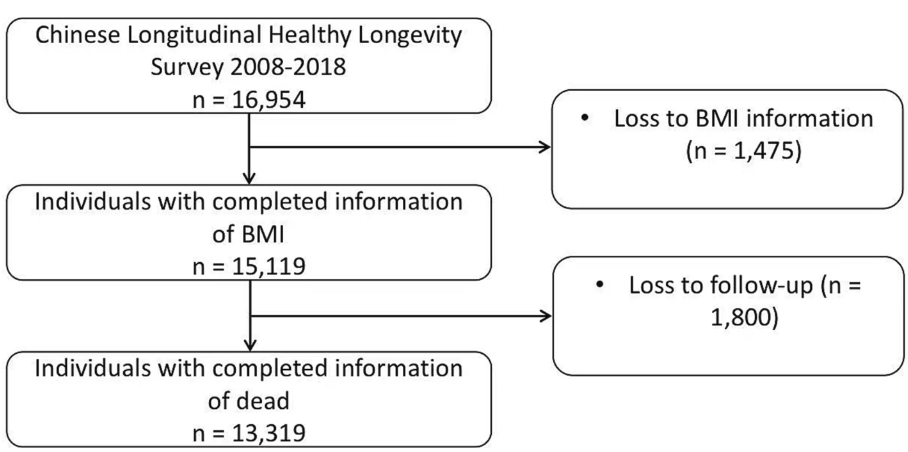


Fig. 1. Flow chart of study object selection.

subgroups. In the model, we imported the interactive variable to test the interaction effect between covariate variables and BMI for all-cause mortality. The restricted cubic spline regression was used to investigate the variation tendency of BMI level and mortality in different groups and subgroups. Possible confounders, including age, sex, blood pressure, diabetes, smoking status and drinking status, were controlled and adjusted in the analytical model. $P < 0.05$ was considered statistically significant.

3. Results

In the follow-up period, 9,375 participants were classified as dead and 3,944 were considered survivors. We analyzed the clinical characteristics of the elderly based on their surviving status (Table 1). Overall, males had a higher risk of all-cause mortality than females. Risk for all-cause mortality was higher in the lower BMI group than in the highest BMI group (≥25 kg/m^2).

The relationship between BMI and cumulative mortality was shown in Table 2. We used the restricted cubic spline method to estimate the association between BMI and all-cause mortality. Using overweight as a reference point, changes in the risk of death can be estimated in relation to BMI values above or below overweight. It was found that the relative risks of death in the underweight group and the normal weight group were 1.214 and 1.103, respectively (P < 0.001). After adjusting for sex, age, lifestyle and disease history, the underweight and normal weight groups had higher HR for mortality compared with overweight group, with the HR (and 95% C.I) being 1.213 (1.112 ~ 1.323) and 1.104 (1.106 ~ 1.200), respectively. The cumulative survival rate was highest in the overweight and obese group, lowest in the underweight group, and intermediate in the normal-weight group (Fig. 2). Recent studies in patients with ischemic stroke have also confirmed that overweight and obese patients had a significantly reduced 1-year mortality risk ratio compared with non-overweight patients (Chaudhary et al., 2021).

We also performed subgroup analyses of HRs for the all-cause mortality at different BMI levels (Table 3). Irrespective of sex, lower HR of mortality was overall associated with high BMI. Similarly, in the hypertension and normal blood pressure groups, the higher HR of mortality was also related to low BMI. Conversely, drinking status had no effect on the relationship between BMI level and risk of all-cause mortality. Of note, history of type 2 diabetes critically influenced mortality. Despite not observing an alteration in HR of mortality related to a low BMI in senior subjects with type 2 diabetes, this association was observed in the present sample of non-type 2 diabetes participants.

Fig. 3 shows analyzed data regarding a dose–response relationship of BMI with all-cause mortality. We found a tendency for a lower risk of all-cause mortality in participants with higher BMI levels although this was not a linear relationship observed for all participants. In terms of sex differences, we noticed that the relationship of BMI and the HR for all-cause mortality was a "U" shape in male individuals whereas this shape was not found in female participants (Fig. 3B,C). Throughout the different BMI categories, the association between HR and BMI for mortality varied. Compared with the underweight and normal weight groups, the individuals in the overweight and obese group had a opposite trend between the BMI and the HR for mortality, meaning that high BMI levels tended to be associated with a higher risk of death (Fig. 3D-F). These results suggested there was a nonlinear association between BMI and mortality.

We also observed this significant nonlinear relationship when looking at patients with type 2 diabetes (P overall = 0.008 and P non-

Table 1
Clinical characteristics of Chinese elderly people (aged ≥ 65 years) filtered according to the surviving status in 2008–2018 CLHLS.

Variables	Surviving (N = 3944)(w%)	Death (N = 9375)(w%)	χ^2	P
Sex				
Male	31.6	68.4	18.979	<0.001
Female	28.1	71.9		
Age(years)				
≤70	79.2	20.8	4137.845	<0.001
71 ~ 80	57.4	42.6		
81 ~ 85	32.5	67.5		
86 ~ 90	17.5	82.5		
91 ~ 95	9.1	90.9		
≥96	6.6	93.4		
BMI(Kg/m^2)				
≤18.5	19.8	80.2	402.165	<0.001
18.6 ~ 24.9	32.7	67.3		
≥25	46.5	53.5		
Smoking				
Yes	35.9	64.1	55.444	<0.001
No	28.2	71.8		
Drinking				
Yes	34.6	65.4	35.764	<0.001
No	28.5	71.5		
Hypertension				
Yes	35.2	64.8	50.338	<0.001
No	28.3	71.7		
Don't know	26.8	73.2		
Diabetes				
Yes	40.1	59.9	20.504	<0.001
No	29.4	70.6		
Don't know	25.7	74.3		

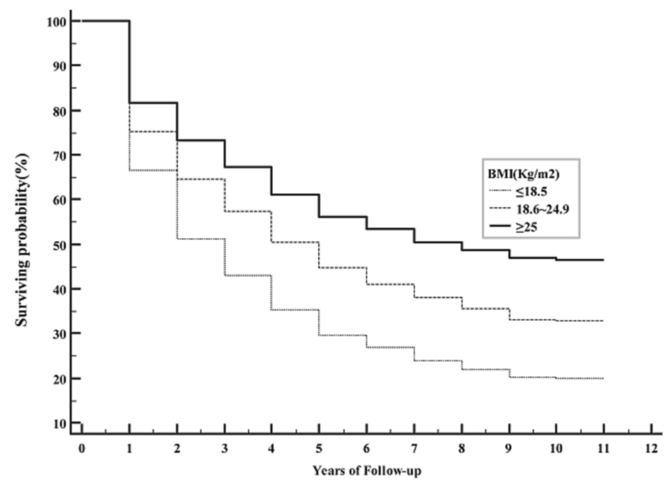
N = unweighted number of participants; w% = weighted percentages; BMI, body mass index; χ^2, chi-square test.

Table 2
Hazard ratio (95% C.I) of the BMI levels for all-cause mortality among elderly Chinese of aged ≥65 years in 2008–2018 CLHLS.

	BMI (kg/m^2) ≤18.5	18.6 ~ 24.9	≥25	P for trend
Model1	1.214(1.114 ~ 1.323)	1.103(1.015 ~ 1.199)	1	<0.001
Model2	1.213(1.113 ~ 1.322)	1.104(1.106 ~ 1.200)	1	<0.001
Model3	1.213(1.112 ~ 1.323)	1.104(1.106 ~ 1.200)	1	<0.001

Model1: Adjusted sex and age
Model2: Adjusted sex, age, smoking status and drinking status.
Model3: Adjusted sex, age, smoking status, drinking status, hypertension and diabetes.

CI, confidence interval; BMI, body mass index.



Number at risk BMI(Kg/m^2)	0	1	2	3	4	5	6	7	8	9	10	11
≤18.5	4553	1525	694	373	357	259	124	128	95	82	12	904
18.6~24.9	7579	1879	818	549	519	439	268	231	201	171	24	2495
≥25	1172	216	99	69	72	57	32	35	22	20	5	545

(Years of follow-up)

Fig. 2. Survival analysis diagram of three groups with different BMI levels during follow-up period among elderly Chinese aged ≥65 years in 2008–2018 CLHLS.

Table 3
Subgroups analysis of the hazard ratio (95 %C.I) of the BMI levels for all-cause mortality among elderly Chinese aged ≥65 years in 2008–2018 CLHLS.

Variables	BMI (kg/m^2) ≤18.5	18.6 ~ 24.9	≥25	*P* for trend	*P* for interaction
Sex					
Male	1.235 (1.083 ~ 1.408)	1.089 (0.963 ~ 1.232)	1	<0.001	0.528
Female	1.205 (1.073 ~ 1.353)	1.118 (0.998 ~ 1.252)	1	<0.001	
Diabetes					
Yes	1.257 (0.788 ~ 2.003)	1.143 (0.794 ~ 1.646)	1	0.329	0.33
No	1.209 (1.105 ~ 1.322)	1.102 (1.011 ~ 1.202)	1	<0.001	
Hypertension					
Yes	1.420 (1.187 ~ 1.698)	1.252 (1.062 ~ 1.477)	1	<0.001	0.214
No	1.149 (1.039 ~ 1.270)	1.053 (0.955 ~ 1.161)	1	<0.001	
Smoking					
Yes	1.239 (0.994 ~ 1.544)	1.108 (0.899 ~ 1.366)	1	0.018	0.913
No	1.209 (1.100 ~ 1.328)	1.103 (1.007 ~ 1.208)	1	<0.001	
Drinking					
Yes	1.204 (0.977 ~ 1.485)	1.056 (0.867 ~ 1.286)	1	0.016	0.394
No	1.216 (1.105 ~ 1.337)	1.114 (1.106 ~ 1.222)	1	<0.001	

Note: All models were adjusted sex, age, hypertension, smoking, and drinking except when the variable was regarded as subgroup. BMI, body mass index.

linearity = 0.004, Fig. 4G). Among individuals with non-type 2 diabetes, the curved shape that reflected the association of BMI and the HR for mortality showed a gradual decrease as the baseline BMI levels increased (*P* overall < 0.001 and *P* non-linearity = 0.021, Fig. 4H). However, the curve shape in the type 2 diabetes patients was ruleless. The interaction effect of BMI and type 2 diabetes for mortality was significant and its *P* value was 0.033 (Fig. 5A). In Fig. 5B it is shown that there was no interaction effect of BMI and smoking status for mortality, because the shapes of the curves in different smoking status population were indiscriminate (Fig. 5A,B). In other subgroups, we observed that the mortality was decreased with increased baseline BMI levels, although the trend was not linear (Fig. 4).

4. Discussion

In this study, using the CLHLS database tracking dataset comprised of data from Chinese elderly and its follow-up for 10 years, we found a strong negative association between BMI and all-cause mortality in non-diabetic populations. In contrast, BMI showed an approximately non-linear U-shaped association with all-cause mortality among diabetic populations, with the minimum risk being 25 kg/m^2.

Many epidemiologic studies have explored the relationship of BMI with mortality, but the observed U-, J- or reversed J-shaped associations remains unclear. An analysis of more than ten million people across four continents found that all-cause mortality was lowest among populations with a BMI of 20–25 kg/m^2, with a significant increase being seen in all-cause mortality below and above this range (Di Angelantonio et al., 2016). Accordingly, another large study in the UK confirmed a J-shaped correlation of BMI and overall mortality, with an estimated HR of 0.81 for every 5 kg/m^2 increase in BMI lower than 25 kg/m^2 and HR of 1.21 for BMI above this value (Bhaskaran et al., 2018). Interestingly, this nicely correlates work done by Tabara Y et al. which demonstrated a reverse J-shaped association between BMI and all-cause mortality among Japanese senior individuals (Tabara et al., 2021). Contrasting with these results, our study provides new data showing that risk for all-cause mortality among groups was highest in the underweight group, followed by the normal group and with the overweight and obese group

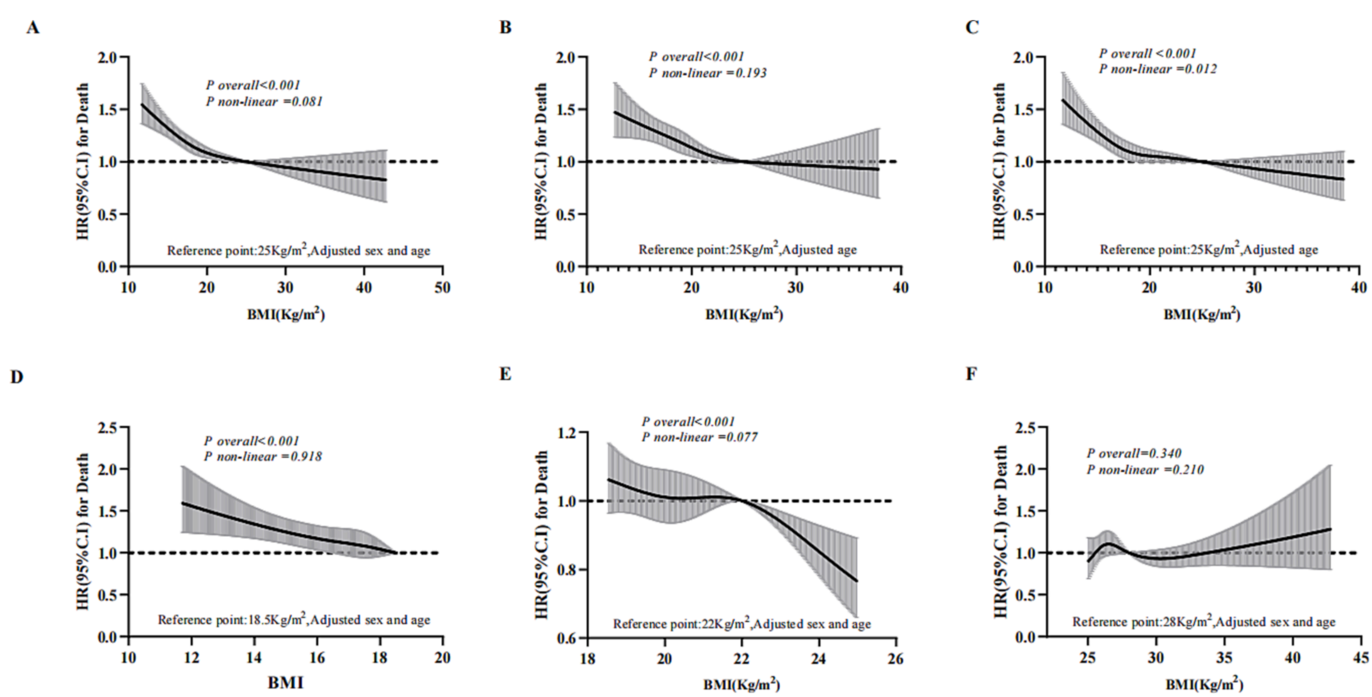


Fig. 3. Dose-response relationship between BMI and risk of all-cause mortality in the elderly Chinese population aged ≥65 years in 2008–2018 CLHLS. Relationship between BMI and HR of mortality in all participants (A) as well as in male (B) and female (C) participants. Relationship between BMI and HR of mortality in the underweight (D), normal weight (E) and overweight and obese (F) groups. Shaded areas represent 95% confidence intervals. BMI, body mass index; HR, hazard ratio.

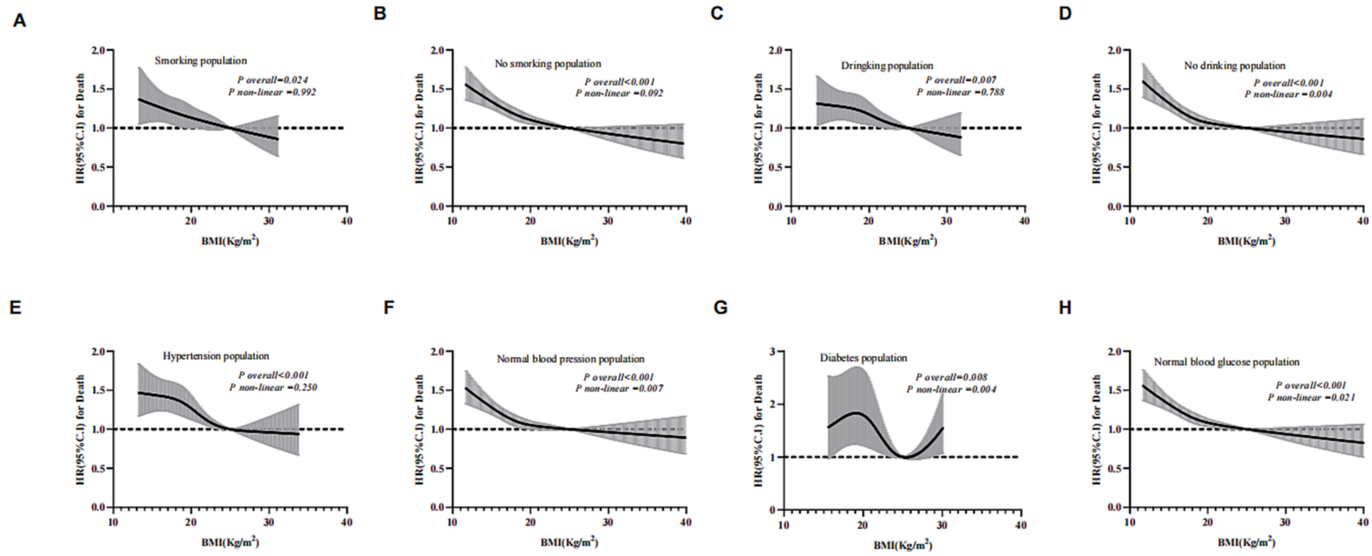


Fig. 4. Subgroup analysis of smoking status, drinking status, hypertension and type 2 diabetes assessing the association between body mass index (BMI) and hazard ratio (HR) of mortality among elderly Chinese aged ≥65 years in 2008–2018 CLHLS. A: BMI and the HR of mortality in smoking population; B: BMI and the HR of mortality in no smoking population; C: BMI and the HR of mortality in drinking population; D: BMI and the HR of mortality in no drinking population; E: BMI and the HR of mortality in hypertension population; F: BMI and the HR of mortality in normal blood pressure population; G: BMI and the HR of mortality in type 2 diabetes population; H: BMI and the HR of mortality in non-type 2 diabetes population. All models were adjusted for sex, age, hypertension, diabetes, smoking status, and drinking status, except the variable that was regarded as subgroup. Shaded areas represent 95% confidence intervals. BMI, body mass index; HR, hazard ratio.

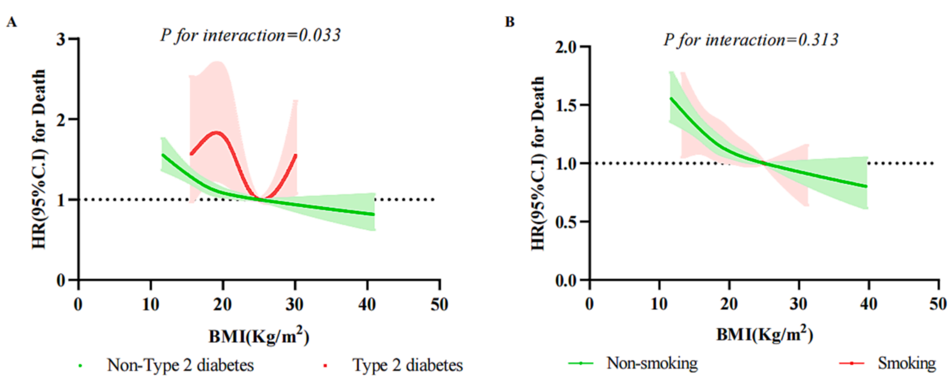


Fig. 5. Interaction of subgroup analysis of type 2 diabetes and smoking status on BMI and hazard ratio (HR) of all-cause mortality among elderly Chinese aged ≥65 years in 2008–2018 CLHLS. A: Interaction of type 2 diabetes status on the relationship between BMI and the HR of mortality; B: Interaction of smoking status on the relationship between BMI and the HR of mortality. Shaded areas represent 95% confidence intervals. BMI, body mass index; HR, hazard ratio.

being the lowest, suggesting that BMI level is an influential factor in the risk of mortality among senior individuals. Thus, we suspect that high BMI-presenting individuals, i.e., belonging to the overweight and obesity category, may have some protective effect on mortality in Chinese older adults. Previous studies have confirmed that metabolic risk factors including age, gender, smoking, drinking, hypertension and diabetes effected the risk of all-cause mortality (Bhaskaran et al., 2018; Sun et al., 2019; Patra et al., 2021; Lee et al., 2021; Sun et al., 2020); with obesity being generally accompanied by a series of metabolic diseases such as atherosclerosis, diabetes, hypertension, and cardiovascular disease. However, our study demonstrated that after adjusting for the abovementioned risk factors, the risk for mortality remained highest in the underweight group.

Our study further explored whether there was a dose–response relationship between BMI and mortality and, importantly, found that there was a nonlinear association between these two factors. Strikingly, a lower BMI classification may be associated with a higher risk of all-cause mortality. While previous studies have confirmed that smoking significantly increased the risk of various diseases, including CVDs, respiratory diseases, diabetes, and multi-organ cancers, which lead to premature deaths (Zhu et al., 2021; Lariscy et al., 2018); we reported that deaths among elderly Chinese were not attributable to smoking, as there was no interaction effect of BMI and smoking status for mortality (Fig. 5).

Contrary to the common biologic effects of obesity, overweight or obese patients appear to have a better prognosis than normal-weight patients, a phenomenon known as “obesity paradox” (Park et al., 2020). While this applied to individuals without type 2 diabetes, when the study population was limited to people with type 2 diabetes we had no evidence of a protective effect of obesity on mortality. Some investigators have suggested that moderate weight loss may provide a benefit in improving cardiovascular risk factors in overweight and obese patients with type 2 diabetes (Lin et al., 2019). Interestingly, there was an interaction of type 2 diabetes on BMI and all-cause mortality (Fig. 1). BMI was tightly associated with an U-shaped association with all-cause mortality among the tested type 2 diabetes population. Compared to obesity, type 2 diabetes appeared to be a rather stronger predictor of all-cause mortality outcome, which could offset the positive influence of obesity on all-cause mortality outcome. Although the outcomes of our study were slightly different between patients with and without type 2 diabetes, the risk of mortality was highest among the underweight group, regardless of glycemic status, with similar results being found in other studies (Park et al., 2020; Colombo et al., 2015; Zhao et al., 2018). In a population-based study of patients with acute myocardial infarction in Germany, a protective effect of overweight and obesity on mortality was found only in the non-diabetic populations, but not in people with diabetes (Colombo et al., 2015). A study of Chinese rural adults by Zhao et al. (Zhao et al., 2018) demonstrated a curvy relationship between BMI and all-cause mortality after 6 years of follow-up. In fact, a decrease in BMI, even within the normal range, was found to be associated with increased mortality, regardless of glycemic status. For diabetic populations with a BMI of 24 kg/m^2 or below, a lower BMI was related to an increased risk of mortality whereas a higher BMI was protective (Park et al., 2020). Another recent study from a cohort of southern Chinese adults aged ≥35 years found that BMI was negatively related to all-cause mortality (Hu et al., 2022). Our data partly differs from these studies (Hu et al., 2022) because our inverse association was only present in the non-diabetic population. Moreover, our research subjects were the elderly people from all regions of China, which may better reflect the survival characteristics of Chinese elderly populations.

The pathophysiological explanation for the obesity paradox remains speculative, but several possible causes have been proposed to explain these survival outcomes. One such hypothesis relates to the fact that moderate obesity in later life can improve survival and reduce frailty and cachexia. BMI is only a simple and convenient measure of obesity and may only roughly reflect obesity. A lower BMI may reflect sarcopenia, defined as a loss of muscle mass, which is typically accompanied by malnutrition, a catabolic state, decreased physical activity, or related coexisting conditions (Song et al., 2022). Some authors have suggested that weight loss should be avoided in patients with chronic diseases, as adipose tissue may serve as an energy store during acute or spontaneous exacerbations of certain diseases (Gravina et al., 2021). Overweight could provide a metabolic reserve in elderly patients and prevent adverse outcomes such as frailty, malnutrition, and osteoporosis (Song et al., 2022; Costanzo et al., 2015). Others believed that overweight subjects who survived early in life may have longevity genes that may have protected them from death during the current follow-up period (Weiss et al., 2008). Genetic susceptibility combined with adequate energy storage in the form of fat may help to protect these individuals from catabolic processes (Weiss et al., 2008). Another hypothesis was that people with a higher BMI might be more susceptible to cardiovascular disease or other metabolism-related diseases, and therefore more likely to access healthcare earlier, which in turn leaded to better outcomes (Bosello and Vanzo, 2021; Curcic et al., 2019). In addition, we speculate that some individuals who are more vulnerable to the adverse effects of high BMI may die before reaching old age. These limitations may have contributed to some bias in such results. It is noteworthy to consider that some recent studies have suggested that the obesity paradox could be fully or partially explained by residual confounding factors, and some people believe that BMI may not fully reflect obesity (Wang and Yi, 2022; Badrick et al., 2017; Shirahama et al., 2022). Of course, BMI may not accurately distinguish excess body fat from increased lean mass, and some have argued that BMI may not be a perfect tool for distinguishing normal weight from overweight or obesity. However, previous studies that have used body-fat measurements or abdominal circumference to confirm the existence of an obesity paradox may show promising results (Wang and Yi, 2022; Shirahama et al., 2022; Keller et al., 2019). Therefore, as a measurement tool, BMI is certainly not the problem and/or explanation for the emergence of the obesity paradox.

The primary advantage of our study was that Chinese elderly people were used as research subjects, using representative longitudinal survey data with a large national sample, long follow-up time and large sample size. Second, this study focused on the association between BMI and all-cause mortality among Chinese older adults, which is helpful to better understand the survival advantages of the elderly in China. Several limitations are acknowledged. Firstly, weight loss due to illness, physical exercise, socioeconomic status, medications, etc., may affect the relationship between BMI and all-cause mortality. Data was not adjusted to weight loss and other relevant clinical history due to the large percentage of missing historical data and lack of information on weight loss due to medication and disease. Finally, the absence of a complete classification of causes of death in cohort studies precluded analysis of the association of BMI with specific causes of death.

5. Conclusions

In the study group, the Chinese elderly population, BMI was non-linearly related to all-cause mortality, with the highest risk being presented by the underweight group. The obesity paradox existed within the non-type 2 diabetes subgroup, where BMI had a nonlinear negative relationship with mortality whereas in type 2 diabetes there was a U-shaped association. In people with type 2 diabetes and BMI values exceeding 25 kg/m^2, higher baseline BMI was associated with a higher risk of all-cause mortality, suggesting that the obesity paradox observed in some subpopulations did not challenge the weight management recommendations for diabetics. Altogether, our study hints at the possibility that being obese may have a protective effect on all-cause mortality among the non-diabetic elderly individuals whereas being underweight may display an increased risk of mortality.

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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.

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